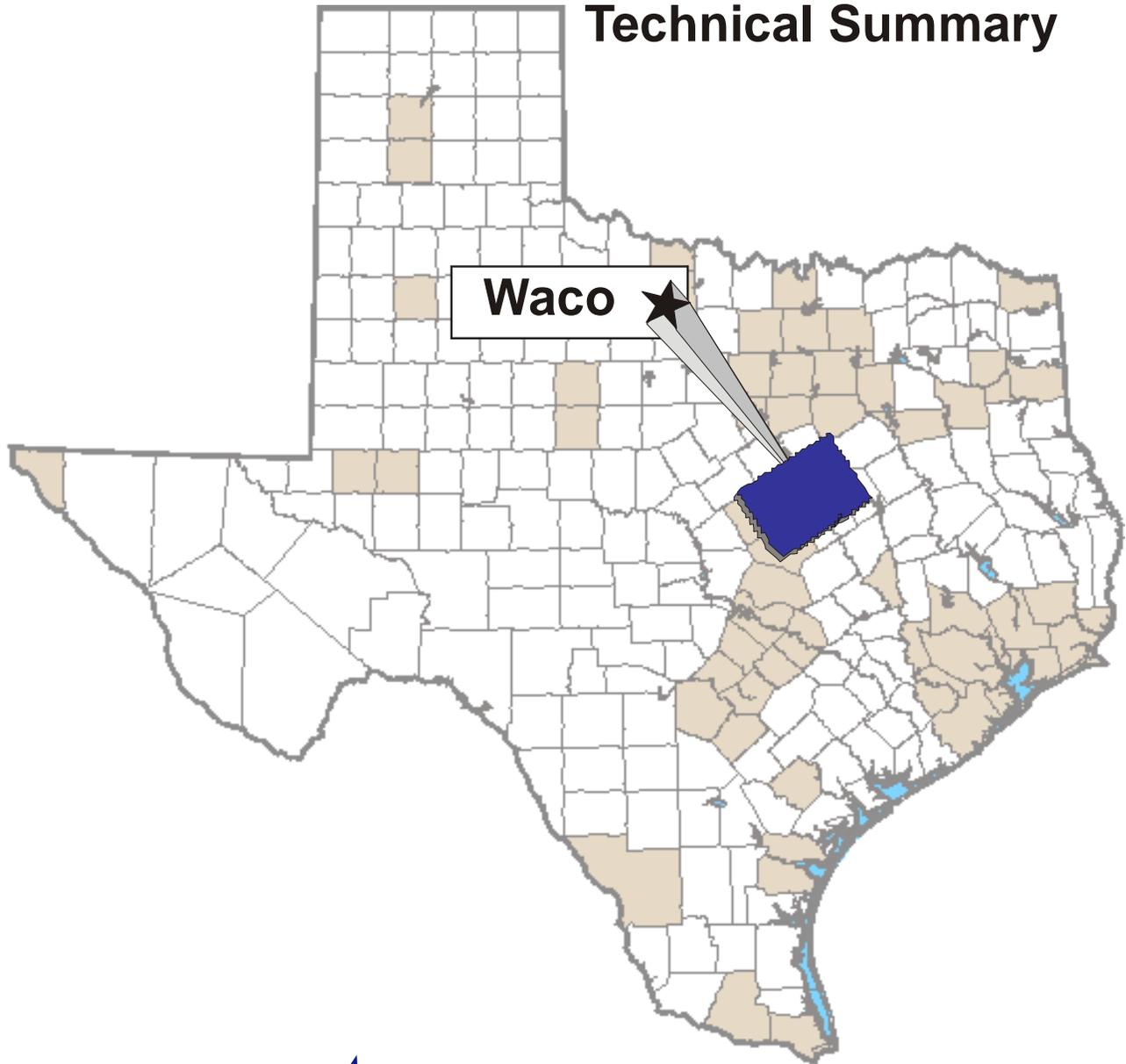


2008/2009 Waco Commercial Vehicle Travel Survey Technical Summary



Prepared by the
Texas Transportation Institute
December 2010

**2008/2009 Waco
Commercial Vehicle Survey**

TECHNICAL SUMMARY

Texas Department of Transportation Travel Survey Program

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TABLE OF CONTENTS

List of Figures	vii
List of Tables	viii
Introduction.....	1
Survey Methodology.....	2
Survey Results	3
Vehicle Characteristics	3
Registered Commercial Vehicles.....	3
Surveyed Commercial Vehicles	5
Trip Frequency	8
Trip Characteristics	10
Cargo Characteristics.....	12
Trip Length.....	21
Travel Time and Speed.....	25
Trip Tours.....	29
Survey Expansion.....	32
Survey Summary.....	36
References.....	38
Appendix.....	39

LIST OF FIGURES

Figure 1. Waco Study Area.....	1
Figure 2. Model Year of Registered Trucks in the Waco Study Area.	4
Figure 3. Type of Fuel Used by Surveyed Commercial Vehicles.....	6
Figure 4. Model Year of Surveyed Commercial Vehicles.	7
Figure 5. Inter-Zonal, Intra-Zonal, and External Trips.	9
Figure 6. Total Trips per Vehicle.....	10
Figure 7. Total Internal Trips per Vehicle.	10
Figure 8. Cargo Load Status at Trip Start.	12
Figure 9. Commodity Groups at Trip Destinations.....	16
Figure 10. Land Use Types at Trip Destinations.	16
Figure 11. Cargo Trip Purposes at Trip Destinations.	18
Figure 12. TAZ Boundary and Base Locations of Surveyed Commercial Vehicles.	22
Figure 13. Trip Origins and Destinations of Surveyed Commercial Vehicles.....	22
Figure 14. Surveyed Commercial Vehicle Trips TLFD.....	24
Figure 15. Surveyed Commercial Vehicle Trips Travel Time.....	26
Figure 16. Cargo Vehicle Trips within Trip Tours by Trip Type.	31
Figure 17. Service Vehicle Trips within Trip Tours by Trip Type.	32
Figure 18. Vehicle Classification Count Stations in the Waco Study Area.	33

LIST OF TABLES

Table 1. Survey Recruitment Participation.	2
Table 2. Gross Vehicle Weight of Registered Trucks in the Waco Study Area.	3
Table 3. Vehicle Classification Type of Surveyed Commercial Vehicles.	5
Table 4. Gross Vehicle Weight of Surveyed Commercial Vehicles.	6
Table 5. Model Year and Average of Reported Odometer Readings of Surveyed Commercial Vehicles. ...	8
Table 6. Total Internal and External Trips.	9
Table 7. Land Use Types at Trip Destinations.	11
Table 8. Trip Purposes at Trip Destinations.	11
Table 9. Cargo Classification Types.	13
Table 10. Types of Cargo being Transported at Trip Destinations.	14
Table 11. Equivalency between SAM Commodity Groups and Survey Cargo Classification Types.	15
Table 12. Equivalency between Land Use Categories and Survey Types of Place.	15
Table 13. Cargo Trips by Commodity Group and Land Use at Trip Destinations.	17
Table 14. Cargo Trips by Commodity Group and Trip Purpose at Trip Destinations.	18
Table 15. Average Net Cargo Weight by Commodity Group and Land Use at Trip Destinations.	19
Table 16. Average Net Cargo Weight by Commodity Group and Trip Purpose at Trip Destinations.	19
Table 17. Cargo Trips and Net Cargo Weight by Commodity Group at Trip Destinations.	20
Table 18. Cargo Trips and Net Cargo Weights by Land Use at Trip Destinations.	20
Table 19. Cargo Trips and Net Cargo Weights by Trip Purpose at Trip Destinations.	21
Table 20. Trip Length Frequency Distribution (Grouped Interval).	23
Table 21. Trip Length Frequency Distribution (Ungrouped).	23
Table 22. Average Trip Length to Destinations by Land Use Type.	24
Table 23. Average Trip Length to Destinations by Commodity Group.	25
Table 24. Travel Time Frequency Distribution (Grouped Interval).	26
Table 25. Travel Time Frequency Distribution (Ungrouped).	27
Table 26. Average Travel Time and Speed to Destinations by Land Use Type.	28
Table 27. Average Travel Time and Speed to Destinations by Commodity Group.	28
Table 28. Base and Non-Base Trips.	29
Table 29. Trip Tours per Vehicle.	30
Table 30. External, Inter-Zonal and Intra-Zonal Trips within Trip Tours.	30
Table 31. Non-Base Trips within Trip Tours.	31
Table 32. 2007 HPMS Estimates of Weekday VMT in the Waco Study Area.	33
Table 33. Percentage of Commercial and Non-Commercial Vehicles by Functional Classification.	34
Table 34. Estimated VMT for Commercial and Non-Commercial Vehicles.	34
Table 35. Key Survey Results and Expanded Trip and VMT Data.	35

INTRODUCTION

In 2008/2009, the Transportation Planning and Programming (TPP) Division of the Texas Department of Transportation (TxDOT) funded a commercial vehicle survey in the Waco Metropolitan Planning Organization (MPO) study area. The purpose of this survey was to collect data on travel and trip-making characteristics of commercial vehicles that will enable TxDOT to plan for and forecast commercial vehicle travel demand within the Waco urban area.

The study area, shown in Figure 1, is located in Central Texas and covers all of McLennan County, and includes the city of Waco as its urban center. The study area has a total land area of 1,042 square miles and population density of approximately 205 persons per square mile based on the 2000 Census. The total population in 2008 for McLennan County was 230,000, which includes 124,000 for the city of Waco.



Figure 1. Waco Study Area.

This report presents a technical summary of the commercial vehicle travel surveys conducted in 2008/2009 in the Waco urban area and documents the data collected and the analysis results for the study area. The forms used in the survey are included in the Appendix of this report.

SURVEY METHODOLOGY

The commercial vehicle surveys were conducted during the period between April 2008 through May 2009, with a break during the summer months of June and July 2008. TxDOT contracted with Alliance Transportation Group (ATG) to conduct the Waco Commercial Vehicle Survey. The Texas Transportation Institute (TTI) provided technical assistance to both TxDOT and ATG in the effort.

The survey sample was randomly selected from a listing of all businesses, individuals, and public agencies that own, operate, or lease commercial vehicles in the study area. The list was generated from the Texas Workforce Commission (TWC) employer database that was provided to the vendor in random order. Randomly-selected businesses were contacted and requested to participate in the survey. Those who agreed to participate were provided survey packets and instructions on how the survey forms should be filled out. Drivers of commercial vehicles from these establishments were asked to keep a 24-hour diary of the locations of all trips made by each vehicle.

Table 1 shows that more than 4,870 contacts were made during the recruitment process. Contacts were tracked based on the following three categories:

- Agreed to Participate. The company or individual operated qualifying vehicles making trips within the study area, agreed to participate, complete, and return the survey materials.
- Refused to Participate. The company or individual operated qualifying vehicles making trips within the study area but refused to participate in the survey.
- Not Participating. The company or individual did not operate a qualifying vehicle making trips within the study area; or the company or individual operated a qualifying vehicle, but it did not make trips within the study area.

Table 1. Survey Recruitment Participation.

Recruitment Category	Contact Calls	
	Number	Percent of Total
Agreed to Participate	402	8.24
Refused to Participate	237	4.86
Not Participating	4,237	86.90
Total	4,876	100.00

Source: ATG, 2009.

A total of 178 companies participated in the Waco commercial vehicle survey, from which a total of 313 surveys were obtained. TTI processed and reviewed the survey data collected to ensure that it was complete and followed the guidelines set forth in TxDOT's bid specification for the project. A data check program was utilized to examine the accuracy of geocoding of locations and the logic of survey responses. Data errors were expected to be corrected prior to final data submittals by the vendor. However, it was not unusual to find inconsistencies in the data during actual data processing and analysis. One survey reported only one trip (home to base location), and no travel log was recorded after reaching the base location. This survey was therefore not included in the survey analysis.

The results presented in this technical summary are based on data from 312 surveyed commercial vehicles.

SURVEY RESULTS

Vehicle Characteristics

This section presents the characteristics of registered trucks and surveyed commercial vehicles to provide an overview of the type and condition of commercial vehicles operating within the Waco study area. Information on registered trucks includes the number of diesel-fueled and gasoline-fueled trucks by gross vehicle weight and by model year. Information on surveyed commercial vehicles includes vehicle make, model and year, odometer reading, gross vehicle weight, vehicle classification, and type of fuel used.

Registered Commercial Vehicles

Table 2 shows the distribution of registered trucks by gross vehicle weight, based on 2009 TxDOT vehicle registration data. It shows that there were 3,902 trucks registered in the study area in 2009 and there were more diesel-fueled trucks (2,905) than gasoline-fueled trucks (997). Approximately 58 percent of the diesel-fueled trucks and 74 percent of the gasoline-fueled trucks had a gross vehicle weight between 8,500 lbs. and 10,000 lbs.

Table 2. Gross Vehicle Weight of Registered Trucks in the Waco Study Area.

Gross Vehicle Weight (lbs.)	Diesel-Fueled		Gasoline-Fueled		All Trucks	
	Number of Trucks	Percent of Total	Number of Trucks	Percent of Total	Number of Trucks	Percent of Total
> 8500	1,402	48.26	560	56.17	1,962	50.28
> 10000	277	9.54	173	17.35	450	11.53
> 14000	116	3.99	70	7.02	186	4.77
> 16000	117	4.02	43	4.31	160	4.10
> 19500	285	9.81	107	10.73	392	10.05
> 26000	189	6.51	25	2.51	214	5.48
> 33000	314	10.81	18	1.81	332	8.51
> 60000	205	7.06	1	0.10	206	5.28
Total	2,905	100.00	997	100.00	3,902	100.00

Source: TxDOT, 2009.

Figure 2 shows the distribution of registered trucks by model year. The majority of the diesel-fueled trucks (73 percent) were less than 10 years old, compared to 58 percent for gasoline-fueled trucks. More than 13 percent of the gasoline-fueled trucks were older than 20 years, compared to less than 5 percent for diesel-fueled trucks.

