

Commercial Vehicle Surveys: To Measure Commodities or Truck Trips?

Purpose of the Working Paper

Commercial vehicles constitute a measurable and growing portion of roadway VMT, and are challenging for urban areas to include in their travel demand forecasts. In addition, information about the type and amount of commercial vehicle travel is critical to congestion management and safety planning. This discussion attempts to set out some of the most common issues in developing a study of commercial vehicles, and offers data on truck travel characteristics from various studies around the US. This discussion will be helpful to urban areas considering a commercial vehicle survey, both in informing the design of such a study and in providing some comparative data for benchmarking.

Acknowledgements

Much of this discussion is taken from a document called “Commodities or Truck Trips, A working Paper” written by Nancy McGuckin and John Hamburg (1996) as training material for traffic engineers and transportation planners in the consulting firm of Barton-Aschman Associates. This document re-visits and updates that original piece, any errors the responsibility of Nancy McGuckin.

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Overview

The predominant mode used for freight transportation is truck. Freight activity can be measured by weight (tons or ton-miles), by volume, or by value. When measuring domestic freight by ton-miles, rail becomes increasingly important as a mode. Considering all freight movement, both intercity and local, trucks account for almost 80 percent of the freight revenues in the U.S. "Revenues" refers to fees for transportation spent by shippers.

Nationally, about 40 percent of goods movement is between cities (inter-urban) which leaves 60 percent within the local area (intra-urban). There may be factors that drive a local area's share of intercity travel higher, such as agricultural export, a large cargo airport, and geographic peculiarities. A rule of thumb is that rail is economical for goods movement over distances of 750 miles or more, although some opportunity may exist for the 250 to 750 mile range. The rail penetration of the market for goods movement over 750 miles is only about 25 percent, generally because of the poor on-time performance of rail, especially with the growing need to support 'just-in-time' manufacturing operations. Another constraint to the growth of rail shipping is the poor performance of rail in the management of fragile goods.

The majority of truck traffic (60 percent) is typically within the confines of a single urban area. Many things require transportation of goods to dispersed local destinations. The competition of providers to deliver goods and services to stores, homes, and businesses either saves the consumer money, or offers greater convenience and choice. Given recent trends, it is unlikely that the portion of freight moved by trucks within city limits will fall significantly; on the contrary intra-urban truck traffic will probably continue to grow.

The ease and efficiency of goods movement in a region is intricately linked to the metropolitan economy. Business and industrial location choices are not only tied to market access, but to dependable transportation facilities for the distribution of products to consumers. Despite its importance, few regions have examined and planned their transportation networks with goods movement in mind. The link between goods movement and economic development has long been acknowledged, but few regions examine the goods movement network as an economic asset or try to integrate transportation development with area wide economic development goals. If planning agencies wish to include issues related to truck travel in the planning process a study of the commodities moving by truck and/or a truck trip generation survey would be required to obtain locally-specific data. Many areas include trucking and intermodal operators specifically in the outreach process. Uses of the data collected in truck surveys are outlined in the next section.

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It should be noted that measuring commodity flow as a basis to estimate truck trips has limited utility in developing trip generation models. Commodity flow (especially as tracked by large, national commodity-flow databases, such as the Census CFS) does not always translate into trip estimates for the following reasons:

- The amount of trucks moving empty can be between 25 and 35 percent of the truck trips in a region.
- The geography of goods flow which includes:
 - Trips within a study area (Internal only) comprise about 60% of all truck trips when large and small trucks are included. The goods moving fully within an area are not accounted for by most large commodity flow databases.
 - Trips from outside an area to inside an area (External-Internal) depend so much on the area location, size, and characteristics. These would be partially accounted for by large commodity flow databases.
 - Goods moving through an area can often be tracked from goods flow databases
- Regional and seasonal differences in commodity amount and type, destination type and location, etc.
- The growth of intermodal shipments which makes tracking mode (train/truck) difficult using large commodity databases:
 - Growth of container shipments, separation of truck and goods
 - Greater economy/efficiency on rail means more rail-truck distribution within an area.
 - Growth of imports through water ports and truck to rail movements (Drayage)

At this point in the state of the practice of surveying and forecasting truck travel, the recommended design includes directly measuring truck trips, and obtaining data on commodities for the sampled trips. This allows a linkage of the smaller local survey to the larger national commodity survey, and also allows the local travel demand model to identify truck-generators within the study area and use a four-step approach to generate and distribute truck travel based on land-use forecasts.

Uses of Truck Trip Data

Potential applications for freight truck trip information include:

Congestion Management and Safety

- Document origins, destinations, and routes used by freight trucks traveling through congested urban areas
- Provide base data to evaluate opportunities to reduce freight truck traffic through urban areas during peak commute periods
- Provide base data to evaluate other policies relating to truck route prohibitions in urban areas

Corridor Planning

- Identify highway corridors most critical to key industries
- Pinpoint major freight truck generators for specific corridors
- Document routes most widely utilized for national and international trade
- Provide base data to project freight truck traffic growth and decline for specific corridors

- Provide base data to estimate the economic value of specific commodities shipped in specific corridors

Intermodal System Planning

- Delineate essential highways linked to rail, air, deep water and river ports
- Evaluate intermodal systems most critical to key industries
- Track geographic proximity of intermodal facilities relative to the origins and destinations of trucks utilizing those facilities
- Provide base data to project changes in highway usage that would result from rail-line abandonment or closing of key river ports
- Document highway segments with the highest average freight cargo volumes and weights
- Provide base data to project future changes in freight cargo volumes and weights on specific highway segments

Commercial Vehicles and Safety

Accidents are always a concern. The mix of trucks and other transport on a busy road can pose special dangers. Overall, a few facts from NHTSA put truck accidents into perspective:

- Large trucks account for 3 percent of all registered vehicles, 7 percent of total vehicle miles traveled, and 8 percent of vehicles involved in fatal crashes.
- Large trucks are more likely to be involved in a fatal, multiple vehicle crash than were passenger vehicles
- Most of the fatal crashes involving large trucks occurred in rural areas (63 percent), during daytime (66 percent) and on weekdays (80 percent).
- In the majority (72 percent for the most current data) of cases involving a two-vehicle fatal crash between a large truck and another vehicle, police reported one or more contributing factor for the other vehicle driver and none for the truck driver. In 17 percent, one or more factors were reported for the truck driver and none for the other driver. In 9 percent of the cases, factors were reported for both drivers, and in 2 percent no contributing factors were cited for either driver.

