CAMBRIDGE SYSTEMATICS

Accounting for Commercial Vehicles in Urban Transportation Models

Task 4 - Methods, Parameters, and Data Sources

final

report

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.

with

Arun Chatterjee, Ph.D.
Harry Cohen, Ph.D.

February 2004

www.camsys.com

final report

Accounting for Commercial Vehicles in Urban Transportation Models

Task 4 - Methods, Parameters, and Data Sources

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.
100 Cambridge Park Drive, Suite 400
Cambridge, Massachusetts 02140

with

Arun Chatterjee, Ph.D.
Harry Cohen, Ph.D.

date

February 2004

Table of Contents

List of Tables

List of Figures

Executive Summary

In October 2002, the Federal Highway Administration began a research project to evaluate the magnitude and distribution of commercial vehicles in urban transportation planning models. The research was designed to look at all travel that is not adequately represented by the current state-of-the-practice for urban transportation planning models, which are developed from household travel surveys. Household travel surveys are designed only to capture household-related personal travel. Trips made for commercial purposes or using commercial vehicles are not captured. Some household travel surveys may inadvertently capture commercial trips such as realtors or tradesman making door-to-door visits but this does not represent a comprehensive assessment of this type of commercial vehicle travel.

To date, the literature and modeling for commercial vehicles has focused on urban freight distribution. The state-of-the-practice in the modeling of commercial vehicle travel in the urban transportation context has been geared toward developing a limited number of commercial vehicle trip generation factors, typically only disaggregated by truck type; for example, light, medium and heavy trucks. The traditional approach of relating these rates to land use activity has been found to be limited for application in travel demand modeling due to lack of data on differences in trip purpose, vehicle occupancy, and origin-destination (O-D) patterns. This study is the first to develop methods for forecasting ***all*** commercial vehicles, rather than just those involved in the distribution of urban freight.

This project is the first phase of a two-phase project to develop methods for forecasting commercial vehicles in urban transportation planning models. The goal of the first phase is to research, evaluate and identify methods for forecasting commercial vehicles in urban transportation planning models. The goal of the second phase is to develop these methods and estimate parameters that can be used in urban transportation planning models across the country.

The first phase has three primary work tasks:

1. Assess recent and current literature relevant to the treatment of different types of commercial vehicles in urban transportation models. As part of this work, a set of commercial vehicle categories was established.
2. Compile available data and information and estimate the magnitude and spatial/temporal distribution of different types of commercial vehicles. As part of this work, the commercial vehicle categories were refined and prioritized.
3. Develop methods and data sources that can be used to forecast commercial vehicles in urban transportation planning models.

The focus of this report is on the third work task to identify methods, parameters and data sources that can be used to estimate and forecast commercial vehicles in urban transportation planning models. The purpose of this phase of the project was not to estimate the parameters, but rather to identify the parameters that would be most appropriate. As part of the previous work efforts, we defined a commercial vehicle as one that is used primarily for commercial purposes. Some, but not all, commercial vehicles will be registered as commercial vehicles, since some vehicles registered as non-commercial may be used primarily for commercial purposes (we expect that these would be used for business and personal services). Commercial vehicles include autos, trucks and buses and are operated by both public and private sector agencies.

TYPES OF COMMERCIAL VEHICLES

Trips made by commercial vehicles are organized into three groups, based on what is being carried and what economic, demographic and land use factors influence the magnitude and distribution of these trips. The three groups of commercial vehicles are vehicles that move people, move goods and provide services.

These three groups are further subdivided into 12 specific categories of commercial vehicles, based on the same criteria. These 12 categories of commercial vehicles are:

1. School buses;
2. Shuttle services at airports, rail stations;
3. Private transportation, such as taxis and limousines;
4. Paratransit, such as social service vans and church buses;
5. Rental cars;
6. Package, product and mail delivery, such as USPS, FedEx, UPS, etc.;
7. Urban freight distribution and warehouse deliveries;
8. Construction transport;
9. Safety vehicles, including police, fire, etc.;
10. Utility vehicles, including garbage pickup, meter readers, maintenance, plumbers and electricians, etc.;
11. Public service vehicles, including Federal, state, city and local government; and
12. Business and personal services, including realtors, door-to-door sales, and vehicles used for professional or personal services. These vehicles are primarily vans, pickups, and autos.

These 12 categories of commercial vehicles are direct subsets of the three commercial vehicle groups, as follows:

- School bus, shuttle services, taxis, paratransit and rental cars are vehicles moving people;
- Package delivery, urban freight distribution and construction transport are vehicles moving goods; and
- Safety, utility and public service vehicles and business and personal services are vehicles providing services.

METHODS FOR ESTIMATING AND FORECASTING COMMERCIAL VEHICLE TRAVEL

There were three categories of methods developed for use in forecasting commercial vehicles for urban transportation planning models:

- **The Aggregate Demand Method**, which estimates fleet size, trips, and VMT by commercial vehicle category directly from regional estimates of demographic data (such as population and employment) using national default parameters;
- **The Network-based Quick Response Method**, which estimates trips, origin and destinations and routes for each type of commercial vehicle using zonal estimates of demographic data and roadway networks using national default parameters; and
- **The Model Estimation Method**, which estimates trips, origin and destinations and routes for each type of commercial vehicle using zonal estimates of demographic data and roadway networks using parameters derived from local survey data.

The primary objective of the Aggregate Demand Method is to support emissions analysis and to improve validation of aggregate statistics in planning models. The primary objective of the Network-based Quick Response Method is to determine the effects of commercial vehicles on congestion and to improve validation of network volumes in planning models.