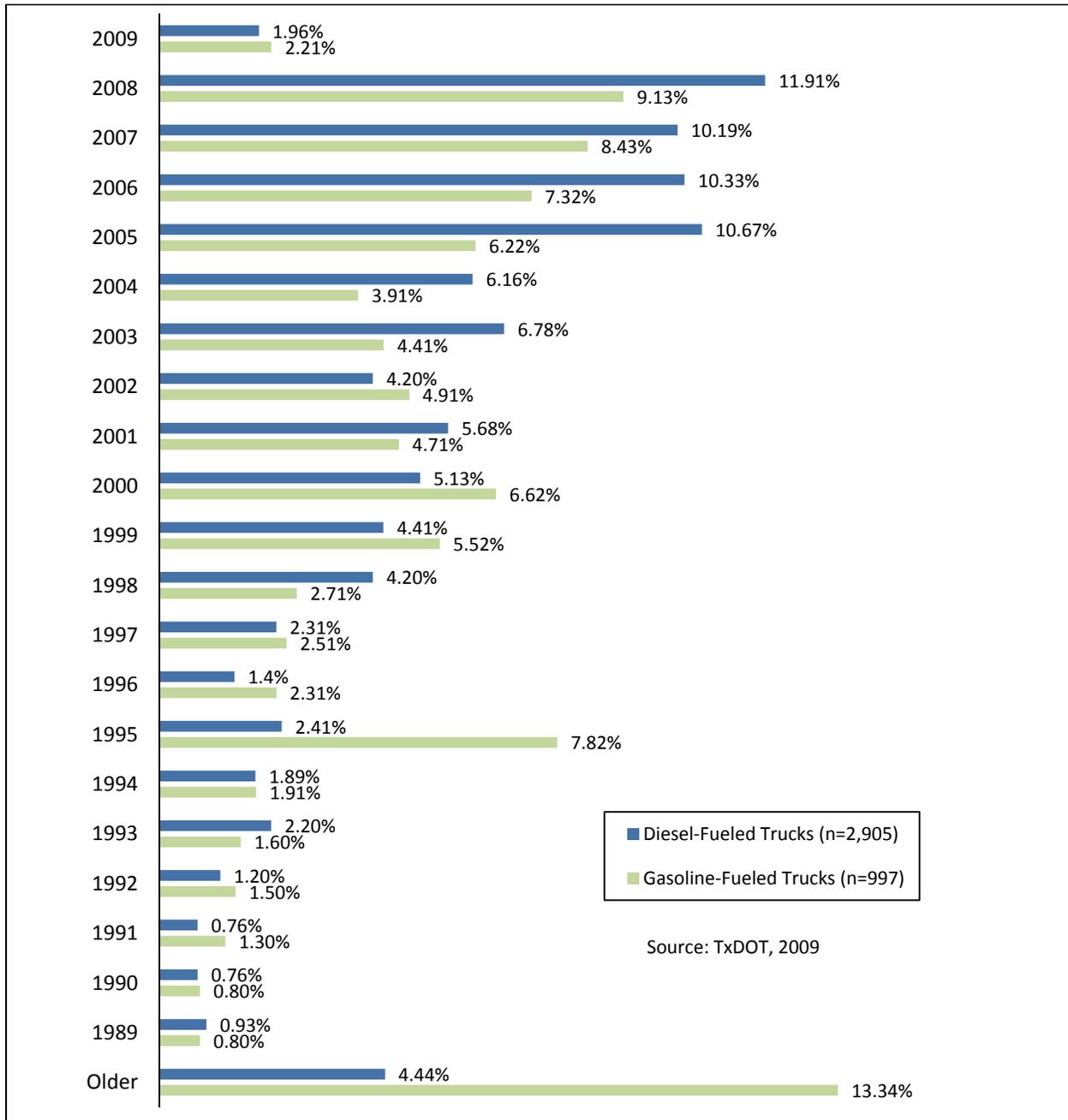


Figure 2. Model Year of Registered Trucks in the Waco Study Area.

Surveyed Commercial Vehicles

Commercial vehicles that participated in the Waco commercial vehicle survey were classified based on the nine vehicle types listed in Table 3. These commercial vehicles were further categorized as either cargo/freight transport or service vehicles.

Cargo vehicles were defined as vehicles mainly used to transport cargo or freight, which were typically bulk goods, materials, and cargo in large quantities for wholesale distribution. Service vehicles were defined as vehicles mainly used to perform services such as those used by building contractors, plumbers, electricians, cable and telephone services/repairs, and delivery vans/vehicles used by local retailers. These also included company fleet vehicles or fleets and maintenance vehicles for public agencies such as TxDOT, city, county, or school districts.

Of the total 312 commercial vehicles surveyed, 126 were cargo vehicles and 186 were service vehicles. Table 3 shows the vehicle classification type of these vehicles. Among surveyed cargo vehicles, approximately 35 percent were single unit two-axle trucks (six-wheelers), 25 percent were pick-up trucks, 18 percent were semi tractor/trailer combinations, and 12 percent were vans. Among surveyed service vehicles, approximately 52 percent were pick-up trucks, 24 percent were vans, and 10 percent were single unit two-axle trucks.

Table 3. Vehicle Classification Type of Surveyed Commercial Vehicles.

Vehicle Classification	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Vehicles	Percent of Total	Number of Vehicles	Percent of Total	Number of Vehicles	Percent of Total
Passenger Car	0	0.00	16	8.60	16	5.13
Pick-Up Truck	32	25.40	96	51.61	128	41.03
Van (passenger or mini)	15	11.90	45	24.19	60	19.23
Sport Utility Vehicle	0	0.00	9	4.84	9	2.88
Single Unit two-axle (six wheels)	44	34.92	19	10.22	63	20.19
Single Unit three-axle (10 wheels)	10	7.94	1	0.54	11	3.53
Single Unit four-axle (14 wheels)	1	0.79	0	0.00	1	0.32
Semi (all tractor-trailer combinations)	22	17.46	0	0.00	22	7.05
Other	2	1.59	0	0.00	2	0.64
Total	126	100.00	186	100.00	312	100.00

Figure 3 shows the distribution of surveyed commercial vehicles by fuel type. Approximately 86 percent of the service vehicles used gasoline, and the remaining 14 percent used diesel. Among cargo vehicles, 61 percent used diesel and 38 percent used gasoline. Less than one percent of cargo and service vehicles surveyed used another type of fuel, such as propane.

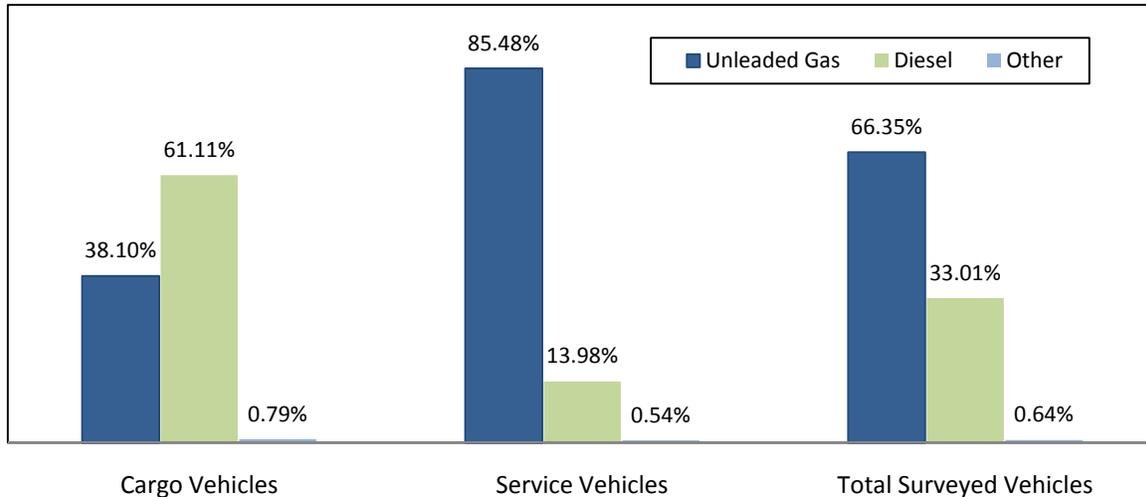


Figure 3. Type of Fuel Used by Surveyed Commercial Vehicles.

Table 4 shows the gross vehicle weight of surveyed commercial vehicles. Over 49 percent of the service vehicles had a gross vehicle weight of less than 8,500 lbs., while 50 percent of the cargo vehicles had a gross vehicle weight of more than 19,500 lbs. but not exceeding 90,000 lbs.

Table 4. Gross Vehicle Weight of Surveyed Commercial Vehicles.

Gross Vehicle Weight (lbs.)	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Vehicles	Percent of Total	Number of Vehicles	Percent of Total	Number of Vehicles	Percent of Total
< 8,500	31	24.60	92	49.46	123	39.42
> 8,500	10	7.94	33	17.74	43	13.78
> 10,000	11	8.73	20	10.75	31	9.94
> 14,000	2	1.59	5	2.68	7	2.24
> 16,000	4	3.17	1	0.54	5	1.60
> 19,500	8	6.35	1	0.54	9	2.89
> 26,000	17	13.49	4	2.15	21	6.73
> 33,000	10	7.94	9	4.84	19	6.09
> 60,000	28	22.22	2	1.08	30	9.62
Unknown	5	3.97	19	10.22	24	7.69
Total	126	100.00	186	100.00	312	100.00

Figure 4 shows the distribution of surveyed vehicles by model year. Approximately 79 percent of the cargo vehicles and service vehicles were less than 10 years old. The average age for cargo vehicles was 5.89 years, while the average age for service vehicles was 6.11 years.

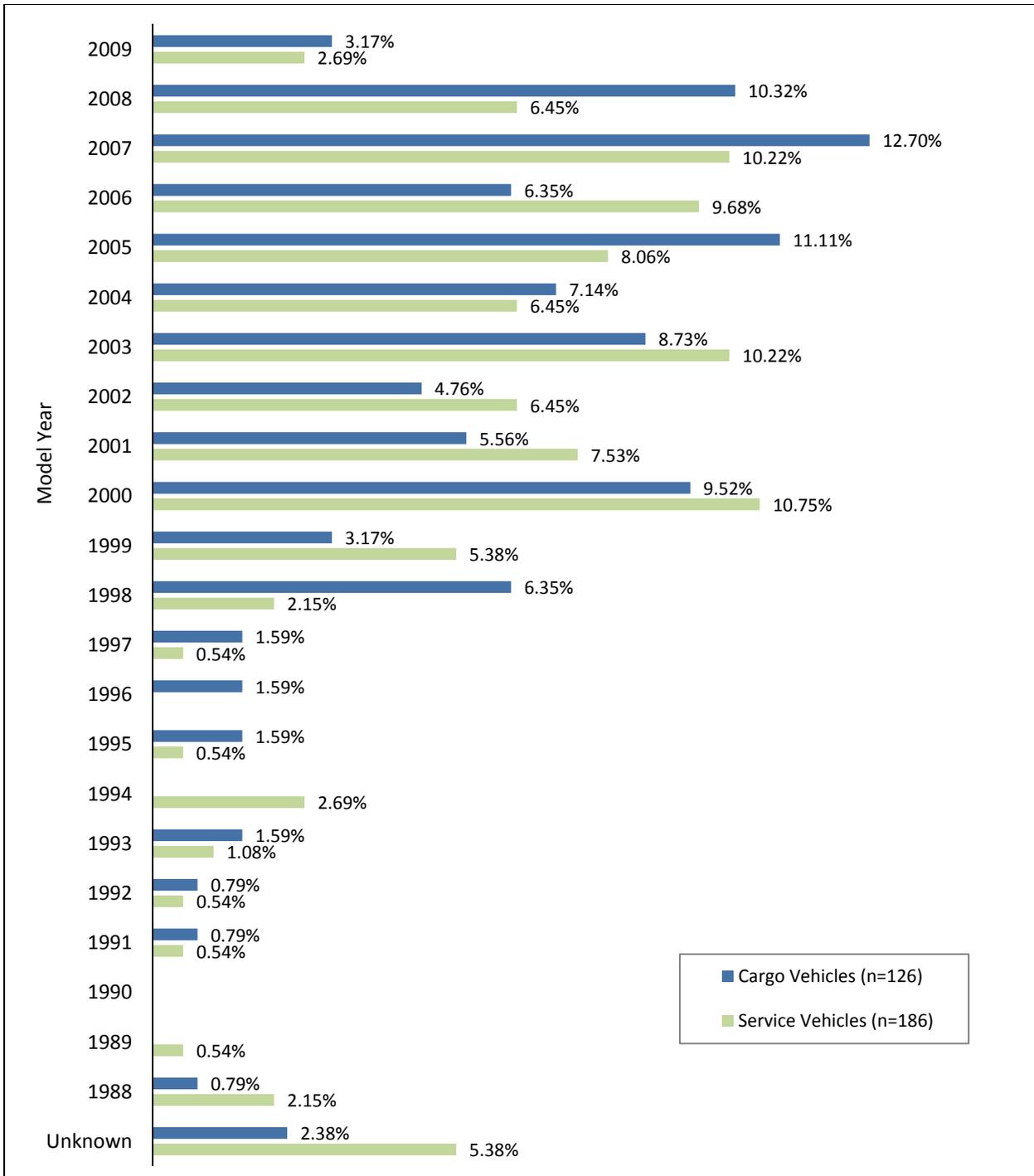


Figure 4. Model Year of Surveyed Commercial Vehicles.

Table 5 shows the average vehicle mileage by model year based on odometer readings reported by 235 surveyed vehicles (92 cargo vehicles and 143 service vehicles) at the beginning of their travel day. The average odometer mileage for cargo vehicles was 159,554 miles, compared to 110,236 miles for service vehicles.

Table 5. Model Year and Average of Reported Odometer Readings of Surveyed Commercial Vehicles.

Model Year	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Vehicles	Average of Reported Odometer Readings	Number of Vehicles	Average of Reported Odometer Readings	Number of Vehicles	Average of Reported Odometer Readings
2009	3	16,070	3	5,168	6	10,619
2008	5	10,001	11	14,237	16	12,913
2007	8	153,621	15	40,742	23	80,004
2006	7	128,439	13	60,942	20	84,566
2005	9	115,643	12	71,261	21	90,282
2004	8	158,606	6	110,258	14	137,885
2003	11	153,104	16	150,918	27	151,808
2002	5	153,476	8	124,070	13	135,380
2001	5	330,067	11	137,369	16	197,587
2000	10	186,690	17	139,429	27	156,933
1999	3	146,751	10	162,999	13	159,250
1998	7	279,170	2	129,278	9	245,861
1997	1	250,362	1	222,570	2	236,466
1996	2	131,961	0	0	2	131,961
1995	2	73,200	1	137,165	3	94,522
1994	0	0	5	249,394	5	249,394
1993	2	175,691	2	83,500	4	129,595
1992	1	252,364	1	192,125	2	222,245
1991	1	265,000	0	0	1	265,000
1990	0	0	0	0	0	0
1989	0	0	1	131,654	1	131,654
1988	1	130,471	4	253,060	5	228,542
Unknown	1	120,000	4	96,171	5	100,937
Total	92	159,554	143	110,236	235	129,543

Trip Frequency

The surveyed commercial vehicles generated 2,156 trips, of which 1,774 were internal trips and 382 were external trips. Internal trips were defined as those trips made within or between zones inside the Waco study area. These trips were further distinguished as inter-zonal trips, those trips made from one zone to another, or intra-zonal trips, those made within the same zone. External trips were defined as those trips having one or both ends of the trip outside of the study area.

Figure 5 shows the distribution of inter-zonal, intra-zonal and external trips and Table 6 provides the breakdown of these trips. Approximately 82 percent of the total trips were internal, of which 76 percent were inter-zonal and 6 percent were intra-zonal. The remaining 18 percent were external trips. Cargo vehicles generated 880 trips, of which approximately 68 percent were inter-zonal trips, 3 percent were intra-zonal trips, and about 29 percent were external trips. Service vehicles generated 1,276 trips, of which 82 percent were inter-zonal, nearly 8 percent were intra-zonal trips, and 10 percent were external trips.