Most truckers are well-trained and careful drivers. However, while cars have gotten lighter over the last decades to increase fuel efficiency, allowable truck loads has increased leading to greater weight disparity. The weight of vehicles impacts stopping time and distance, which can be critical in traffic. In addition, distracted driving, greater congestion, just in time delivery, and other factors may all play a role in truck safety. If safety is a special concern in the area, information on the amount and details of the types of crashes—especially fatal crashes—can be assembled¹. Table 1 shows the most recent data on the amount and type of fatal crashes involving large trucks for the nation as a whole.

¹ For example, NHTSA publishes Traffic Safety Facts annually and the TIFA data is public use

Table 1 - Percent and Type of Fatal Crashes Involving Large Trucks

Crash Type	Fatal	
	Number	Percent
Large Truck Rear-Ending Passenger Vehicle	172	4.6%
Passenger Vehicle Rear-Ending Large Truck	627	16.6%
Large Truck Crossing Center Median (Head-On)	127	3.4%
Passenger Vehicle Crossing Center Median (Head-On)	646	17.1%
Large Truck Striking Passenger Vehicle (Other)	1165	30.9%
Passenger Vehicle Striking Large Truck (Other)	857	22.7%
Other Collision	178	4.7%
Total	3,772	100.00%

Source: analysis by author on Trucks in Fatal Accidents (TIFA) 2009 public sas file

Meeting with the '100 Biggest Trucking Firms'--Collecting Data from Secondary Sources

One method which has worked well in assessing the feasibility of policy changes affecting trucks and truck travel goes directly to the representatives of the largest trucking firms in the study area. This method is based on focus groups or workshops, or series of meetings, attended by high representatives of the largest firms to discuss specific problems and potential solutions. However, if the current problems associated with trucks primarily stem from safety and regulation issues, the offenders will largely be from smaller, independent truckers or firms. These smaller operators are harder to identify and much harder to incorporate into the planning process.

If a dialogue with the largest trucking firms is considered useful, the first step in this process would be to identify the largest trucking firms in the study area.

The American Trucking Association (ATA), the Chamber of Commerce, Dun & Bradstreet, or other sources could prove useful in identifying potential participants. For this methodology to work well, recruiting for the workshops or meetings must be from top-level agency or transportation consultants to top-level executives in the targeted firms. A first contact letter would be mailed to the contact person, once identified, setting out the agenda of such a meeting, and offering an invitation. This letter should be followed up by a telephone call to help the contact at the firm identify the best participant, and to answer any questions about the process. This telephone call is instrumental in eliciting participation by the right parties.

This method has the advantage of incorporating the community of truck owners/operators into the planning process, and of using existing data and consolidating it for travel planning. This approach may be used in conjunction with a direct survey of commercial vehicles. The weakness of this approach is the lack of quantitative rigor—it should be considered a qualitative approach, and the data collected from the owners/operators used as strategic, rather than specific, information.

Collecting Primary Data on Truck Trips

If more quantitative data is required—for example to provide inputs into a truck trip generation model—then a quantitative survey must be conducted. The commercial vehicle survey, formerly

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referred to as the truck and taxi survey, was an important component of the comprehensive studies of the 1960's and 70's. More recently the lean budget years, coupled with the fact that truck travel is typically 10 to 12 percent of all trips, tended to diminish the perceived need for the conduct of this type of survey. However, concerns about improving air quality, safety, and congestion has refocused interest in collecting better information about commercial vehicle travel in urban areas.

Significant differences in trip characteristics make it inappropriate to factor resident auto trip tables to account for commercial vehicles. Household and truck activity are not directly related, and in some cases mutually exclusive--such as truck limitations in residential areas. The logical solution is to base the activity of these vehicles on employment density and type, rather than household density as is the case with person trips.

Information on the cargo carried by sampled vehicles is generally obtained in the format of Standard Transportation Cargo Codes (STCC), now North American Industry Classification System (or NAICS, at: <http://www.census.gov/eos/www/naics/>) but a truck trip survey is not designed to be a cargo or goods movement survey. The design of the survey will lead to the analysis of commercial vehicle trip characteristics for development of a truck trip model. The detail on the type and amount of goods obtained in this small sample survey is not sufficient to make references about the total amount and type of goods in an urban area.

Experience in conducting and analyzing a number of commercial vehicle surveys, for estimating trip generation and trip attraction as well as air quality forecasting, has led to a set of critical design issues that surface over and over again. Some of these issues are briefly discussed below.

Critical Design Issues in a Commercial Vehicle Survey

How to Develop a Universe?

The first step in the design of a survey of trucks making trips in the study area is to determine the universe from which to pull a sample. A listing of trucks garaged in the area must be established before the sample can be identified. It seems as if one could select trucks from a DMV file, for instance. However, some of the trucks making trips in the region are registered in the region, and some of the trucks making trips in the region are registered in other counties adjacent to the study area, or even in other states. Some of the trucks registered in the region are actually garaged elsewhere. Some trucks are registered in the region but leased to other operators who may or may not be identifiable. Some trucks are making stops in the region, and others are simply traveling through.

In addition, using the DMV files does not provide a robust sample because tractor cabs and trailers can be separated, and licensed separately. For most study areas, multiple state listings would have to be included, since trucks registered in one area (due to different licensing fees) are often garaged in others. To effectively use the DMV file, if that is the choice, requires that the separate vehicle listings be combined under the same garage address, so recruiting is efficient. This can entail a lot of sifting and sorting to aggregate the separate vehicles into their correct garage location. The telephone number or contact is not listed on most vehicle registration files, therefore once garage locations are developed the site must be manually looked up. We've hit a number of snags at this point, with business registration names differing from site location names, or sites just not appearing in any telephone listing (industrial sites especially).