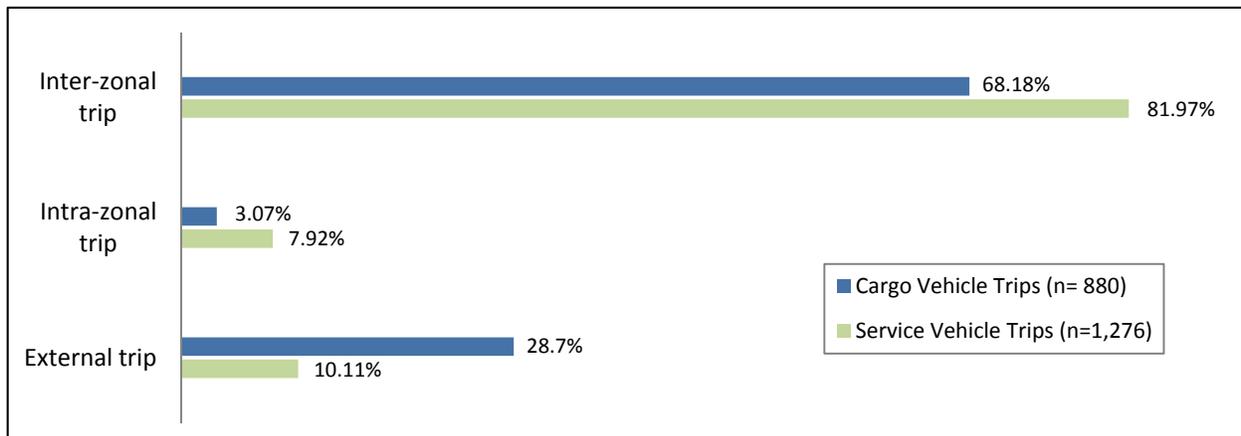


Figure 5. Inter-Zonal, Intra-Zonal, and External Trips.

Table 6. Total Internal and External Trips.

Trip Type	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Inter-Zonal	600	68.18	1,046	81.97	1,646	76.34
Intra-Zonal	27	3.07	101	7.92	128	5.94
Total Internal	627	71.25	1,147	89.89	1,774	82.28
External	253	28.75	129	10.11	382	17.72
Total	880	100.00	1,276	100.00	2,156	100.00

Figure 6 shows the distribution of total commercial vehicle trips (internal and external trips), which varied from two trips to 19 trips per cargo and service vehicle. Figure 7 shows the distribution of total internal trips only. Approximately 10 percent of the cargo vehicles and 3 percent of the service vehicles made one internal trip per day. In contrast, the total trips made by the surveyed vehicles indicated a minimum of two trips per day. The variation is attributed to the exclusion of external trips. The average number of total trips per day for cargo vehicles was 6.98 trips, compared to 6.86 trips for service vehicles. The average number of internal trips per day for cargo vehicles was 5.70 trips, compared to 6.59 trips for service vehicles.

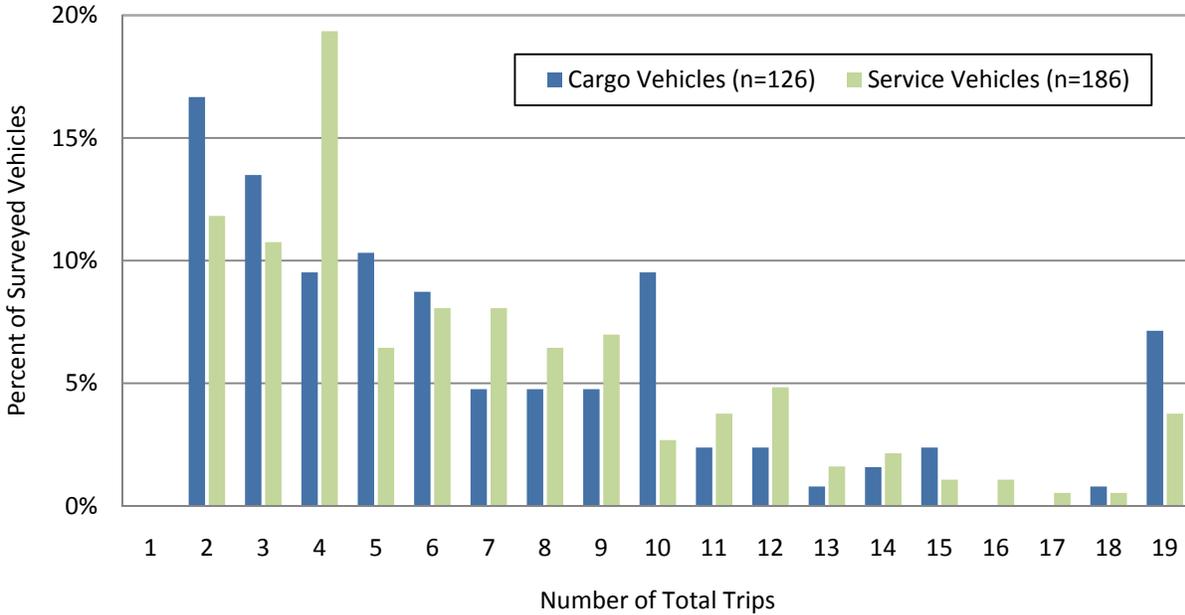


Figure 6. Total Trips per Vehicle.

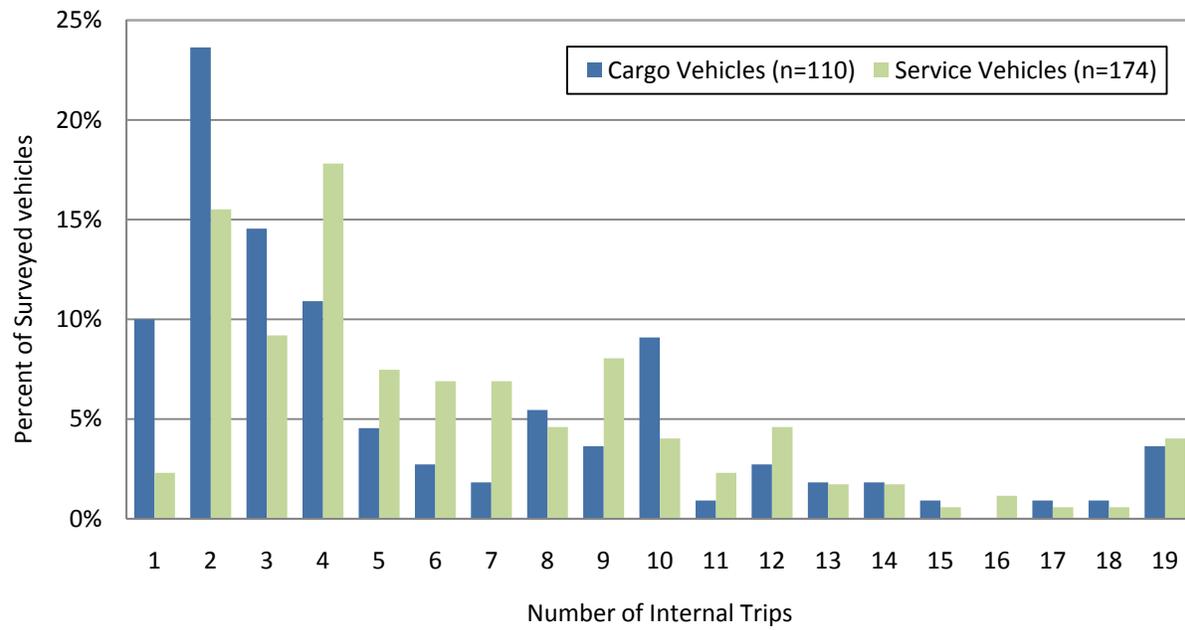


Figure 7. Total Internal Trips per Vehicle.

Trip Characteristics

Information on the type of land use activity at the trip origin and destination locations, and the purpose of trips being made are important in estimating commercial vehicle trip patterns. The analysis of trips presented in this section is based solely on internal trips, and does not include external trips.

Table 7 shows the land use types at the trip destinations. Approximately 31 percent of the total internal cargo vehicle trips occurred at retail/shopping places and 24 percent occurred at industrial/manufacturing sites. For service vehicle trips, 22 percent occurred at residential sites, and 15 percent were at office buildings.

Table 7. Land Use Types at Trip Destinations.

Land Use Type	Cargo Vehicles		Service Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Office Building (non-government)	41	6.54	174	15.17
Retail/Shopping	193	30.78	130	11.33
Industrial/Manufacturing	151	24.08	60	5.23
Medical/Hospital	14	2.23	52	4.53
Education (12th grade or less, college, trade)	15	2.39	64	5.58
Government Office/Building	2	0.32	62	5.41
Residential	51	8.14	246	21.45
Airport	0	0.00	8	0.70
Intermodal Facility	1	0.16	4	0.35
Warehouse	35	5.58	59	5.15
Distribution Center	26	4.15	38	3.31
Construction Site	45	7.18	56	4.88
Other	52	8.29	152	13.25
Refused/Unknown	1	0.16	42	3.66
Total Trips	627	100.00	1,147	100.00

Table 8 shows the trip purposes at the destination locations. Approximately 49 percent of the total internal cargo vehicle trips were delivery, 20 percent were return-to-base location, and 16 percent were pick-up. For service vehicle trips, 39 percent were service-related, 19 percent were return-to-base location, and 17 percent were delivery.

Table 8. Trip Purposes at Trip Destinations.

Trip Purpose	Cargo Vehicles		Service Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Base Location	127	20.26	213	18.57
Delivery	307	48.96	197	17.18
Pick-Up	103	16.43	78	6.80
Pick-Up and Delivery	35	5.58	51	4.44
Maintenance (fuel, oil, etc.)	12	1.91	17	1.48
Driver Needs (lunch, etc.)	10	1.60	70	6.10
Service-Related	18	2.87	452	39.41
Other	15	2.39	58	5.06
Refused/Unknown	0	0.00	11	0.96
Total	627	100.00	1,147	100.00

Cargo Characteristics

Information on the type of cargo being delivered or picked-up at each stop, the weight of cargo, and the type of land use where the cargo trip occurred were collected to examine the movement of commodities within and outside of the Waco study area. The analysis presented in this section is for internal and external trips made by surveyed cargo vehicles only, and does not include the trips made by service vehicles.

The analysis of cargo trip data examined the types of cargo being transported at trip destinations, the trip purpose and land use activity at each stop, and the estimated net weight of the cargo being picked-up and/or delivered for each trip. There were several inconsistencies observed in the cargo trip data. Some trips that reported full or partial cargo loads did not provide the weight of the cargo but indicated the type of cargo being transported. Some trips that reported the delivery trip purpose did not provide the cargo weight at drop-off. There were some trips that reported the cargo weight at pick-up but the weight was not consistent at drop-off. Such inconsistencies generated errors in the estimation of the cargo net weight for that particular trip. Hence, it was necessary to manually process the cargo trip data, and use the researchers' judgment when making changes as deemed fit.

Figure 8 shows the load status of surveyed cargo vehicles at the beginning of the trip. Approximately 61 percent of the cargo vehicles reported partial load status, while 14 percent were fully loaded with cargo and the remaining 25 percent were empty. The types of cargo in the survey were based on 22 classification types listed in Table 9.

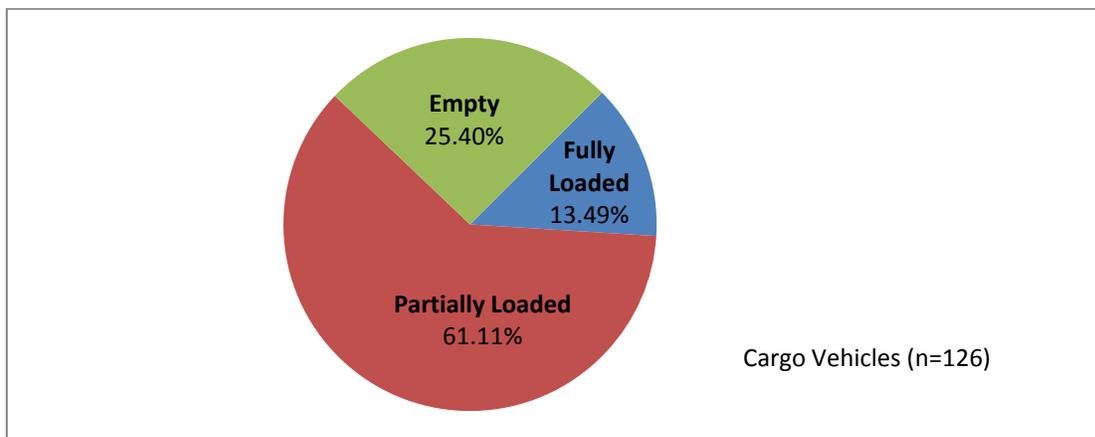


Figure 8. Cargo Load Status at Trip Start.

Table 9. Cargo Classification Types.

Survey Cargo Classification	Cargo Description
1. Farm Products	Livestock, fertilizer, dirt, landscaping, etc.
2. Forest Products	Trees, sod, etc.
3. Marine Products	Fresh fish, seafood, etc.
4. Metals and Minerals	Crude petroleum, natural gas, propane, metal, gypsum, etc.
5. Food, Health, and Beauty Products	Assorted food products, cosmetics, etc.
6. Tobacco Products	Cigarettes, cigars, and chewing tobacco
7. Textiles	Clothing, linens, etc.
8. Wood Products	Lumber, paper, cardboard, wood pulp, etc.
9. Printed Matter	Newspapers, magazines, books, etc.
10. Chemical Products	Soap, paint, household or industrial chemicals, etc.
11. Refined Petroleum or Coal	Gasoline, etc.
12. Rubber, Plastic, and Styrofoam	Finished products of rubber, plastic, or styrofoam
13. Clay, Concrete, Glass, or Stone	Finished products of clay, concrete, glass, or stone
14. Manufactured Goods and Equipment.	Miscellaneous products -machinery, appliances, furniture, etc.
15. Wastes	Waste products including scrap and recyclable materials
16. Miscellaneous Shipments	U.S. mail, U.P.S., Federal Express, and other mixed cargo
17. Hazardous Materials	Hazardous chemicals and substances
18. Transportation	Automobiles and other transport vehicles
19. Unclassified Cargo	Cargo not falling within one of the above categories
20. Driver Refused to Answer	Driver refused to answer
21. Unknown to Driver	Unknown to driver
22. Empty	Empty (including empty shipping containers)

Table 10 shows the distribution of trips by cargo type. Approximately 90 percent of the total cargo vehicle trips were transporting cargo, while the remaining 10 percent were not carrying cargo. The most frequently transported cargo types were manufactured goods and equipment (25 percent), food, health, and beauty products (20 percent), unclassified or other cargo (15 percent), and clay, concrete, glass or stone products (10 percent).

Table 10. Types of Cargo being Transported at Trip Destinations.

Cargo Type	Cargo Vehicles	
	Number of Trips	Percent of Total
Farm Products	35	4.44
Forest Products	9	1.14
Marine Products	0	0.00
Metals and Minerals	16	2.02
Food, Health, and Beauty Products	160	20.28
Tobacco Products	0	0.00
Textiles	2	0.25
Wood Products	44	5.58
Printed Matter	14	1.77
Chemical Products	1	0.13
Refined Petroleum or Coal Products	37	4.69
Rubber, Plastic, and Styrofoam Products	8	1.01
Clay, Concrete, Glass, or Stone	81	10.27
Manufactured Goods and Equipment	198	25.10
Wastes	1	0.13
Miscellaneous Shipments	18	2.28
Hazardous Materials	0	0.00
Transportation	11	1.39
Unclassified/Other Cargo	119	15.08
Driver Refused to Answer	13	1.65
Unknown to Driver	22	2.79
Total Trips with Cargo	789	89.66*
Empty	91	10.34*
Total Cargo Vehicle Trips	880	100.00

Note: * Value is calculated from total cargo vehicle trips.

The commodity grouping scheme used by TxDOT in the Texas Statewide Analysis Model (SAM) was used to aggregate the cargo types into 10 commodity groups. The types of place option in the survey were categorized into seven land use categories. Table 11 shows the equivalency between SAM commodity groups and cargo classification types from the survey, while Table 12 shows the equivalency between land use categories and type of place options from the survey. Those items *in italics* did not have equivalents, but were added or grouped together so as not to exclude any trips in the analysis.

Table 11. Equivalency between SAM Commodity Groups and Survey Cargo Classification Types.

Commodity Group	Survey Cargo Classification
1 Agriculture	Farm Products, Forest Products, Marine Products
2 Raw Materials	Metals and Minerals, Chemical Products, Refined Petroleum, Coal
3 Food	Food, Health and Beauty Products, Tobacco Products
4 Textiles	Textiles, Rubber, Plastic, and Styrofoam Products
5 Wood	Wood Products, Printed Matter
6 Building Materials	Clay, Concrete, Glass or Stone Products
7 Machinery	Manufactured Goods/Equipment
8 Miscellaneous	Wastes, Miscellaneous Shipments
9 Secondary	Unclassified Cargo
10 Hazardous Materials	Hazardous Materials
<i>Transportation</i>	<i>Transportation</i>
<i>Empty</i>	<i>Empty</i>
<i>Unknown</i>	<i>Unknown to Driver/ Driver Refused to Answer</i>

Table 12. Equivalency between Land Use Categories and Survey Types of Place.

Land Use Category	Survey Type of Place
1 Office	Office Building
2 Retail	Retail/Shopping
3 Industrial	Industrial/Manufacturing
4 Medical	Medical/Hospital
5 Education	Educational (12th grade or less and college, trade, etc.)
6 Government	Government Office/Building
7 Residential	Residential
<i>Other</i>	<i>Airport, Inter-Modal Facility, Warehouse, Distribution Center, Construction Site, Other</i>

Figure 9 shows the distribution of cargo trips at destination locations by commodity group and Figure 10 shows the distribution by land use type. More than 22 percent of the trips were transporting machinery, and 18 percent were transporting food products. Approximately 10 percent were not carrying cargo. Approximately 33 percent of the trips occurred at retail sites, 25 percent occurred at “other” land use types, and 21 percent were at industrial sites. Table 13 provides the breakdown of cargo trips by commodity group and land use type.

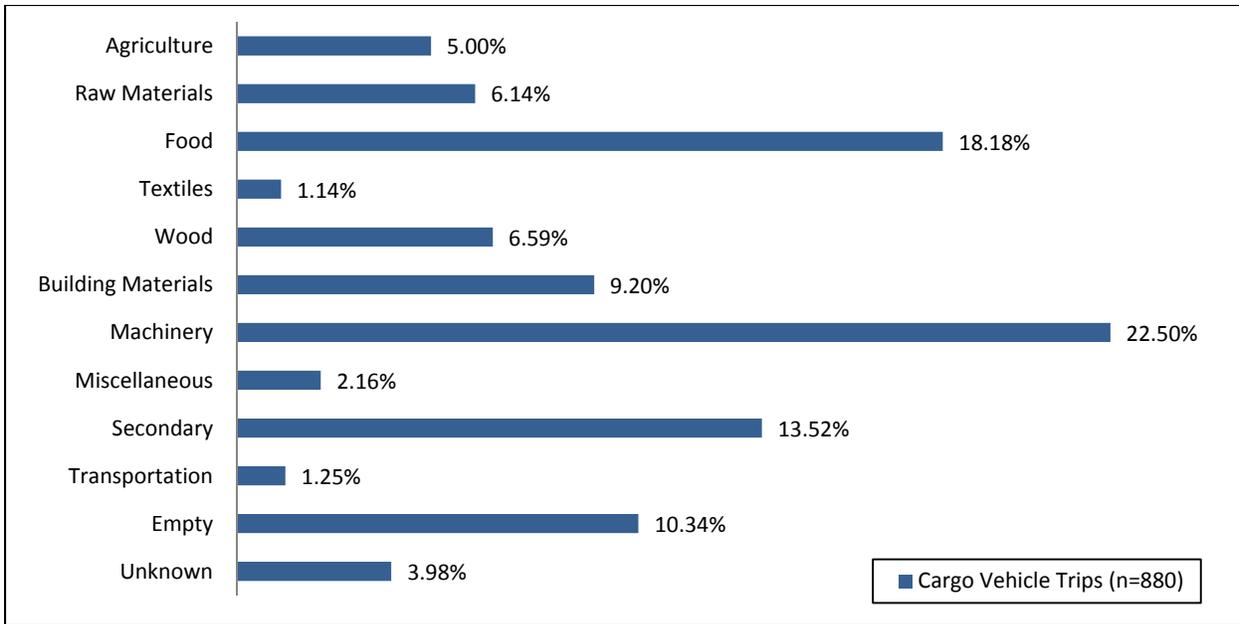


Figure 9. Commodity Groups at Trip Destinations.

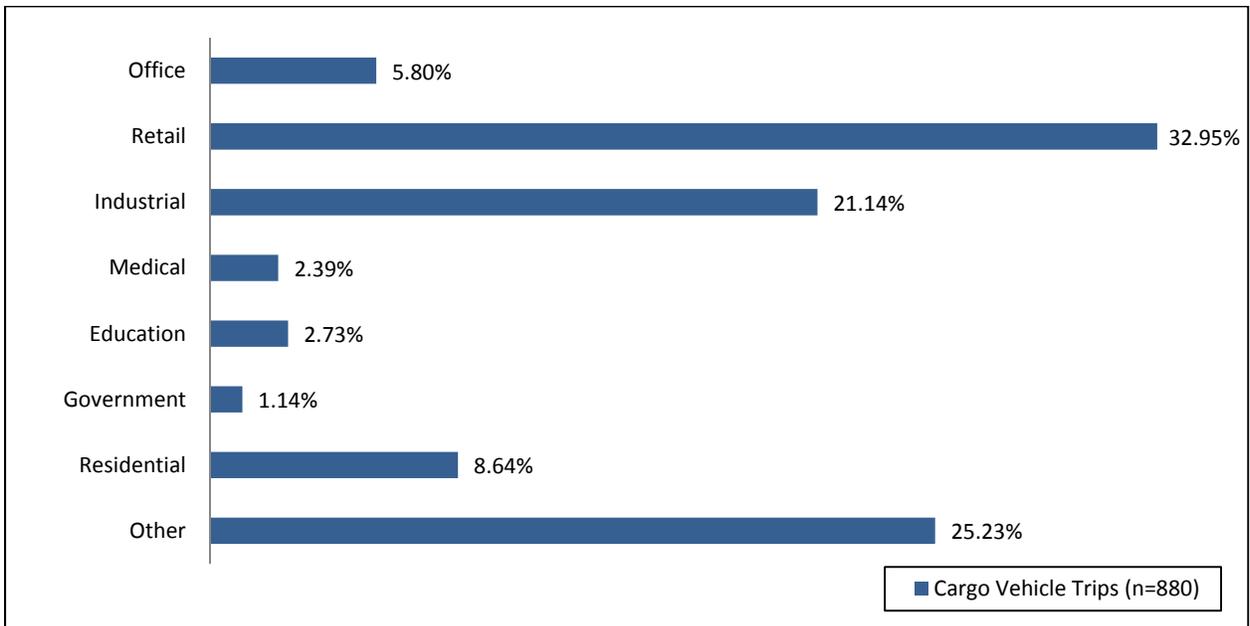


Figure 10. Land Use Types at Trip Destinations.

Table 13. Cargo Trips by Commodity Group and Land Use at Trip Destinations.

Commodity Group	Land Use								Total Trips	Percent of Total
	Office	Retail	Ind'l	Med	Edu	Gov't	Res	Other		
Agriculture	4	17	4	0	3	0	1	15	44	5.00
Raw Materials	2	11	31	5	0	0	2	3	54	6.14
Food	1	147	2	6	0	0	0	4	160	18.18
Textiles	2	0	1	0	0	0	1	6	10	1.14
Wood	9	4	23	0	3	0	10	9	58	6.59
Building Materials	2	0	28	0	2	0	8	41	81	9.20
Machinery	7	56	40	0	8	6	34	47	198	22.50
Miscellaneous	0	2	8	0	1	1	3	4	19	2.16
Secondary	4	26	26	8	4	3	3	45	119	13.52
Transportation	0	2	6	0	0	0	0	3	11	1.25
Empty	16	20	15	2	0	0	3	35	91	10.34
Unknown	4	5	2	0	3	0	11	10	35	3.98
Total	51	290	186	21	24	10	76	222	880	100.00
Percent of Total	5.80	32.95	21.14	2.38	2.73	1.14	8.64	25.22	100.00	

The analysis of cargo weight by cargo type provides information on the volume and type of commodities being moved from the time the surveyed cargo vehicle left its base location, began its trip, and continued making trips until it reached its destination and returned to its base location. The net cargo weight for each trip was estimated based on the cargo weight being picked-up and/or being dropped-off, consistent with the reported trip purpose for each stop. There were several cases when cargo types were changed between trips (e.g., reported as empty cargo or food type), even if the same cargo was being transported either for delivery or pick-up. The driver of the surveyed cargo vehicle reported a different trip purpose during a particular stop (e.g., driver needs - lunch, etc.), which indicated that no cargo was either delivered and/or picked-up but the cargo remained in transit. In such cases, the cargo weight from the trip origin should be the net cargo weight at that particular stop or trip destination with its corresponding cargo type. If a delivery occurred during that particular stop, the cargo weight for that particular drop-off should be deducted from the current weight load, and if cargo was picked-up, the cargo weight should be added to the current weight load, thus resulting in an estimated net cargo weight for that particular trip.

Figure 11 shows the distribution of cargo trips at destination locations by trip purpose, while Table 14 shows a detailed summary of trips by commodity group and trip purpose.

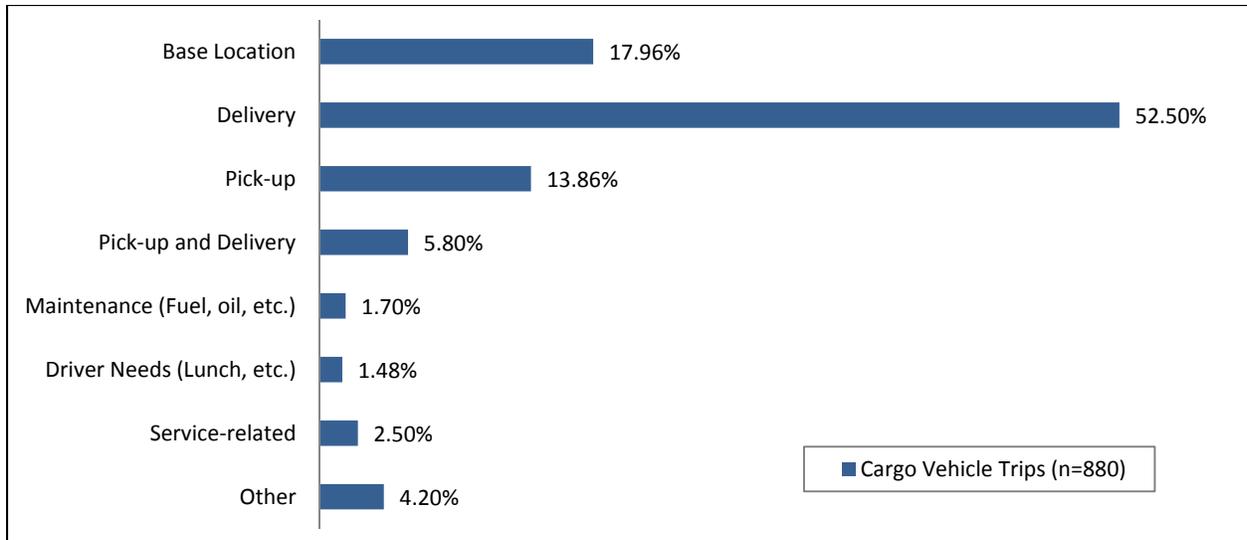


Figure 11. Cargo Trip Purposes at Trip Destinations.

Table 14. Cargo Trips by Commodity Group and Trip Purpose at Trip Destinations.

Commodity Group	Trip Purpose								Total Trips	Percent of Total
	Base Location	Delivery	Pick-Up	Pick-Up and Delivery	Maintenance	Driver Needs	Service-related	Other		
Agriculture	4	22	7	3	1	0	7	0	44	5.00
Raw Materials	10	20	3	16	1	1	0	3	54	6.14
Food	1	154	3	1	0	1	0	0	160	18.18
Textile	0	5	4	1	0	0	0	0	10	1.14
Wood	10	35	8	1	0	0	1	3	58	6.59
Building Materials	2	42	35	1	0	1	0	0	81	9.20
Machinery	32	92	30	21	9	2	7	5	198	22.50
Miscellaneous	1	8	8	0	0	1	1	0	19	2.16
Secondary	12	61	18	6	0	2	1	19	119	13.52
Transportation	3	4	3	0	0	0	0	1	11	1.25
Empty	75	1	0	1	2	5	4	3	91	10.34
Unknown	8	18	3	0	2	0	1	3	35	3.98
Total Trips	158	462	122	51	15	13	22	37	880	100.00
Percent of Total	17.96	52.50	13.86	5.80	1.70	1.48	2.50	4.20	100.00	

Approximately 53 percent of the total cargo vehicle trips were delivery, with food and machinery being the most frequently delivered cargo among commodity groups. Building materials and machinery showed the highest number of trips for pick-up. The trip purpose “pick-up” made up 14 percent of the total cargo trips. However, these do not represent the actual proportion of trips that picked-up cargo because some of the trips coded as “base location” trip purpose were also the pick-up locations for cargo.

Table 15 shows the distribution of average net cargo weight per trip by commodity group and land use type at the destination locations. Building materials being transported to education sites showed the highest average net cargo weight, followed by textiles being transported to office and industrial sites, and raw materials being transported to “other” land use types.

Table 15. Average Net Cargo Weight by Commodity Group and Land Use at Trip Destinations.

Commodity Group	Land Use (Average Net Cargo Weight in lbs.)							
	Office	Retail	Ind'l	Med	Educ	Gov't	Res	Other
Agriculture	1,000	1,488	14,833	0	1,358	0	300	3,176
Raw Materials	3,440	3,910	12,449	14,153	0	0	3,661	40,088
Food	25	7,876	0	846	0	0	0	541
Textiles	41,250	0	40,000	0	0	0	200	30,625
Wood	1,342	7,225	2,376	0	12	0	17,125	7,455
Building Materials	12,401	0	34,270	0	47,000	0	24,076	34,487
Machinery	1,706	2,117	10,461	0	355	1,036	2,518	1,058
Miscellaneous	0	900	6,413	0	180	0	0	2,811
Secondary	12,137	9,992	4,581	11,396	24,500	4,670	1,200	10,641
Transportation	0	48	152	0	0	0	0	170
Unknown	17,525	5,408	50	0	2,733	0	3,047	12,698

Table 16 shows the distribution of average net cargo weight at the trip destinations by commodity group and trip purpose. Building materials and wood products showed the highest average net cargo weight for pick-up and delivery.