Due to these difficulties the survey approach may want to use an alternate two-stage methodology that uses lists of businesses developed from D&B files, or other business lists. A sample of the businesses in the directory can be telephoned and screened as to whether or not a commercial vehicle is garaged at that location. An inventory of all commercial vehicles garaged at the recruited business location would be compiled, with the license plate number of each vehicle. In this method a sample vehicle is chosen from the inventory of vehicles by matching a random digit to the last number of the license plate.

Generally, between 10 and 25 percent of the contacted sites have a commercial vehicle, but the terminology and definition of such vehicles needs to be clearly stated to ensure that the estimation of the universe is correct. The number/percent of sites with vehicles are tracked by industry type, area type, and other pertinent variables, and some data about the number and type of vehicles at each site is obtained. The final number of truck trips generated by sampled vehicles at the participating sites is first raised to the total number of vehicles at the sampled sites, and then to the total estimated vehicles and sites within the strata (industry type/area type).

Although this method is sound it is time-consuming and costly per trip record obtained. Careful thought is required in planning a commercial vehicle survey about how to develop a robust universe of garage locations and vehicles, and how to select a representative sample of each.

Most employers do not own or lease commercial vehicles: in a recent Denver study 74% had no commercial vehicle garaged at the location, while 26% of the employers garaged one or more commercial vehicle(s) at their business locations. Based on these data, Table 2 shows an estimate of the number of vehicles by industry type for the study area. These data may be considered transferable for the purposes of establishing a survey design. A table similar to this should be prepared from the screening call data to estimate the number of commercial vehicles garaged in the specific geographic area of interest. Of course, the data should be collected using the local planning areas' land-use types in as much detail as possible.

Table 2 - Estimated Number of Vehicles by Type of Business (Data from Denver Commercial Vehicle Survey)

Type of Business (SIC Designation):	Number of Businesses (D&B Summary)	Estimated Number with at Least One Commercial Vehicle	Mean Number of Trucks per Site	Total Estimated Trucks at Commercial Sites
Industrial (1-4999)	18,168	4,542	7.9	35,882
Retail (50-5999)	21,768	5,442	3.2	17,414
Service (70-8999)	35,918	8,980	3.7	33,226
Office and Govt. (60-6799, 91-9799)	9,323	2,330	6.4	14,912
Total	85,177	21,294	4.8	101,434

Survey Methodology

Once a universe of sites with commercial vehicles has been developed, and a sample of vehicles within a representative assortment of sites selected as a sample, the truck survey can be designed. The approach to this type of survey resembles a home interview survey--the truck is equivalent to the household member who keeps track of each trip made during a sample day, and the commercial (garage) location is equivalent to the household location. The trip generation is tied to the garage location (by industry type and area type).

The survey methodology can also be compared to the household travel survey--a vehicle at the sampled site is randomly selected, the owner/operator is recruited to participate in the survey, and the participant driver(s) record all of the trips made in the sampled vehicle during a 24-hour period on a travel diary. The owner/operator is then re-contacted and a trained interviewer collects the survey data. One method we have used in the past is similar to the household travel survey--a telephone recruit, mail-out of the survey packet, and a telephone retrieval of trip data. This method has worked well, with some modifications to the recruiting procedures, and with allowing a mail-back of the survey form when a telephone interview cannot be arranged.

Expansion

The expansion of the sample data is a two-stage process. First the sampled trucks are raised to represent all of the trucks garaged at the sample location, to estimate a trip rate per site by industry type. The trip rate is applied to the proportion of sites of that type which have trucks (as estimated from the universe). This gives a control total for the number of internally generated truck trips linked to employment by type in the study area.

As a second control total, the consultant team has developed an expansion technique using estimates of total truck VMT by facility type. The details are attached as Appendix A.

Vehicle Weight

There is a lot of confusion about collecting the weight of the vehicle, especially for input into an air quality model. Generally we ask for the empty weight and the loaded weight, but these data may or may not be known with precision by the driver/operator, especially of the smaller vehicles. Larger vehicles usually have better information on tare weight and cargo weight. For input into air quality analysis software the weights of the vehicle and the fuel-type determine the type of truck or designation category:

Table 3 - Truck Type Categories as Defined by Weight

Designation:	Weight (GVW)	Fuel Type
Light Duty Gas Trucks Type 1	6,000 lbs	Gasoline
Light Duty Gas Trucks Type 2	6,001-8,500 lbs	Gasoline
Heavy Duty Gas Vehicles	8,501 and over lbs	Gasoline
Light Duty Diesel Vehicles	8,500 and less lbs.	Diesel
Heavy Duty Diesel Vehicles	8,501 and over lbs	Diesel

The Gross Vehicle Weight (GVW) is different than the weight listed on the DMV file, for air-quality analysis the GVW is the empty weight of the vehicle plus the weight of the vehicle when fully loaded. However, the weight obtained from the driver/owner on the sample day should be carried in the data file. Up to one-half of the vehicles which make trips on the sample day will not be carrying any freight, for these trucks the parameters given as defaults in air quality analysis (such as Mobile5) will overestimate the GVW.

Definition of Vehicle Types

Defining and categorizing trucks and other commercial vehicles in the study area is not as straightforward as it would appear. As shown in Table 3, vehicles are often classified by a combination of fuel type and weight. The FHWA classification scheme is by silhouette for manual classification counts. Automatic classification counters use number of axles, and of course cannot determine fuel type.

The Texas models incorporate only trucks with three-axles and more, since axles were an easy match to automatic vehicle counters. The North Carolina models include cars used commercially, pickups and vans, and panel trucks as well as big trucks. The trip rates, lengths, routes, land-use at destination, etc. is very different for each vehicle type. For example, Table 4 shows the average miles driven on the survey day by vehicle type, and the average trip length in minutes from reported data by vehicle type (this data is from Triad, North Carolina where commercial cars, vans, and trucks were included in the sample frame).