Table 17 shows distribution of cargo trips and net cargo weights at the trip destinations by commodity group. Overall, the average net cargo weight per trip was approximately 9,900 lbs. Building materials showed the highest average net cargo weight of 33,400 lbs. per trip. However, machinery and food were the most frequently transported commodity groups with average net cargo weights of approximately 3,700 lbs. and 7,400 lbs. per trip, respectively.

Table 16. Average Net Cargo Weight by Commodity Group and Trip Purpose at Trip Destinations.

Commodity Group	Trip Purpose (Average Net Cargo Weight in lbs.)							
	Base Location	Delivery	Pick-Up	Pick-up and Delivery	Main-tenance	Driver Needs	Service-related	Other
Agriculture	3,839	2,988	9,539	3,048	0	0	0	0
Raw Materials	6,840	7,475	29	15,930	3,767	3,792	0	29,333
Food	25	7,537	1,218	1,499	0	0	0	0
Textile	0	20,675	40,000	42,500	0	0	0	0
Wood	3,165	6,862	3,290	3,300	0	0	7	0
Building Materials	12,401	31,651	34,037	98,540	0	40,720	0	0
Machinery	2,694	3,091	10,497	1,721	1,374	675	856	925
Miscellaneous	9,687	697	6,413	0	0	366	180	0
Secondary	7,712	10,400	12,200	17,883	0	290	0	3,105
Transportation	248	65	170	0	0	0	0	5
Unknown	11,269	5,457	17,525	0	8,000	0	10	968

Table 17. Cargo Trips and Net Cargo Weight by Commodity Group at Trip Destinations.

Commodity Group	Total Cargo Trips	Total Net Cargo Weight (lbs.)	Number of Trips*	Average Net Cargo Weight (lbs.)*
Agriculture	44	114,728	29	3,956
Raw Materials	54	442,215	36	12,284
Food	160	1,157,165	157	7,370
Textile	10	245,200	8	30,650
Wood	58	288,267	52	5,544
Building Materials	81	2,638,249	79	33,396
Machinery	198	599,839	164	3,658
Miscellaneous	19	63,625	14	4,545
Secondary	119	1,101,239	117	9,412
Transportation	11	1,516	11	138
Empty	91	-	-	-
Unknown	21	145,611	21	6,934
Total	880	6,797,654	688	9,880

*Excluding trips with empty cargo.

Table 18 shows the distribution of cargo trips and net cargo weights at the trip destinations by land use type. The “other” land use category showed the highest average net cargo weight of 13,600 lbs. per trip, followed by industrial sites with an average net cargo weight of 12,250 lbs. per trip. However, the highest frequency of trips occurred at retail sites, with an average net cargo weight of 6,700 lbs. per trip.

Table 18. Cargo Trips and Net Cargo Weights by Land Use at Trip Destinations.

Land Use	Total Cargo Trips	Total Net Cargo Weight (lbs.)	Number of Trips*	Average Net Cargo Weight (lbs.)*
Office	51	206,393	26	7,938
Retail	290	1,558,398	231	6,746
Industrial	186	1,899,167	155	12,253
Medical	21	167,009	19	8,790
Education	24	207,330	24	8,639
Government	10	20,224	9	2,247
Residential	76	423,019	54	7,834
Other	222	2,316,072	170	13,624
Total	880	6,797,612	688	9,880

*Excluding trips with empty cargo.

Table 19 shows the distribution of cargo trips and net cargo weights at the trip destinations by trip purpose. Cargo pick-up had the highest average net weight of almost 18,000 lbs. per trip. However, there were more delivery trips, with an average net cargo weight of 9,200 lbs. per trip.

Table 19. Cargo Trips and Net Cargo Weights by Trip Purpose at Trip Destinations.

Trip Purpose	Total Cargo Trips	Total Net Cargo Weight (lbs.)	Number of Trips*	Average Net Cargo Weight (lbs.)*
Return to Base Location	158	316,758	67	4,728
Delivery	462	3,853,663	418	9,219
Pick-Up	122	1,869,399	104	17,975
Pick-Up and Delivery	51	535,656	48	11,160
Maintenance (fuel, oil, etc.)	15	17,264	6	2,877
Driver Needs (lunch, etc.)	13	46,807	7	6,687
Service-Related	22	4,477	8	560
Other	37	153,588	30	5,120
Total	880	6,797,612	688	9,880

*Excluding trips with empty cargo.

Trip Length

Odometer readings at the beginning and end of the trip are useful in estimating travel distances for external and intra-zonal trips. The Waco commercial vehicle survey, however, only provided odometer mileage on each vehicle for the beginning of the trip and not for the end of the trip. Because this incomplete information makes odometer readings not particularly useful for trip length measurement in this analysis, network matrices available for the study area were used to estimate trip lengths. The network matrices provide travel distance and time estimates from one zone to another zone in the Waco study area network. Since each reported trip in the survey was coded with a traffic analysis zone (TAZ) number assigned to the study area, it was then possible to estimate the trip length based on the distance provided in the network matrix.

Figure 12 shows the TAZ boundary and base locations of surveyed commercial vehicles within the Waco study area, while Figure 13 shows the origin and destination locations of surveyed vehicle trips. Any trip that had at least one trip outside of the Waco TAZ structure was considered an external trip.

The results presented in this section pertain to trip length characteristics for 1,646 inter-zonal trips only. Table 20 shows the trip length frequency distribution (TLFD), grouped at five-mile intervals, while Table 21 and Figure 14 show the ungrouped TLFD.

Approximately 65 percent of the trips made by service vehicles and 59 percent of the trips made by cargo vehicles had trip lengths less than five miles. More than 20 percent of the trips had trip lengths between 6 miles and 10 miles. The longest trip length reported by cargo vehicles and service vehicles was 37 and 36 miles, respectively.

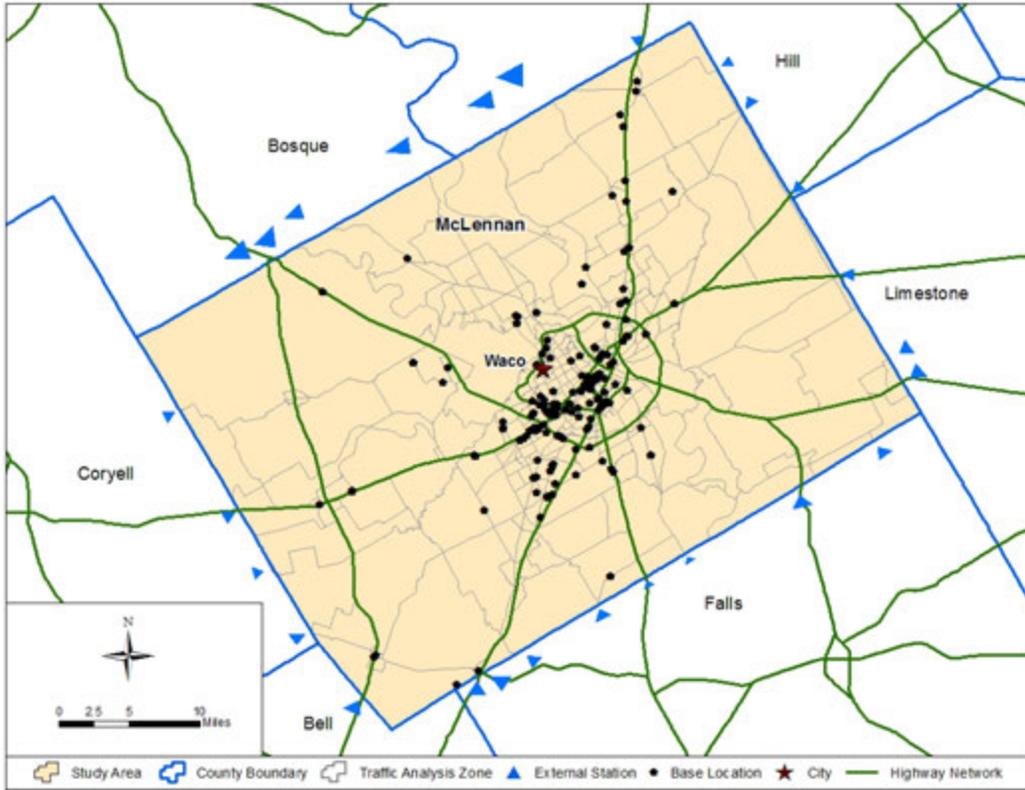


Figure 12. TAZ Boundary and Base Locations of Surveyed Commercial Vehicles.

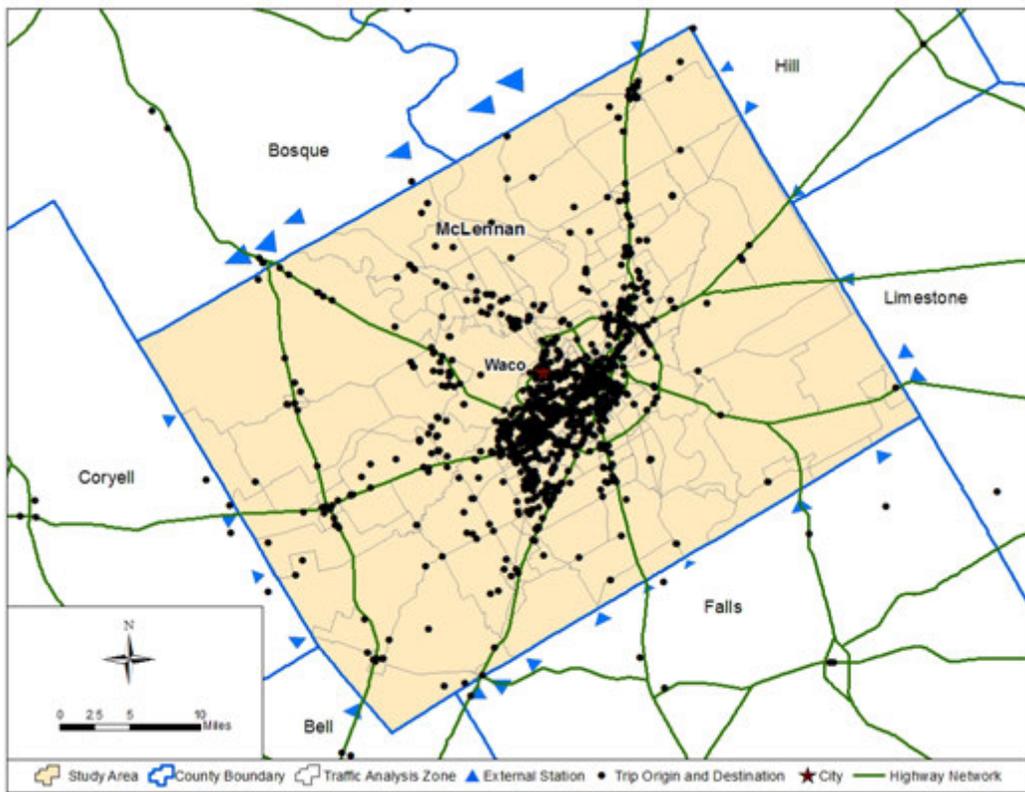


Figure 13. Trip Origins and Destinations of Surveyed Commercial Vehicles.

Table 20. Trip Length Frequency Distribution (Grouped Interval).

Trip Length (miles)	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Less than 5	351	58.51	678	64.82	1,029	62.52
6 to 10	138	23.00	219	20.94	357	21.69
11 to 15	54	9.00	99	9.46	153	9.30
16 to 20	35	5.83	31	2.96	66	4.01
21 to 25	15	2.50	14	1.34	29	1.76
26 to 30	5	0.83	4	0.38	9	0.54
31 to 35	0	0.00	0	0.00	0	0.00
36 to 40	2	0.33	1	0.10	3	0.18
Total	600	100.00	1,046	100.00	1,646	100.00

Table 21. Trip Length Frequency Distribution (Ungrouped).

Trip Length (miles)	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total
1	103	17.16	238	22.75	341	20.72
2	94	15.67	147	14.06	241	14.64
3	65	10.83	133	12.72	198	12.03
4	39	6.50	89	8.51	128	7.77
5	50	8.33	71	6.79	121	7.35
6	29	4.83	72	6.88	101	6.14
7	49	8.17	54	5.16	103	6.26
8	28	4.67	34	3.25	62	3.77
9	21	3.50	32	3.06	53	3.22
10	11	1.83	27	2.58	38	2.31
11	19	3.17	23	2.20	42	2.55
12	19	3.17	29	2.77	48	2.92
13	8	1.33	16	1.53	24	1.46
14	4	0.67	18	1.72	22	1.34
15	4	0.67	13	1.24	17	1.03
16	20	3.33	11	1.05	31	1.88
17	2	0.33	7	0.67	9	0.55
18	4	0.67	6	0.57	10	0.61
19	3	0.50	2	0.19	5	0.30
20	6	1.00	5	0.48	11	0.67
21	6	1.00	5	0.48	11	0.67
22	5	0.83	6	0.57	11	0.67
23	4	0.67	2	0.19	6	0.36
24	0	0.00	1	0.10	1	0.06
26	0	0.00	2	0.19	2	0.12
27	1	0.17	0	0.00	1	0.06
28	3	0.50	0	0.00	3	0.18
29	1	0.17	2	0.19	3	0.18
36	0	0.00	1	0.10	1	0.06
37	2	0.33	0	0.00	2	0.12
Total	600	100.00	1,046	100.00	1,646	100.00

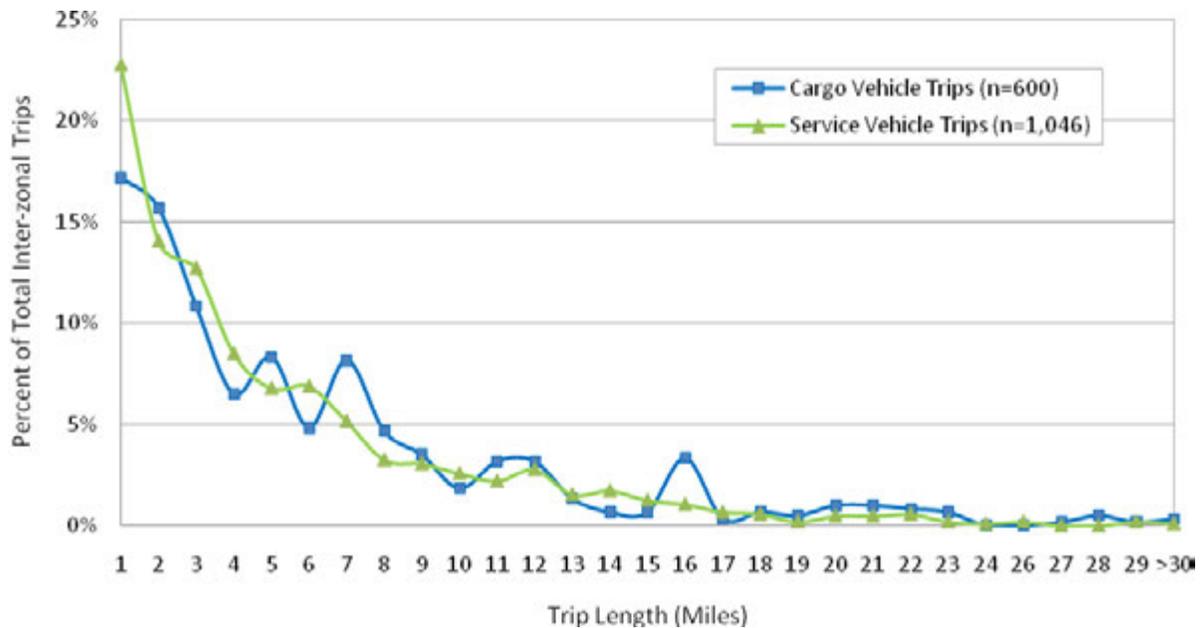


Figure 14. Surveyed Commercial Vehicle Trips TLFD.