Table 4 - Average Miles Driven on the Survey Day by Vehicle Type (Data from Triad, North Carolina Commercial Vehicle survey)

Vehicle Type	Miles Driven on Survey Day	Average Travel Time per Trip (mins)
Single Unit Truck	98.44	18.93
Combination Truck	181.06	38.19
Pickup Truck	57.52	17.85
Van	69.21	37.97
Car	76.98	18.46
Overall	84.79	23.93

Table 5 presents the estimated proportion of total vehicle miles of travel by eight classifications in the Houston-Galveston Region. These classifications use the fuel type and weight as illustrated in the discussion on vehicle weight and shown in Table 3.

Table 5 - Proportionate Distribution of VMT by Vehicle Classification (Houston-Galveston Commercial Vehicle Survey)

Designation:	Proportion of VMT
Light Duty Gas Vehicles (Cars)	51.3 %
Light Duty Diesel Vehicles (Cars)	0.5 %
Light Duty Gas Trucks Type 1	28.9 %
Light Duty Gas Trucks Type 2	7.9 %
Heavy Duty Gas Vehicles	7.1 %
Light Duty Diesel Vehicles	0.4 %
Heavy Duty Diesel Vehicles	3.7 %
Motorcycles	0.2 %

Using similar proportions from classification counts done in the region, an estimate of the total vehicle miles of travel by vehicles classified as trucks (the non-shaded rows) may be developed. After removing the estimated truck vehicle miles of travel made by trucks passing through the study area – usually estimated from an external survey-- the total vehicle miles of travel for each classification of truck would be divided by the vehicle miles of travel for the surveyed trucks to calculate an expansion factor. The details of this approach are discussed in Appendix A.

Vehicles to Include in the Survey

In addition to the question of how to define vehicle types, there is a question of what specific vehicles to include in the sample frame. Many vehicles besides heavy duty trucks will use diesel fuel and turn up in classification counts by axle. Some of these vehicles may not be included in the sample, and information on these types can be collected separately or not at all:

- Transit buses on fixed routes can be analyzed for the VMT from available data
- VMT estimates for school buses can be ascertained from mileage accrual--direct contact with service providers (school districts or independent contractors)
- Post Office vehicle's VMT can be obtained from mileage accruals or analyzed from the Post Office forms 3997 and 4533 for local and regional routes. Postal vehicles are 1 percent of all trucks, but can be 2 percent of all trips within a study area (CATS). The routes will be analyzed for the amount of travel on neighborhood streets, and the amount on collectors and more major facilities.
- Police Vehicle's VMT can be obtained by directly contacting each precinct for mileage accrual.
- Rental and leased trucks at leasing stations (U-Haul, etc.). Although mileage is obtained on the rental record, these trips may or may not be within the study area-- these data should be obtained from a separate visitor survey.
- Fire Station Vehicles and Emergency Medical Service (EMS) Vehicles have widely variant trip characteristics. We recommend that these vehicles not be surveyed.
- Garbage Trucks travel primarily on neighborhood roads and alleys. We recommend that these trucks not be surveyed.

The determination of which vehicles to include is a critical step in the survey design process. The resources required in obtaining the VMT data from all providers and sources listed above are considerable.

Other Considerations

To assist in air quality modeling—which requires an estimate of hot and cold starts—information on whether or not the vehicle was turned off at the destination should be collected for each trip end. It is not too surprising that nearly 30 percent of the sampled vehicles did not turn off their engine at the stop. Table 6 shows these data by land-use type.

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Table 6 - Percent of Trips by Whether Vehicle Was Turned Off at Destination (data from the Triad, North Carolina Survey)

Industry Type	YES		NO	
	Trips	Percent	Trips	Percent
Industrial	841	79.2%	221	20.8%
Retail	444	84.6%	81	15.4%
Special Retail	122	64.9%	66	35.1%
Service	495	76.7%	150	23.3%
Office	131	79.9%	33	20.1%
Other (Unclass.)	13	92.9%	1	7.1%
Total	2046	78.8%	552	21.2%

To understand the pattern of business activity and its link to truck and commercial vehicle traffic, it is critical to spend some time assessing the types of businesses in the study. The NAICs codes are helpful; but local areas use many designations of business types. As long as the socio-demographic forecast uses the same designations, the future truck trips can be linked to future land use. For example, using the first two digits of the NAICs code (in parentheses) businesses in a study area can be grouped into different categories:

NAICs category 1 (Basic Industries) include:

Utilities (22), construction (23), manufacturing (31), transportation and warehousing (48), and wholesale trade (42).

NAICs category 2 (Service 1) includes:

Information (51), finance and insurance (52), and professional and technical services (54)

NAICs category 3 (Service 2) includes:

Management of companies (55), Arts/Entertainment/Recreation (71), and Other Services (81)

NAICs category 4 (Retail) includes:

Retail trade (44) and Accommodation and Food Service (72)

NAICs category 5 (Not Sampled) include:

Educational Services (61), Health Care and Social Assistance (62), Waste management and remediation (56), Agriculture and Forestry (11), Mining (21)

The last group of businesses need not be included in the sample. Data to estimate the number and type of vehicles serving establishments in this last group can be collected from public sources. For instance, the number of school buses and their daily trip making characteristics (Educational Services) should be available from the local school board or transportation agency. Large hospitals will share information about the number of EMS vehicles, the number of garbage trucks and their daily activity may be available from local area contractors. In addition, the number and type of postal service vehicles (especially for larger facilities) needs to be collected to enhance the sampled estimates. Responsibility for the collection of these data lies with the local planning area, and attention to this

segment of the total trip generation will greatly enhance the estimates obtained from the sample survey.

Cargo Type

Cargo is usually tracked by the Standard Classification of Transported Goods (SCTG), but real life experience indicates that the use of these codes is cumbersome and the resulting data too fine for meaningful analysis. The number of trips by commodity type in each of the categories is so small that the categories will most likely be substantially combined to produce robust numbers of trips. Typically, these commodity proportions are then analyzed as attractions to various land-uses. In addition, many independent carriers are not sure what they're carrying (classified as "Other"), or like UPS they are carrying an assortment (Freight All Kinds). Small carriers (vans and panel trucks) which represent a good proportion of the commercial trips in an area may be carrying non-classified goods (flowers/take-out-meals/catering equipment/lawn equipment/etc.) Another issue eluded to earlier concerns the amount of trucks moving empty. Table 7 shows the percent of trips by cargo type destined to various land-uses.