Table 22 shows the average trip length to destinations by land use type for cargo and service vehicles. Overall, the average distance traveled by the surveyed vehicles was 6.08 miles, with cargo vehicles averaging 6.65 miles per trip and service vehicles averaging 5.75 miles per trip.

Table 22. Average Trip Length to Destinations by Land Use Type.

Land Use	Cargo vehicles			Service vehicles			All vehicles		
	Number of Trips	Total Trip Length (miles)	Average Trip Length (miles)	Number of Trips	Total Trip Length (miles)	Average Trip Length (miles)	Number of Trips	Total Trip Length (miles)	Average Trip Length (miles)
Office	41	277	6.76	162	929	5.74	203	1,206	5.94
Retail	180	780	4.34	124	688	5.55	304	1,469	4.83
Industrial	145	1,167	8.05	54	352	6.52	199	1,519	7.63
Medical	13	37	2.87	48	272	5.67	61	310	5.07
Education	14	98	7.01	61	381	6.24	75	479	6.38
Government	2	6	2.96	52	294	5.65	54	300	5.55
Residential	50	453	9.05	214	1,121	5.24	264	1,574	5.96
Other	155	1,169	7.54	331	1,981	5.98	486	3,149	6.48
Total	600	3,987	6.65	1,046	6,018	5.75	1,646	10,005	6.08

The most number of trips by cargo vehicles occurred at retail sites, with an average trip length of 4.34 miles, followed by “other” land use types and industrial sites with average trip lengths of 7.54 miles and 8.05 miles, respectively. Cargo trips to residential sites had the longest average travel distance of 9.05 miles, but these trips made up only 8 percent of the total cargo trips. For service vehicles, trips to industrial sites had the longest average trip length of 6.52 miles per trip. The highest frequency of trips occurred at “other” land use types, averaging 5.98 miles per trip. A significant number of trips also occurred at residential and office sites, with average trip lengths of 5.24 and 5.74 miles, respectively.

Table 23 shows the average trip length to destinations by commodity group for trips made by cargo vehicles only. Machinery was the most frequently transported commodity, with an average trip length of 6.20 miles. Trips that transported building materials showed the longest average travel distance of 11.97 miles, followed by agriculture commodities with 7.34 miles. The average trip length for trips with empty cargo was 7.79 miles.

Table 23. Average Trip Length to Destinations by Commodity Group.

Commodity Group	Cargo Vehicles		
	Number of Trips	Total Trip Length (miles)	Average Trip Length (miles)
Agriculture	29	213	7.34
Raw Materials	40	217	5.43
Food	78	307	3.94
Textiles	4	27	6.75
Wood	48	269	5.60
Building Materials	73	874	11.97
Machinery	127	788	6.20
Miscellaneous	12	45	3.75
Secondary	77	437	5.68
Transportation	9	25	2.78
Empty	78	608	7.79
Unknown	25	177	7.08
Total	600	3,987	6.65

Travel Time and Speed

The Waco commercial vehicle survey provided travel logs on the arrival and departure times for each trip made by surveyed commercial vehicles. The travel logs can be compared with the network travel time matrix table available for the study area. However, some of the reported travel logs had missing departure or arrival times, which rendered them unreliable in generating accurate estimates. Hence, as has been done in the estimation of trip lengths, travel time estimates were generated from the network travel time matrix table available for the Waco study area, and travel speed estimates were derived from the estimated trip lengths.

Table 24 shows the travel time frequency distribution of inter-zonal trips, grouped at five-minute intervals, while Figure 15 and Table 25 show the ungrouped distribution. Approximately 39 percent of the trips made by cargo vehicles were not more than five minutes, 27 percent were between 6-and-10 minutes, and 18 percent were between 11-and-15 minutes. For service vehicles, approximately 44 percent of the trips were less than five minutes, 29 percent were between 6-and-10 minutes, and 13 percent were between 11-and-15 minutes. As shown in Table 25, the longest duration of travel was 47 minutes for cargo and service vehicles.

Table 24. Travel Time Frequency Distribution (Grouped Interval).

Travel Time (minutes)	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Less than 5	231	38.50	460	43.98	691	41.98
6 to 10	160	26.66	307	29.35	467	28.37
11 to 15	109	18.17	135	12.91	244	14.83
16 to 20	54	9.00	84	8.03	138	8.39
21 to 25	18	3.00	39	3.72	57	3.46
26 to 30	12	2.00	12	1.14	24	1.46
31 to 35	10	1.67	5	0.48	15	0.91
36 to 40	4	0.67	1	0.10	5	0.30
41 to 45	0	0.00	2	0.19	2	0.12
46 to 50	2	0.33	1	0.10	3	0.18
Total	600	100.00	1,046	100.00	1,646	100.00

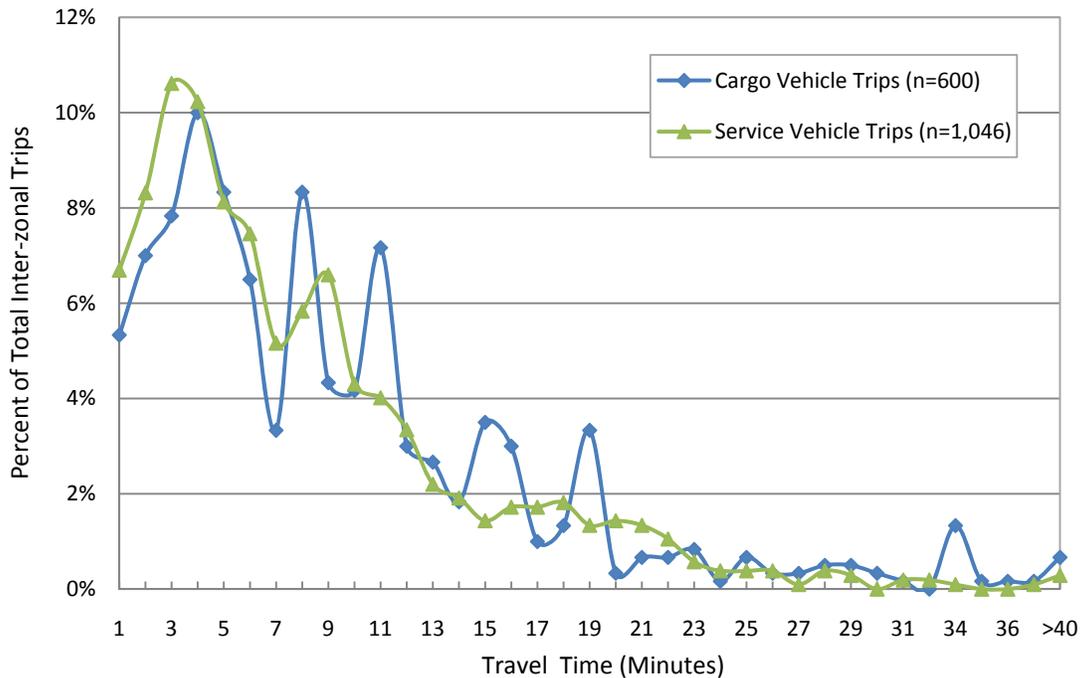


Figure 15. Surveyed Commercial Vehicle Trips Travel Time.

Table 25. Travel Time Frequency Distribution (Ungrouped).

Travel Time (minutes)	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of	Percent of	Number of	Percent of	Number of	Percent of
	Trips	Total	Trips	Total	Trips	Total
1	32	5.33	70	6.69	102	6.20
2	42	7.00	87	8.32	129	7.84
3	47	7.83	111	10.61	158	9.60
4	60	10.00	107	10.23	167	10.15
5	50	8.34	85	8.12	135	8.20
6	39	6.50	78	7.46	117	7.11
7	20	3.33	54	5.16	74	4.50
8	50	8.34	61	5.83	111	6.74
9	26	4.33	69	6.60	95	5.77
10	25	4.17	45	4.30	70	4.25
11	43	7.17	42	4.02	85	5.17
12	18	3.00	35	3.34	53	3.22
13	16	2.67	23	2.20	39	2.37
14	11	1.83	20	1.91	31	1.88
15	21	3.50	15	1.43	36	2.19
16	18	3.00	18	1.72	36	2.19
17	6	1.00	18	1.72	24	1.46
18	8	1.33	19	1.82	27	1.64
19	20	3.33	14	1.34	34	2.07
20	2	0.33	15	1.43	17	1.03
21	4	0.67	14	1.34	18	1.09
22	4	0.67	11	1.05	15	0.91
23	5	0.83	6	0.57	11	0.67
24	1	0.17	4	0.38	5	0.30
25	4	0.67	4	0.38	8	0.49
26	2	0.33	4	0.38	6	0.36
27	2	0.33	1	0.10	3	0.18
28	3	0.50	4	0.38	7	0.43
29	3	0.50	3	0.29	6	0.36
30	2	0.33	0	0.00	2	0.12
31	1	0.17	2	0.19	3	0.18
32	0	0.00	2	0.19	2	0.12
34	8	1.33	1	0.10	9	0.55
35	1	0.17	0	0.00	1	0.06
36	1	0.17	0	0.00	1	0.06
37	1	0.17	1	0.10	2	0.12
40	2	0.33	0	0.00	2	0.12
41	0	0.00	1	0.10	1	0.06
42	0	0.00	1	0.10	1	0.06
47	2	0.33	1	0.10	3	0.18
Total	600	100.00	1,046	100.00	1,646	100.00

Table 26 shows the average travel time and speed to destinations by land use for cargo and service vehicles. Overall, the average travel time for all surveyed vehicles was 9.12 minutes, with cargo vehicles averaging 9.93 minutes and service vehicles averaging 8.66 minutes. By land use type, trips made by cargo vehicles to residences had the longest average travel duration of 13.20 minutes, with an average travel speed of 39.40 miles per hour (mph). For service vehicles, trips to industrial and education sites had

the highest average travel time exceeding 9 minutes, with an average travel speed of 38.53 mph and 36.61 mph, respectively.

Table 27 shows the average travel time and speed to destinations by commodity group for trips made by cargo vehicles only. Trips transporting building materials had the longest average trip duration of 16.82 minutes, with an average travel speed of 42.31 mph. Agriculture commodities followed with an average travel time of 11.01 minutes and an average travel speed of 39.04 mph.

Table 26. Average Travel Time and Speed to Destinations by Land Use Type.

Land Use	Cargo Vehicles			Service Vehicles			All Vehicles		
	Number of Trips	Average Travel Time (minutes)	Average Travel Speed (mph)	Number of Trips	Average Travel Time (minutes)	Average Travel Speed (mph)	Number of Trips	Average Travel Time (minutes)	Average Travel Speed (mph)
Office	41	10.22	36.88	162	8.69	37.13	203	9.00	37.08
Retail	180	6.78	35.10	124	8.30	37.07	304	7.40	35.90
Industrial	145	11.66	38.88	54	9.40	38.53	199	11.05	38.78
Medical	13	4.93	34.74	48	8.76	35.85	61	7.94	35.62
Education	14	10.51	37.52	61	9.54	36.61	75	9.72	36.78
Government	2	5.43	33.17	52	8.63	37.47	54	8.51	37.31
Residential	50	13.20	39.40	214	7.95	37.27	264	8.95	37.68
Other	155	11.25	37.42	331	8.94	36.94	486	9.68	37.10
Total	600	9.93	37.14	1,046	8.66	37.09	1,646	9.12	37.11

Table 27. Average Travel Time and Speed to Destinations by Commodity Group.

Commodity Group	Cargo Vehicles		
	Number of Trips	Average Travel Time (minutes)	Average Travel Speed (mph)
Agriculture	29	11.01	39.04
Raw Materials	40	8.39	38.02
Food	78	6.21	34.37
Textiles	4	10.28	36.12
Wood	48	8.66	36.88
Building Materials	73	16.82	42.31
Machinery	127	9.34	35.95
Miscellaneous	12	6.05	32.76
Secondary	77	8.73	36.87
Transportation	9	4.96	33.28
Empty	78	11.37	36.92
Unknown	25	10.81	38.03
Total	600	9.93	37.14

Trip Tours

The analyses of trip tours show the amount of circuitous travel undertaken by commercial vehicles in the study area. Trip tours are defined as a combination (or chaining) of trips in which a vehicle leaves and returns to a common point, typically its base location.

To accurately analyze trip tours, external trips had to be included in the analysis. This is done because it is possible for trip tours to begin within the study area, then travel outside the study area, and then end or return to the study area. Therefore, to exclude external trips in the analysis could result in not capturing those trips that occur outside the study area that take place within the trip tour.

There were 2,156 trips observed from the Waco commercial vehicle survey. Each trip in the survey provided information on whether or not the origin of the trip was the vehicle's base location. This served as the basis for determining if the trip was a base trip or a non-base trip. A base trip was defined as when either trip ends (origin or destination) began or ended at the base location. If neither trip end was at the base location, then the trip was considered as a non-base trip.

As Table 28 shows, approximately 54 percent of the total trips generated by cargo vehicles were non-base trips and 46 percent were base trips. For trips made by service vehicles, 57 percent were non-base trips and 43 percent were base trips.

Table 28. Base and Non-Base Trips.

Trip Type	Cargo Vehicles		Service Vehicles		All Vehicles	
	Number of Trips	Percent of Total	Number of Trips	Percent of Total	Number of Trips	Percent of Total
Base	404	45.91	549	43.03	953	44.20
Non-Base	476	54.09	727	56.97	1,203	55.80
Total	880	100.00	1,276	100.0	2,156	100.00

The analyses of trip tours involved counting all the trips that began at the base location until the vehicle returned to its base location. Those trips that did not start and end at their base location were considered open tours. There were 13 cargo vehicles and 36 service vehicles surveyed that made open tours. The open tours consisted of 527 trips, of which 186 were cargo vehicle trips and 341 were service vehicle trips. The following results pertain only to the 1,629 trips that occurred within the trip tours and do not include the 527 trips that occurred within the open tours.

Table 29 shows the distribution of trip tours for cargo and service vehicles. There were 441 trip tours generated by the surveyed vehicles, with cargo vehicles making 193 tours and service vehicles producing 248 tours. The number of tours varied from one-to-seven tours for cargo vehicles, and one-to-five tours for service vehicles. Approximately 59 percent of the cargo vehicles made at least one trip tour, 18

percent produced two tours, 12 percent made three tours, and the remaining 33 percent made more than three tours. In the case of service vehicles, approximately 35 percent made at least one trip tour, 33 percent completed two tours, 18 percent made three tours, and the remaining 14 percent made more than three tours.

Table 29. Trip Tours per Vehicle.

Number Of Trip Tours	Cargo Vehicles		Service Vehicles		All Vehicles	
	Total Tours	Percent of Total	Total Tours	Percent of Total	Total Tours	Percent of Total
1	78	40.41	86	34.68	164	37.19
2	28	14.51	82	33.06	110	24.94
3	24	12.44	45	18.15	69	15.65
4	16	8.29	20	8.06	36	8.16
5	40	20.73	15	6.05	55	12.47
6	0	0.00	0	0.00	0	0.00
7	7	3.62	0	0.00	7	1.59
Total	193	100.00	248	100.00	441	100.00

The analyses of trip tours also involved counting the number of non-base trips, external trips, inter-zonal trips and intra-zonal trips within trip tours to determine the total amount and types of travel that occur during the course of the tour. There were 1,629 trips observed within the total 441 trip tours. Out of these trips, 258 were external trips, 1,281 were inter-zonal trips, and 90 were intra-zonal trips.

Table 30 shows the distribution of these trips for cargo and service vehicles. Table 31 shows the number of non-base trips within trip tours separately since non-base trips are not mutually exclusive of the other trip types (i.e., a non-base trip may also be an inter-zonal or external trip).

Table 30. External, Inter-Zonal and Intra-Zonal Trips within Trip Tours.

No. of Trip Tours	External		Inter-Zonal		Intra-Zonal		Total Trips	
	Cargo Vehicles	Service Vehicles						
1	130	63	234	313	9	22	373	398
2	26	15	68	263	4	33	98	311
3	13	0	59	138	2	8	74	146
4	0	9	40	39	0	0	40	48
5	0	0	90	25	1	7	91	32
6	0	0	0	0	0	0	0	0
7	2	0	12	0	4	0	18	0
Total	171	87	503	778	20	70	694	935

Table 31. Non-Base Trips within Trip Tours.

No. of Trip Tours	Non-Base Trips within Trip Tours			Total Trips within Trip Tours					
	Cargo Vehicles	Service Vehicles	All Vehicles	Cargo Vehicles	Percent of Total	Service Vehicles	Percent of Total	All Vehicles	Percent of Total
1	217	226	443	373	53.75	398	42.57	771	47.33
2	44	150	194	98	14.12	311	33.26	409	25.11
3	27	59	86	74	10.66	146	15.62	220	13.51
4	10	14	24	40	5.76	48	5.13	88	5.40
5	12	7	19	91	13.11	32	3.42	123	7.55
6	0	0	0	0	0.00	0	0.00	0	0.00
7	4	0	4	18	2.60	0	0.00	18	1.10
Total	314	456	770	694	100.00	935	100.00	1,629	100.00

Figures 16 and 17 show the percentage distribution of non-base trips, external trips, inter-zonal trips and intra-zonal trips within trip tours for cargo vehicles and service vehicles, respectively.

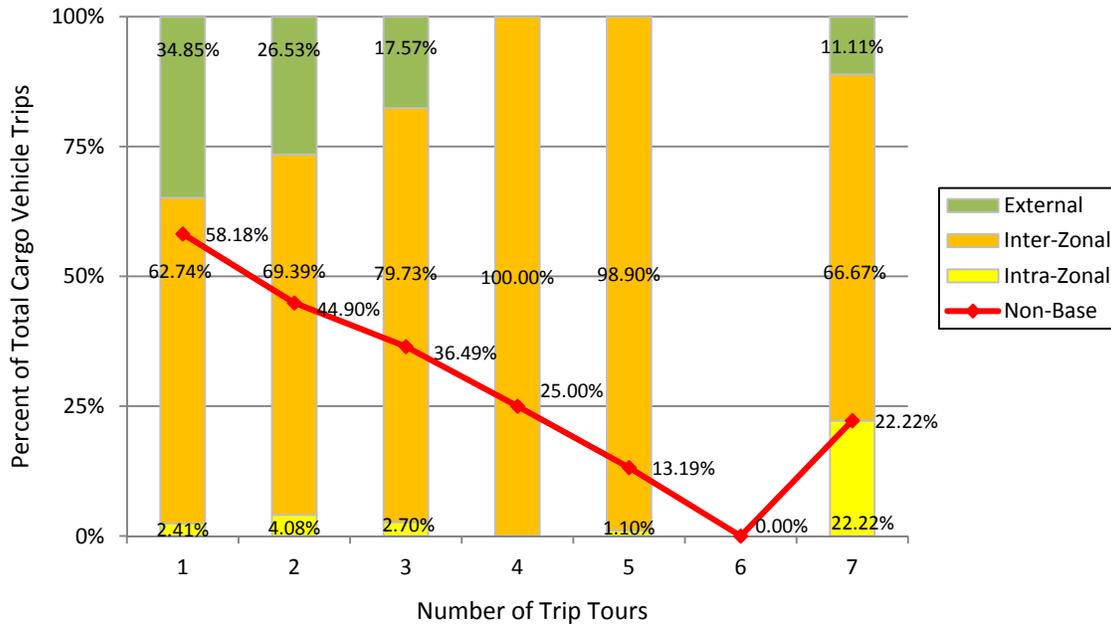


Figure 16. Cargo Vehicle Trips within Trip Tours by Trip Type.

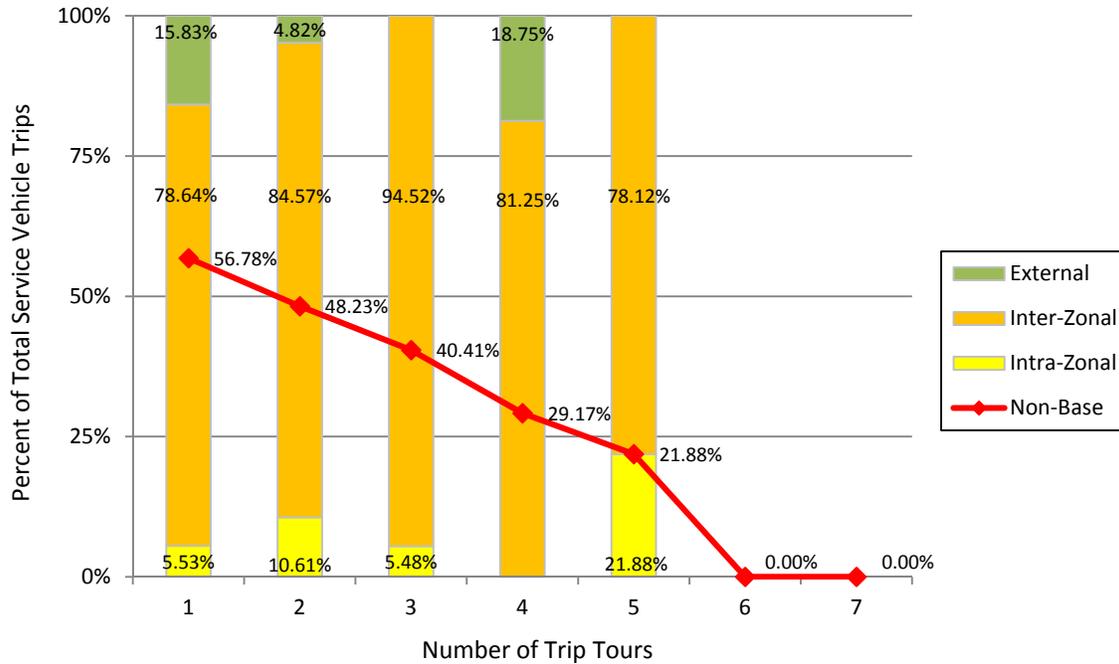


Figure 17. Service Vehicle Trips within Trip Tours by Trip Type.

Survey Expansion

The expansion of commercial vehicle survey data is conducted in an indirect manner. In typical travel surveys, an estimate of the population being sampled is known and data are then expanded to represent that population. In the case of commercial vehicle surveys, the population of vehicles operating in the study area is unknown. Vehicle registration data are not considered a viable basis to estimate the number of commercial vehicles in the study area because other vehicles operating in the area may be registered in neighboring counties. However, in the Waco commercial vehicle survey analysis, information on registered trucks has been included to show how the survey data compare with existing vehicle registration data.

The methodology currently used to expand commercial vehicle survey data is based on vehicle miles of travel (VMT) estimates from the Highway Performance Monitoring System (HPMS), and vehicle classification counts by functional classification for the study area. In essence, an estimate of the commercial VMT is developed from the HPMS data and is then used to expand the VMT observed from sampled commercial vehicles. HPMS data contains annual average daily traffic (AADT) estimates of the total VMT by functionally classified facilities such as freeways, arterials, collectors, and local roadways. Since AADT includes weekend traffic, a correction factor is applied to the data to obtain average weekday VMT by functional classification. Table 32 provides the adjusted 2007 HPMS VMT estimates for the Waco study area.

Table 32. 2007 HPMS Estimates of Weekday VMT in the Waco Study Area.

Functional Classification	Total Weekday VMT
Freeway	2,747,674
Arterial	2,760,567
Collector	1,007,029
Local	419,082
Total	6,934,352

The percentage of commercial and non-commercial vehicles by functional classification were determined by utilizing the commercial vehicle counts from the 2006 Waco External Survey and vehicle classification counts conducted at 125 randomly selected locations in the Waco study area (Figure 18).

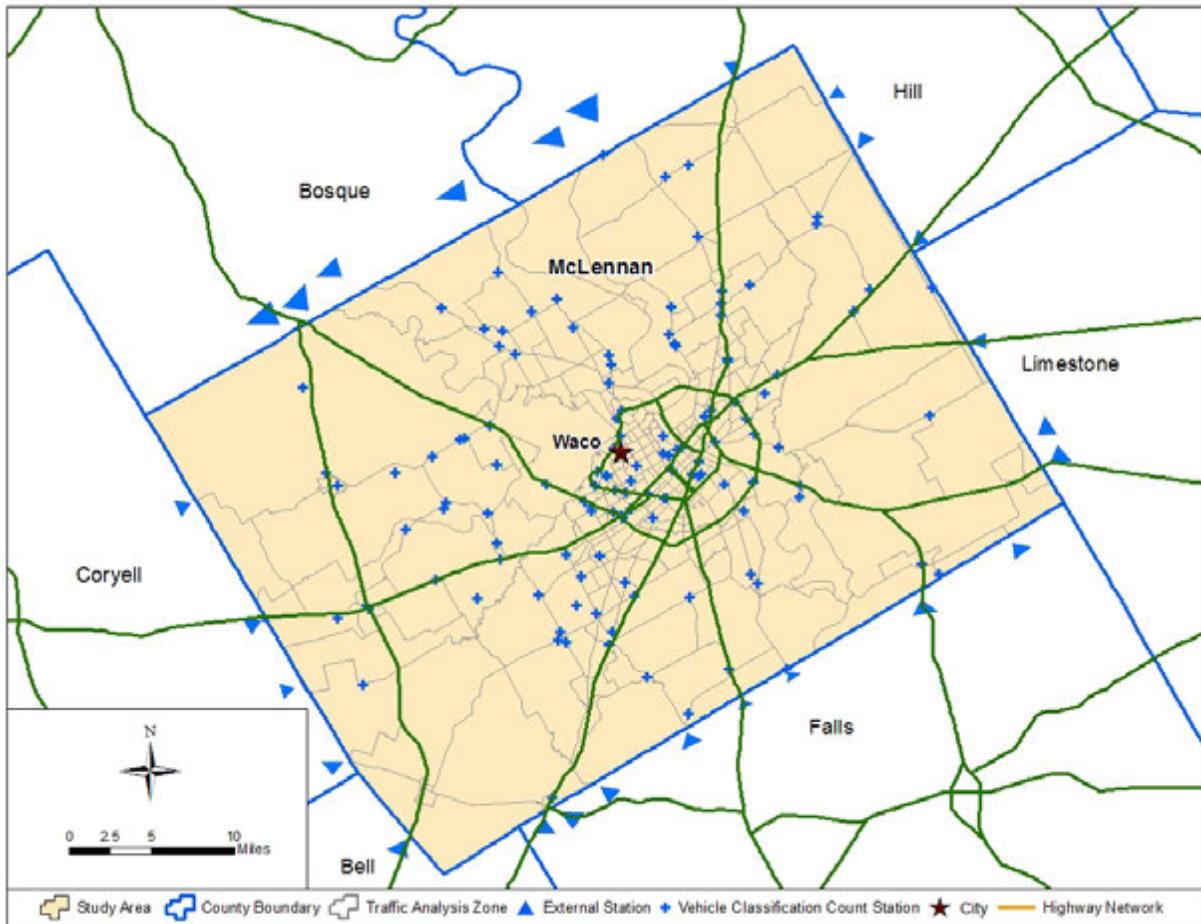


Figure 18. Vehicle Classification Count Stations in the Waco Study Area.

The percentage of commercial vehicles for internal sites for each functional classification were combined with the corresponding percentage for external sites based on the percentage of regional VMT estimated as external travel. Based on the 2006 external survey, external VMT for the study area was 3,061,284 miles. This is approximately 44 percent of the total HPMS VMT of 6,954,352 miles. Therefore, it was reasonable to assume that 56 percent of the total VMT was internal travel. These percentages were applied to obtain the weighted average for each functional classification.

Table 33 provides the internal, external, and weighted percentages of commercial and non-commercial vehicles by functional classification. The weighted percentages were applied to the HPMS estimated weekday VMT shown in Table 32 to estimate the total commercial and non-commercial VMT. Table 34 shows the estimated VMT for commercial and non-commercial vehicles.

Table 33. Percentage of Commercial and Non-Commercial Vehicles by Functional Classification.

Functional Classification	Percent of Commercial Vehicles			Percent of Non-Commercial Vehicles		
	Internal Sites (56%)	External Sites (44%)	Weighted Average	Internal Sites (56%)	External Sites (44%)	Weighted Average
Freeway	28.63	24.09	26.63	71.37	75.91	73.37
Arterial	16.63	12.99	15.03	83.37	87.01	84.97
Collector	12.95	10.53	11.88	87.05	89.47	88.12
Local	9.14	N/A	9.14	90.86	N/A	90.86

Table 34. Estimated VMT for Commercial and Non-Commercial Vehicles.

Functional Classification	Commercial VMT	Non-Commercial VMT	Total VMT
Freeway	731,693	2,015,981	2,747,674
Arterial	414,856	2,345,711	2,760,567
Collector	119,667	887,362	1,007,029
Local	38,304	380,778	419,082
Total	1,304,520	5,629,833	6,934,352

The total commercial VMT of 1,304,520 miles represented all commercial vehicles that traveled within and outside the Waco study area. To properly expand the survey data and determine the total internal commercial vehicle trips generated in the study area, VMT estimates from the external survey had to be subtracted from the total commercial VMT. The external commercial VMT, based on the 2006 external survey, was 624,101 miles. Therefore, internal commercial VMT was 680,419 miles.