Table 7 - Cargo by Land Use at Destination - Percent of Trips (Data from Triad, North Carolina Commercial Vehicle Survey)

Cargo Type	Office /Com	Retail	W-house/ Manuf.	Utility	Const- ruction	Other
Empty	32.1	23.2	32.8	7.5	3.1	1.4
Food	5.7	80.4	4.6	9.3	--	--
Tobacco/Textiles/ Apparel	8.6	10.0	75.7	2.9	2.9	--
Conc./Lumber./Paper or Furniture	60.0	7.3	24.8	2.4	4.2	1.2
Petr./Nat. Gas or Coal	8.6	16.7	58.0	12.3	2.5	1.9
Mach./Equip or Supplies	5.6	6.9	30.6	56.9	--	--
Waste or Scrap/HAZMAT	6.1	39.4	43.9	4.5	1.5	4.5
FAK (Freight All Kinds)	21.7	31.9	33.9	9.4	0.3	2.9
Other	22.6	23.7	36.0	11.2	1.1	4.7
N/A	44.4	20.5	13.0	20.3	0.7	0.7
Total	26.2	26.1	32.1	11.9	1.7	2.0

Some areas, such as Portland, have developed a simplified classification system based on combinations of STCC codes, and some areas, such as the CATS planning region in Chicago, have simply added categories as needed. The coding and classification of cargo are critical elements of the survey design.

Sample Size

The number of samples required is generally estimated based on the acceptable error and the required confidence in the data, and on the available resources and detail of the data which is being collected. Table 8 shows the estimates from previous studies of trucks by type as a percent of the universe of all trucks, the mean number of vehicle trips, and the coefficient of variation. These data can be used to determine sample sizes within a single dimension or strata (e.g. truck type). If more detailed cross-classification strata are used (such as trucks by type by industry type or area type), the estimated sample size will increase.

Table 8 - Estimate of Coefficient of Variation for Truck Type Categories

Designation:	% of Universe	Mean Number of Trips	C.V.
Light Duty Gas Trucks Type 1	56.2%	5.9	0.966
Light Duty Gas Trucks Type 2	2.1%	5.0	0.848
Heavy Duty Gas Vehicles	4.6%	4.4	1.140
Light Duty Diesel Vehicles	20.4%	7.7	0.872
Heavy Duty Diesel Vehicles	16.7%	6.9	0.874
All	100.0%	6.1	0.967

Data Elements

Several different survey instruments may need to be developed to accommodate the data items of interest. Data from the establishment may allow mail-out/mail back or telephone retrieval. Details of the vehicle trip data may rely upon interviews with the driver through telephone or collection of the trip diary through mail back or e-mail.

The second-stage vehicle trip data is collected from a representative sample of the vehicles used by employees of the firm. These vehicles can be randomly sampled from license plate numbers or other designators—importantly vehicles that DO NOT make trips are important to include in the sample. The second-stage vehicle-trip survey must be short enough that participation is high. The driver of the vehicle may not have the same stake in the process as the owner/operator of the sampled establishment. The key data elements are the time of trips, and the origins and destinations of each trip in the sample day. This provides important information to determine the distance traveled. If destination locations can be precisely determined, the distance can be more readily measured.

If the use of a GPS device would obtain more reliable data on these key elements, the survey design should separately include using GPS analysis as a task, and separately provide the resources to adequately analyze the location data.

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Some data must come from the driver, however, such as the purpose of the trip (at a minimum whether work-related or personal) and whether and what commodities were carried or what services were provided for each trip. In many cases the trip might be simply a person traveling to a different site.

The survey design should develop an initial list of data items required and then questions for each stage of the survey. Some examples of questions at different stages include the items listed here (the first four bullets are generally part of the establishment master file and just need to be verified with the sampled businesses):

- Firm name, address, contact person if available, telephone number
- Geocoded location and area type (this is what you are adding to the file)
- 6 digit SIC and NAICS codes
- Employment size and sales ranges

Data Items for the Establishment:

- Total Number of Employees
- How long has this establishment been at this location?
- Whether any vehicles are used by employees of this establishment during their normal duties that are parked at the establishment over night, number of vehicles
- Whether employees take vehicles home at night or use their own vehicles during their normal duties, number of vehicles
- Number of Employees that use vehicles as part of their normal duties
- Basic use of the vehicles for this establishment:
 - Package and Mail Delivery
 - Freight Distribution
 - Construction Transport
 - Safety/Utility Vehicles
 - Public Service Vehicles
 - Business Services
 - Personal Services
 - Rental Cars
- The number by type of vehicles used at this establishment, with license plate number or unique identifier such as make/model/year/color (for sampling of vehicles):
 - Motorcycle
 - Car (passenger/station wagon)
 - Pick-up
 - Van
 - SUV
 - Panel Truck/Step van
 - Combination Truck
 - Other TruckFor Trucks:
 - Weight (empty and loaded)
 - Fuel type (gas/diesel/other)

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- Whether a manifest or GPS is used by drivers (if so, can we obtain the trip data for the sample day(s)?)
- Number/percent of vehicles used for goods movement
- Type of commodity/goods carried
- Land-use at destinations
- Number of vehicle movements by trip type (deliver/pick-up/other) in an average day, per vehicle for non-stationary vehicles
- Number/percent of vehicle stationary in an average day
- Number of deliveries to the site in an average week by type of vehicle
- Number of commercial vehicle trips destined to the site that are not delivering goods in an average week
- Odometer reading for each sampled vehicle at begin and end of the survey day

If needed (at the establishment level):

- Do the trucks at your facility make...?
 - Multiple trips by the same truck in and out every day
 - Travel on a chained series of trips (route) throughout the day, returning to the site once or twice
 - Leave the site once and do not return that day
 - Come in and go out less than once a day
 - Trips vary/Can't say
 - Other (specify)_____
- Can the goods movement/truck trip be shifted in time out of the peak period?
- What factors play a role in locating this facility:
 - Access to major freeways
 - Proximity to major shippers/warehouses
 - Proximity to major ports
 - Proximity to the airport
 - Proximity to rail
- Possible concerns or problems (either Likert scale or open-ended):
 - Does traffic congestion pose a problem for you operation?
 - Are there locations with inadequate pavement or signage in your area?
 - Are there locations where it is difficult for trucks to maneuver in your area?
 - Are there locations where there is inadequate clearance to a bridge or other vertical structure in your area?
 - Are there locations where traffic signals are need in your area?
 - Are there other concerns or problems your trucks experience at or near this facility?