The total internal VMT observed from the commercial vehicle survey was 10,005 miles, of which 3,990 miles were cargo VMT and 6,015 were service VMT. This estimate was based on 1,646 inter-zonal trips (600 cargo vehicle trips and 1,046 service vehicle trips), multiplied by the average trip length (6.65 miles for cargo and 5.75 miles for service vehicles).

The total internal commercial VMT (680,419 miles) represented all commercial vehicles and is not distinguished by cargo or service vehicles. Based on the vehicle classification counts conducted in the study area, approximately 42 percent of the commercial vehicles belonged to Class 5 (two-axle six-tire single unit trailers) through Class 13 (seven or more axle multi-trailers) and were assumed as cargo transport vehicles. Approximately 58 percent of the commercial vehicles belonged to Class 3 (pick-up, van, or two-axle four-tire single unit trailers) and Class 4 (buses) and were assumed as service vehicles. Therefore, to establish the VMT estimates by commercial cargo and service types, it was deemed reasonable to apply these percentages to the total internal commercial VMT. The resulting VMT estimates were 283,576 miles for cargo vehicles and 396,843 miles for service vehicles.

Expansion factors were derived based on the quotient between total internal VMT and observed internal VMT (from the survey) for each commercial vehicle type. The expansion factors (71.07 for cargo vehicles and 65.98 for service vehicles) were then multiplied by the observed number of inter-zonal trips to estimate the total vehicle trips. The resulting trip estimates were approximately 42,643 cargo vehicle trips and 69,016 service vehicle trips. Based on the average number of internal trips per day of 5.70 trips for cargo vehicles and 6.59 trips for service vehicles, 17,954 commercial vehicles (7,481 cargo vehicles and 10,473 service vehicles) were estimated to be operating within the Waco study area on a daily basis. This estimate is more than 4½ times the 3,902 trucks registered in the study area in 2009. Table 35 provides a summary of key results from the Waco commercial vehicle survey and data expansion.

Table 35. Key Survey Results and Expanded Trip and VMT Data.

Indicator	Cargo Vehicles	Service Vehicles	All Vehicles
Sample Size	126	186	312
Total Inter-zonal Trips	600	1,046	1,646
Total Intra-zonal Trips	27	101	128
Total Internal Trips	627	1,147	1,774
Total External Trips	253	129	382
Total Internal and External Trips	880	1,276	2,156
Average Total Trips per Vehicle	6.98	6.86	6.91
Average Total Internal Trips per Vehicle*	5.70	6.59	6.15
Average Trip Length	6.65	5.75	6.08
Observed Internal VMT	3,990 miles	6,015 miles	10,005 miles
Total Internal Commercial VMT	283,576 miles	396,843 miles	680,419 miles
Survey Expansion Factor	71.07	65.98	68.01
Total Expanded Commercial Vehicle Trips	42,643	69,016	111,659
Number of Commercial Vehicles Operating on a Daily Basis	7,481	10,473	17,954

*Based on internal trips of 284 surveyed commercial vehicles (110 cargo vehicles and 174 service vehicles).

SURVEY SUMMARY

This section provides a summary of vehicle and trip characteristics of 312 commercial vehicles that participated in the 2008/2009 Waco commercial vehicle survey. Based on the results from the survey, significant differences, as well as similarities, on travel characteristics were observed between cargo vehicles and service vehicles.

The average vehicle age for cargo vehicles was 5.89 years, compared to 6.11 years for service vehicles. The odometer readings reported by cargo vehicles indicated an average mileage of 159,500 miles, compared to 110,200 miles for service vehicles. In terms of fuel use, approximately 61 percent of cargo vehicles used diesel and 38 percent used unleaded gasoline, while 86 percent of service vehicles used unleaded gasoline and 14 percent used diesel.

The analyses of trip characteristics included in-depth examinations of trip frequency, trip type, average trip length, trip purpose, and land use activity at trip destinations by commercial vehicle type. Surveyed cargo and service vehicles made an average of 6.98 and 6.86 total trips per day, respectively. Excluding the trips made outside of the study area (external trips), however, cargo vehicles produced 5.70 internal trips per day, with average travel distance of 6.65 miles, compared to service vehicles with 6.59 internal trips per day and average trip length of 5.75 miles. The average travel time for cargo vehicles was 9.93 minutes, and 8.66 minutes for service vehicles. The average travel speed for cargo and service vehicles was 37.14 and 37.09 mph, respectively.

In terms of trip purpose at trip destinations, approximately 49 percent of the internal cargo vehicle trips were delivery, 20 percent were return-to-base location, and 16 percent were pick-up. For internal trips made by service vehicles, 39 percent were service-related, 19 percent were return-to-base location, and 17 percent were delivery.

Regarding land use activity, approximately 31 percent of the internal trips by cargo vehicles occurred at retail/shopping places and 24 percent occurred at industrial sites. For service vehicles, approximately 22 percent of the trips occurred at residential sites, 15 percent were at office buildings, and 11 percent occurred at retail/shopping places.

The analyses of cargo characteristics were exclusive to trips made by cargo vehicles only and involved examining the types of cargo/commodities being transported at trip destinations, the trip purposes and land use activity at each stop, and the net weight of cargo being picked-up and/or dropped-off for each trip. Overall, the average net cargo weight was roughly 9,900 lbs. per trip. Building materials showed the highest average net cargo weight of 33,400 lbs. per trip. However, the most frequently transported commodity was machinery, with average net cargo weight of 3,700 lbs. per trip. The “other” land use category showed the highest average net cargo weight of 13,600 lbs. per trip, followed by industrial sites

with average net cargo weight of 12,250 lbs. per trip. However, the highest trip frequency occurred at retail sites with average net cargo weight of 6,700 lbs. per trip. By trip purpose, pick-up had the highest average net cargo weight of 18,000 lbs. per trip, but there were more delivery trips with average net cargo weight of 9,200 lbs. per trip.

The analyses of trip tours involved examining the amount of circuitous travel undertaken by commercial vehicles in the study area. It also involved counting the number of non-base trips, external trips, inter-zonal trips, and intra-zonal trips within trip tours to determine the total amount and types of travel that occur during the course of the tour. There were 441 trip tours generated by the surveyed vehicles, with cargo vehicles making 193 tours and service vehicles producing 248 tours. The number of trip tours per vehicle ranged from one-to-seven tours for cargo vehicles, and one-to-five tours for service vehicles. The number of trips within a tour varied from one trip to a maximum of 13 trips, generating more than 1,600 trips (700 trips by cargo vehicles and 900 trips by service vehicles). Within the trip tours, approximately 78 percent were inter-zonal trips, 16 percent were external trips and the remaining 6 percent were intra-zonal trips. Non-base trips, which were not mutually exclusive of the other trip types, made up approximately 47 percent of the trips within the tours.

Finally, the expansion of commercial vehicle survey data were based on VMT estimates and vehicle classification counts for the Waco study area, as well as on key survey results such as average number of trips and trip length per commercial cargo and service vehicles. Since the commercial VMT estimates do not distinguish by vehicle types, the proportion of cargo and service vehicles was established based on the class types from the commercial vehicle classification counts conducted in the study area. In summary, internal commercial cargo VMT was estimated at 283,600 miles while internal commercial service VMT was estimated at 396,800 miles. Cargo vehicles generated over 42,600 trips and service vehicles generated 69,000 trips. On a daily basis, nearly 18,000 commercial vehicles (7,500 cargo vehicles and 10,500 service vehicles) were estimated to be operating within the Waco study area for the 24-hour survey period. This estimate is more than 4 ½ times the volume of trucks registered in the study area in 2009.

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Texas Department of Transportation (TxDOT). *Rural, Small Urban, and Urbanized Mileage by County and Functional System*. Austin, TX, July 2009.

Alliance-Texas Engineering Company and Wilbur Smith and Associates. *Texas Statewide Analysis Model (SAM) Theory Report*. Texas Department of Transportation, Austin, TX, March 2004.

Farnsworth, Stephen F. *2006 Waco External Survey Technical Summary*. Texas Transportation Institute, The Texas A&M University System, College Station, TX, August 2008.

APPENDIX

**COMMERCIAL VEHICLE SURVEY
PART 1: VEHICLE INFORMATION**

(If you have participated in prior surveys, please fill out this form anyway.)

Vehicle ID#: _____

Vehicle License # : _____

Survey Location (zone): _____

SIC Code: _____

Travel Day: _____
Month / Day

Company or Name of Owner (name on registration):

Address of location where vehicle was based at beginning of travel day:

(Street Address or Nearest Intersection)

City _____ State _____ ZIP _____

Type of Place vehicle was based at on beginning of travel day. (SEE BELOW) _____

Vehicle Info: Make _____ ; Model: _____ ; Year: _____

Vehicle Type 1) Cargo / Freight Transport Vehicle
 2) Service Vehicle (vehicle is not used to transport cargo or freight)

Vehicle Fuel: 1) Unleaded Gas 2) Diesel 3) Propane 4) Hybrid
 5) Other _____ (Specify)

Vehicle Classification:

1) <input type="checkbox"/> Passenger Car	5) <input type="checkbox"/> Single Unit 2-axle (6 wheels)
2) <input type="checkbox"/> Pick-up	6) <input type="checkbox"/> Single Unit 3-axle (10 wheels)
3) <input type="checkbox"/> Van (Cargo or Mini)	7) <input type="checkbox"/> Single Unit 4-axle (14 wheels)
4) <input type="checkbox"/> Sport Utility Vehicle (SUV)	8) <input type="checkbox"/> Semi (all Tractor-Trailer combinations)
	9) <input type="checkbox"/> Other _____

Gross Vehicle Weight: _____ pounds

Beginning Odometer Reading: _____ **Number of Trips Total:** _____

Type of Place Codes		
(1) Office Building	(6) Educational (college, trade, etc.)	(11) Warehouse
(2) Retail / Shopping	(7) Government Office / Building	(12) Distribution Center
(3) Industrial / Manufacturing	(8) Residential	(13) Construction Site
(4) Medical / Hospital	(9) Airport	(14) Other (specify)
(5) Educational (12 th grade or less)	(10) Intermodal Facility	(99) Refused/Unknown

Record Type 21

Commercial Vehicle Survey PART 2: Travel Log

VEHICLE LICENSE #: _____

THE PLACE MY TRAVEL BEGAN TODAY WAS:

Work / Base Location Other Location (Please describe) _____

Type of Place (Specify Type of Place 1-14 or 99, see codes below) _____

(Street address or nearest intersection for place travel began)

TRAVEL DATE _____
Month / Day

(City, state, zip code)

DEPARTURE TIME: _____ am/pm

When you left the above location was your vehicle: Fully Loaded Partially Loaded Empty Not Applicable (Service Vehicle)

If loaded, what is the total weight in pounds of the cargo being transported? (Please provide an estimate if unsure of exact weight) _____

RECORD EVERY PLACE YOU GO, INCLUDING QUICK STOPS

	RECORD the following information about each place <i>NAME of Place:</i> _____ <i>Address including city, state, and zip OR Nearest street intersection or Landmark</i> _____	What time did you arrive and depart this location? (record exact times)	Activity What are you doing at this Location (See options below)	What type of place is this? (see options below)	Is this the work / base location for this vehicle? <input type="checkbox"/> - Yes <input type="checkbox"/> - No	Type of Cargo What is it?	Cargo Weight (in Pounds)
PLACE 1		Arrive: _____ am/pm Depart: _____ am/pm					Delivery Picked Up
PLACE 2		Arrive: _____ am/pm Depart: _____ am/pm					Delivery Picked Up
PLACE 3		Arrive: _____ am/pm Depart: _____ am/pm					Delivery Picked Up

ACTIVITY OPTIONS	TYPE OF PLACE OPTIONS
<ul style="list-style-type: none"> (1) Base Location / Return to Base Location (2) Delivery (3) Pick-Up (4) Pick-Up and Delivery (5) Maintenance (fuel, oil, etc.) (6) Driver Needs (lunch, etc.) (7) Service-Related Business (8) Other (please specify) 	<ul style="list-style-type: none"> (1) Office Building (non-government) (2) Retail / Shopping (3) Industrial / Manufacturing (4) Medical / Hospital (5) Education (12th grade or less) (6) Education (college, trade) (7) Government Office / Building (8) Residential (9) Airport (10) Intermodal Facility (11) Warehouse (12) Distribution Center (13) Construction Site (14) Other (specify) (99) Refused / Unknown

Commercial Vehicle Survey Travel (continued)

	RECORD the following information about each place <i>NAME of Place:</i> _____ <i>Address including city, state, and zip</i> OR <i>Nearest street intersection or Landmark</i> _____	What time did you arrive and depart this location? (record exact times)	Activity What are you doing at this location? (see options below)	What type of place is this? (see options below)	Is this the work / base location for this vehicle? <input type="checkbox"/> - Yes <input type="checkbox"/> - No	Type of Cargo What is it?	Cargo Weight (in Pounds)
PLACE 10		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 11		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 12		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 13		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 14		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up

ACTIVITY OPTIONS	TYPE OF PLACE OPTIONS
(1) Base Location / Return to Base Location (2) Delivery (3) Pick-Up (4) Pick-Up and Delivery (5) Maintenance (fuel, oil, etc.) (6) Driver Needs (lunch, etc.) (7) Service-Related Business (8) Other (please specify)	(1) Office Building (non-government) (2) Retail / Shopping (3) Industrial / Manufacturing (4) Medical / Hospital (5) Education (12 th grade or less) (6) Education (college, trade) (7) Government Office / Building (8) Residential (9) Airport (10) Intermodal Facility (11) Warehouse (12) Distribution Center (13) Construction Site (14) Other (specify) (99) Refused / Unknown

Commercial Vehicle Survey (continued)

	RECORD the following information about each place <i>NAME of Place:</i> _____ <i>Address including city, state, and zip</i> <i>OR</i> <i>Nearest street intersection or Landmark</i>	What time did you arrive and depart this location? (record exact times)	Activity What are you doing at this location? (see options below)	What type of place is this? (see options below)	Is this the work / base location for this vehicle? <input type="checkbox"/> - Yes <input type="checkbox"/> - No	Type of Cargo What is it?	Cargo Weight (in Pounds)
PLACE 15		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 16		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 17		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 18		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up
PLACE 19		Arrive: _____ am/pm Depart: _____ am/pm					_____ Delivery _____ Picked Up

ACTIVITY OPTIONS	TYPE OF PLACE OPTIONS
(1) Base Location / Return to Base Location (2) Delivery (3) Pick-Up (4) Pick-Up and Delivery (5) Maintenance (fuel, oil, etc.) (6) Driver Needs (lunch, etc.) (7) Service-Related Business (8) Other (please specify)	(1) Office Building (non-government) (2) Retail / Shopping (3) Industrial / Manufacturing (4) Medical / Hospital (5) Education (12 th grade or less) (6) Education (college, trade) (7) Government Office / Building (8) Residential (9) Airport (10) Intermodal Facility (11) Warehouse (12) Distribution Center (13) Construction Site (14) Other (specify) (99) Refused / Unknown