For the Vehicle Trip Inventory:

- The origin location of the vehicle before the first trip of the travel day
- The start time of the first trip
- The end time of the trip
- The type of place at destination (e.g. the sampled establishment, another site of the same business, an office, retail center, residence, construction site, lunch location, etc.)
- Address of destination
- Was engine turned off at this stop (Y/N)

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- Purpose of the stop (deliver goods, pick-up goods, service call, meeting, personal stop for driver)
- Type of goods or services provides
- Start location of next trip (the sampled establishment, the end of last trip, other place)

There are several aspects to the coding of the forms that should be considered.

- Use of open ended questions should be avoided, alphanumeric codes are preferable,
- There should be editing and correction for illogical answers, and
- Trip destinations should be geocoded to determine their distance from the establishment

To the extent possible all survey forms should be self coding for the respondent, open ended questions are difficult to process.

Conclusions and Recommendations

“Commercial Vehicles” and “Commercial Travel” include a wide range of vehicle types and trips-- everything from small package delivery, government services, personal services (such as plumbers, lawn care, and realtors), and rental cars. Commercial vehicles have important differences in travel behavior, especially by time of day and geography, when compared to private vehicle activity. It is seldom advised to ‘factor’ home-based trip generation model inputs to account for commercial vehicle activity.

Some of the pressing questions related to commercial vehicle assessment and forecasting include²:

- How much of the traffic in an area is attributable to commercial vehicle movements?
- How are commercial vehicle trips distributed, both by land-use of the origins and destinations of trips, and by time of day of trip-making?
- Can commercial vehicle trips be classified into meaningful categories, and tied to business files (establishment data) to aid in forecasting?
- What economic/demographic/land-use factors influence the magnitude and type of commercial vehicle travel?
- What data are needed to estimate and forecast commercial vehicle trips? What method (and with what resources) can acquire the needed data?

Urban areas struggle with the common issues in conducting these surveys and using the data wisely. Experience in conducting surveys of regional truck travel for input into the truck travel forecasting model offer some general common findings³:

- 1) Trip length distribution and the truck size were related: generally the larger the truck the longer the average trip length.
- 2) Number of daily trips and size of truck were related: generally, the larger the truck the fewer number of average daily trips.

²“The Magnitude and Distribution of Commercial Vehicles in Urban Transportation”, Maren Outwater, Nazul Islam, and Bruce Spear, TRB 2005

³ Truck Travel in the San Francisco Bay Area, prepared for Caltrans District 4 and Alameda County, prepared by Barton-Aschman Associates, December 1995

- 3) Daily peak patterns: truck travel is heaviest in the midday period and declines prior to the P.M. commute period.
- 4) Trucks primarily serve commercial land uses: a majority of truck trips are destined for retail establishments (25 percent), manufacturers (20 percent), or terminals/warehouses (20 percent). However, a growing segment of truck travel (especially smaller panels and vans) is destined to residential locations.
- 5) Local area characteristics determine truck travel type, for instance Chicago is a central hub for truck and rail whereas Phoenix is on a through route connecting the east coast and southern California.

This white paper has outlined some of the thorny issues related to designing and conducting a commercial vehicle survey. The determination of the universe of garage locations is usually an obstacle in the sample design, with the choice falling between using the vehicle registration file, and developing a universe from a listing of businesses in the area. The creation of a strategic panel of the largest truck owners is valuable as a policy tool, but does not garner specific quantitative information about truck movements need to develop trip generation rates for existing garage locations and future land-uses.

The generation of truck trips is tied to the amount and type of employment, allowing the forecast of truck travel to be part of the socioeconomic forecast for the study area. The expansion of the data can be made to the vehicle registrations, but a more precise method has been developed using sample VMT by truck type and facility type and raising it to total truck VMT by facility type. This method provides an accurate description of all truck travel in the region (shown in Appendix A).

This white paper summarizes a few of the more detailed findings from previous commercial vehicle surveys with the idea to help planning agencies and consultants who may be developing future commercial vehicle studies. Carefully designed and executed commercial vehicle surveys can obtain critical information relevant to air quality, safety, and congestion. Hopefully, learning from the past will shed light on the future, and the considerations set out here will help develop robust commercial vehicle studies to obtain information for inclusion in a metropolitan forecast model.

Appendix A

Estimating Truck VMT by Functional Class of Roadway for Truck Survey Expansion

I. Estimation of truck VMT by Functional Class of Highway and Type of Truck using vehicle counts at a sample of locations within a region.

If an estimate of total VMT by each stratum could be made, the mean percentage of trucks for each would require fewer counts than the than the sample size suggested here. The following discussion assumes that estimates of VMT by functional class and geography are not available.

The estimation of regional VMT is often accomplished by multiplying the length of a link by the count of the vehicles traveling that link and summarizing the product across all links in the network. Such an approach requires an estimate of the lengths of all links in a network and the number of trips traveling each link. These data are not typically available. However, an unbiased estimate of VMT can be obtained from vehicle counts at a sample of points in the region provided the road mileage in the region is known.

$$VMT = L \Sigma \frac{V_i}{n}$$

Where:

VMT=VMT is the vehicle miles of travel on the roadway system,

Σ = summation

V_i = volume of vehicles counted at point (i) on the roadway system, and

n = number of sample count locations

L = mileage of roadway system

The standard error of the estimate of VMT is a function of the standard deviation of the mean of the counts on that roadway. This approach can be extended to class of highway *f* and type of vehicle *k* system.

$$VMT_{fk} = L_f \Sigma \frac{V_{ki}}{n}$$

Where:

VMT_{fk} = estimated vehicle miles for functional class *f* and vehicle type *k*.

L_f = mileage of roadway system for that functional class

Σ = summation

V_i = volume of vehicles (k) counted at point (i) on the roadway system, and

n = number of sample count locations

The sample size requirement for count locations is a function of the precision and the level of confidence desired. The precision is a function of the sample size, as shown below.

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Where:

$\sigma_{\bar{x}}$	=	Standard error of the mean count
\bar{x}	=	mean
σ	=	standard deviation of the counts
n	=	number of sample counts

The relative error is the ratio of the standard error of the mean to the mean. Typically the confidence level is 90%, which is associated with 1.645 standard errors of the mean, or 95% which is associated with 1.96 standard errors of the mean. If we wish to have a relative error of $\pm 5\%$ at the 90% confidence level, we can solve for the required sample size knowing the mean and the standard deviation (which we do not know) or the coefficient of variation which we may estimate.

For example (this uses the equation above as a starting point):

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

$$C.V = \frac{\sigma}{\bar{x}} = \text{Coefficient of Variation}$$

$$\epsilon = \frac{\sigma_{\bar{x}}}{\bar{x}} = \text{Relative Error} = \frac{\sigma}{x\sqrt{n}} = \frac{C.V.}{\sqrt{n}}$$

$$n = \frac{C.V.^2}{e^2} \quad (\text{For one standard error})$$

Then for 90% confidence level:

$$n = \frac{(1.645)^2 C.V.^2}{e^2}$$

And if C.V. equals .9 and the relative error (e) is ± 10 percent, then:

$$n = \frac{(1.645)^2 (.9)^2}{.10^2} = 219$$

Of course, depending on the value of C.V. the required sample size (n) will be larger or smaller. Below is an illustration of the effect on sample size for alternative values of coefficient of variation and relative precision of $\pm 10\%$ and $\pm 5\%$ at the 90% confidence level.

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Table 1 shows that depending on the variability of the truck counts, and assuming a standard distribution, reasonable numbers of count locations can be used to estimate regional VMT by trucks. For example, if the C.V is 1.1 the total number of sample locations would be estimated at 527 for a relative error of +/- 10 percent. On the other hand, if C.V. = .7 the total sample count locations would be 133-188.

Table 1 Sample Sizes for Alternative Coefficient of Variation for ± 10% and ± 5% at 90% Confidence Level

Coefficient of Variation	Relative Error	
	± 10%	± 5%
1.1	327	465
1.0	271	384
.9	219	311
.8	173	246
.7	133	188
.6	97	138
.5	68	96

Truck Type

If the truck type will be separately analyzed then the type selected must serve some analytic purpose or scheme including: accident analysis, emission calculations, loading/capacity analyses, etc. First and foremost, the truck types must be accurately recognized by an observer counting traffic. Classifying trucks by the number of axles is a time honored tradition. So also is configuration; tractor, tractor-trailer, dump, tanker, etc. While there is more interest in items such as diesel or gasoline, gross weight, etc. for air quality analysis, these attributes are difficult to assess as a vehicle rolls by at 30 - 55 miles per hour. The counts of trucks by type must be manual classifications or sophisticated counting devices that can, at least distinguish between light, medium, and heavy vehicles.

Functional Class of Roadway

The amount and type of truck traffic varies by the type of roadway, therefore the roadways should be separately classified. Typically, roadways are classified by volumes, such as:

- Interstate/Freeway
- Collectors
- Other Principal Arterials
- Local
- Minor Arterials

However, five classes might be too many to use for expansion by the time the number of truck types and geographic types are considered. Table 2 shows the number of miles in each functional class

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for the three counties in a recent study in North Carolina. Table 3 shows the number and percent by area type. Table 4 shows the roadway miles summed by roadway type and the percent each roadway contributes to the overall system. Table 5 shows the average percent of trucks on each roadway type and the number of observations in three other areas in North Carolina.

Table 2 Functional Roadway Classification Mileage for Triad Study

Roadway Classification	Forsyth County		Guilford County		Davidson and Randolph Counties	
	Urb	Rur	Urb	Rur	Urb	Rur
Interstates	16.17	7.14	30.23	10.62	11.56	3.26
Freeways	41.07	--	86.10	--	9.14	--
Other Principal Arterials	37.04	30.01	83.43	28.28	27.08	24.87
Minor Arterials	82.87	24.50	270.70	18.97	72.30	24.87
Collectors	120.16	157.76	135.86	243.88	36.06	123.03
Local	1058.74	442.76	1218.18	763.24	289.07	366.71
Total	1356.05	662.17	1824.5	1064.99	445.21	542.74

Table 3 Total Roadway Mileage by Roadway Type

	Urban		Rural		All	
Interstates	57.96	1.6	21.02	.9	78.98	1.3
Freeways	136.31	3.8	--	--	136.31	2.3
Other Principal Arterials	147.55	4.1	83.16	3.7	230.71	3.9
Minor Arterials	425.87	11.7	68.34	3.0	494.21	8.4
Collectors	292.08	8.17	524.67	23.1	816.75	13.9
Local	2565.99	70.8	1572.71	69.2	4138.70	70.2
Total	3625.76	10.01	226.90	99.9	5895.66	100.0

Table 4 Functional Classification Mileage and Percent by Roadway Type

Roadway Classification	Forsyth County		Guilford County		Davidson and Randolph Counties		Total	
	num	%	num	%	num	%	num	%
Interstates/ Freeways	64.38	3.2	126.95	3.9	23.96	2.4	215.29	3.7
Other Principal Arterials	67.05	3.3	111.71	3.4	51.95	5.3	230.71	3.9
Minor Arterials	107.37	5.3	289.67	8.9	97.17	9.8	494.21	8.4
Collectors	277.92	13.8	379.74	11.6	159.09	16.1	816.75	13.9
Local	1501.50	74.4	1981.42	72.2	655.78	66.4	4138.70	70.2
Total	2018.22	100.0	2889.49	100.0	987.95	100.0	5895.66	100.1

Table 5 Number of Observations and Average Truck Percent by Functional Class in Three North Carolina Areas ^{4/}

Roadway Classification	Greensboro		Fayetteville		Gastonia		Average	
	num	%	num	%	num	%	num	%
Interstates/ Freeways	2	27.40	2	23.16	2	26.33	2	25.63
Other Principal Arterials	21	17.55	7	17.98	22	13.47	17	16.3
Minor Arterials	21	15.47	16	16.23	17	14.22	18	15.3
Collectors	13	11.68	3	15.01	--	--	8	13.4
Local	63	13.26	25	14.10	6	13.62	31	13.6
Total	120	—	53	—	47	—	76	—

The predominant roadway type in terms of mileage is clearly the local streets with 70 percent of the mileage overall. Interstates and Freeways together have 5.2% of the urban mileage versus .9% of the rural mileage. Other principal arterials have about 4% of the mileage (4.1% for urban and 3.7% for rural). There appears to be a significant difference in minor arterials and collectors when viewed from urban versus rural. Urban minor arterials contribute 11.7% of the mileage versus only 3.0% for rural minor arterials. But rural collectors are 23.1% of rural mileage while urban collectors are only 8.1% of urban mileage.

Stratification

If the volume counts at different locations tend to be less variable than they are overall grouping counts into strata such as type of roadway will increase the precision of the estimated VMT. Moreover, because the purpose is to estimate VMT by trucks or class of truck, truck type is a logical and required assessment for stratification. The three strata classes would be:

- Truck type; e.g. heavy and light
- Functional Class of roadway
- Geography; e.g. Urban and rural

Depending upon actual volumes, the initial categories of functional class would appear to be:

- Interstate/Freeway
- Other Principal Arterials
- Minor Arterials & Collectors
- Local Streets

^{4/}*Estimating Truck Traffic for Analyzing UGM Problems and Opportunities*, Arun Chatterjee, Frederick Wegmann, James Brogan, and Kunchit Piu-Nual, ITE Journal, May 1979, pp. 24-31.

Note that Interstates/Freeways have a percentage of trucks (26%) that is almost twice that of local streets.

Allocation of Counts among Strata

A quota design with the same number of counts per cell is suggested. As a straw man, the sample stratum (each cell) is given the same number of counts. Then there may be some re-assessment.

For instance, if the standard deviation of the count of trucks within a stratum is known or could be approximated one might adjust the allocation to give fewer samples to the least volatile cells and more to cells with higher coefficients of variation—for example, some rural roadways have highly variable truck traffic combined with over-representation in fatal truck crashes. However, the design should balance the concerns about variability in any one stratum and avoid extreme deviation from the equal number of counts per cell.

The recommended stratification is by geography and functional class for count locations. Four functional classes and two area types or $4 \times 2 = 8$; 17-25 count locations in each of the eight strata.

Table 6 Example Number of Count Locations by Functional Class and Area Type6

Function Class	Urban	Rural	Total
Interstate/Freeway	20	20	40
Other Principal Arterials	20	20	40
Minor Arterials & Collect	20	20	40
Local Streets	20	20	40
Total	80	80	160

For expansion, if two or three truck types are used, four functional classes and two or three geographies, there will be these strata for VMT estimation:

- 2 x 4 x 2=16 categories
- 3 x 4 x 2=24 categories
- 2 x 4 x 3=24 categories
- 3 x 4 x 3=36 categories

If two levels of geography are employed, the average count per strata will be equal to 20 (160/8). This argues for holding the strata to 16. If three geographic levels were allowed with the same overall sample count, the cell count would be 33, which puts one in a more tenuous position in calculating precision per stratum.

II. Expanding Sample Truck Percent Data Using VMT Estimates

This section deals with the calculation of factors to raise the sample all trips to represent the universe of all trips. Two approaches will be described; the first approach is the simpler and draws directly upon the Houston-Galveston Report. The second method is an elaboration of the first and more detailed.

A. Through Travel in the Region.

The sample truck data will not include through trips. Because the sample classification counts on which the VMT estimates are based will include through travel, it will be necessary to remove through trips. This can be accomplished if there is a network and a through-trip truck table by the same truck types as used in this study. These can be assigned to the network and the resultant VMT deducted from the strata estimates by geography, functional class and truck type.

B. Calculate Raising Factors - Method 1

1. Overall Sample Trip VMT - The trip length of each trip is the VMT for that trip. This can be obtained via odometer readings or from the distance traveled over a least cost path on the network. This statistic is used in method number 1. The sum of overall sample trip length is the sample trip VMT.

C. Raising Factors - Method 2

VMT by Stratum - Method 2 requires that the trip length of a sampled truck trip be subdivided into functional class and geographic components. This is somewhat more complicated but it can be done using the least cost path method provided the links have been functionally and geographically classified and into an assignment network.

For example, a trip that travels from origin to destination could use links that result in the mileages shown in Table 7.

Table 7 Sample by Roadway Type

	Urban	Rural	Total
Interstate/Freeway	4	0	4
Other Principal Arterial	2	0	2
Minor Arterial & Collections	2	0	2
Local	1	0	1
Total	9	0	9

Thus, this sample trip was nine miles over the road, all of it urban. Other trips would have different functional class and geography components and different overall lengths.

2 (a).Sample VMT by Truck Type

Sum all sample trip lengths by truck type.

2 (b).Sample trip VMT by Truck Type, Functional Class, and Geography

Sum sample trip VMT components by Strata (Truck type, functional class, and geography).

3 (a). Calculate Raising Factors By Truck Type

Divide VMT by truck type (based on counts) VMT by truck type.

The result is a raising factor to be appended to each sample truck trip of that truck type. This approach assumes that the distribution of VMT across strata of functional class and geography is representative.

3 (b). Calculate Raising Factors by Truck Type, Functional Class and Geography - (Method 2)

This approach is much more complicated than method 1 but it is feasible and avoids the assumption of uniform or average distributions of trip components among strata.

In this approach the sum of individual (sample) trips VMT by truck type by stratum is divided into the estimate by stratum based on classification counts. These factors are then appended to each sample record. The factored VMT for a record is calculated as the sum of the products of the factor and sample VMT for that trip for each stratum. An individual trip raising factor can then be calculated by dividing the weighted VMT for that trip by the trip length. Also, the weighted stratum VMT for that sample trip can be aggregated by attributes of the truck itself to obtain a factor for each stratum.