MPOs analyze various types of performance measures, including mobility, safety, reliability, and environmental impacts. These analyses are performed at the regional or county level, at the corridor or traffic analysis zone (TAZ) level, and at the intersection or link level, depending on the purpose of the analyses they carry out. To meet MPOs' varying needs, the project team divided the analyses levels into the following three groups:

1. **Macro** analyses that include county, city, or regional-level analysis. MPOs perform travel demand modeling, ozone precursor studies, and conformity analysis of long-range transportation plans (LRTP) and transportation improvement programs (TIP).
2. **Meso** analyses that include subarea TAZ or corridor-level analysis. MPOs perform operational analysis, intelligent transportation systems (ITS) studies,

travel demand management (TDM) studies, and transportation system management (TSM) studies.

3. **Micro** analyses that include link or intersection-level analysis. MPOs perform site impact analysis, carbon dioxide hotspot analysis, congestion management studies, and intersection analysis.

Both the Aggregate Demand and the Network-based Quick Response Methods have been developed to address the macro analyses, with the difference being that Network-based Quick Response Methods would be more useful for commercial vehicle categories that have larger impacts on congestion or air quality. The Model Estimation Methods are primarily for the meso level of analysis because it is more useful to use local data when considering subarea or corridor-level analyses. This report does not present a method to address the micro level of analyses, leaving this subject instead for future research.

There are also other methods identified that were identified for future research but not pursued as part of this project because these are not currently in practice. Many of these future methods hold promise for advancing the state-of-the-practice in estimating commercial vehicles in urban transportation planning packages and should be considered in future evaluations. These methods for future research include: tour-based models, supply chain models and integrated models.

The overall share of total VMT for the urban areas in the project team's evaluation represented by commercial vehicles ranges from three to 25 percent. This percent indicates that commercial vehicles should be considered directly in urban transportation planning models, at a minimum with the Aggregate Demand Methods, but preferably with Network-based Quick Response Method or Model Estimation Methods.

Data Sources

Data sources were identified and compiled in the previous work documented in the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, November 2003). These data were expanded and further analyzed to provide data sources required for forecasting commercial vehicle travel in urban transportation planning models. Data sources were described separately for their use in forecasting individual commercial vehicles by category and are summarized below:

- Sociodemographic data that would support the estimation of production and attraction trips, generally from U.S. Census data;
- Average mileage, fleet size, and vehicle miles traveled (VMT) evaluated in the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, November 2003);
- Data on vehicle type, generally derived from vehicle registration data;

- Data on trips per vehicle and trips by time of day, generally derived from commercial vehicle survey datasets; and
- Data on vehicle occupancy, where applicable, for commercial vehicles moving people, but not for commercial vehicles moving goods or providing services.

Methods by Vehicle Category

The methods were developed separately for each of the 12 individual commercial vehicle categories. In many cases, the methods and data sources were similar, but there are differences in application based on available data and expectations for certain causal relationships with demographic variables. The Aggregate Demand and Network-based Quick Response Methods are described for each of the 12 commercial vehicle categories. The Model Estimation Method is not described separately because it follows the same procedures that the Network-based Quick Response Method follows, only is based on locally specific data sources rather than national default data sources.

The travel behavior characteristics that are described for the Aggregate Demand Method include the fleet size, the vehicle trips and the vehicle miles traveled for each commercial vehicle category. For each travel behavior characteristic, we provide a description of appropriate methods and in most cases, an estimate of the parameter for these travel behavior characteristics. These estimates are derived from available data, which is frequently limited in sample size, and not recommended to represent a national default value for the parameter estimates.

The travel behavior characteristics that are described for the Network-based Quick Response Method include the trips produced and attracted to a traffic analysis zone, the trips distributed between traffic analysis zones, the vehicle type, the time of day, the vehicle occupancy (for commercial vehicles moving people) and the characteristics of trip assignment. Again, we provide a description of the methods and an estimate of the parameter, but with limited sample sizes available to estimate these parameters.

Methods by Vehicle Group

Following the evaluation of forecasting commercial vehicle travel by vehicle category (12), the same travel behavior characteristics of the Aggregate Demand analysis and Network-based Quick Response Methods were evaluated by groups of commercial vehicles. These groups represent aggregations of the commercial vehicle categories based on the primary purpose of the commercial vehicle: to move people, to move goods or to provide services. The methods and parameters developed for these groups of commercial vehicles are intended for use by metropolitan planning organizations that do not need or want to segregate commercial vehicles into 12 categories. It also is intended to work in coordination with the commercial vehicle categories for agencies that require additional detail for some groups but not others. For example, agencies may decide that it is useful to have greater accuracy for commercial vehicles moving goods and providing services, but that this additional accuracy is not required for commercial vehicles moving people.

Calibration and Validation Data

Model calibration and validation data should be a unique source distinct from the data used in estimating model parameters. As a result, one needs to identify unique sources of data that can support model calibration and validation. For the purpose of this report, calibration and validation data are those data that can be used to compare with model predictions and determine the reasonableness of the model parameters. Model calibration and validation data also are used as a means to adjust the model parameter values so that travel predicted by the model matches observed travel in the region. This is especially important when applying nationally derived model parameters to a specific region.

There are three types of data that were identified in the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, November 2003) that are appropriate for use in calibrating and validating commercial vehicles in urban transportation planning models:

- **Vehicle Registration Data** – Every state collects data on vehicle registrations that are potentially useful in identifying the commercial vehicles by category that are registered in urban areas or statewide. These data can be used directly to estimate fleet size, but do not necessarily provide data on vehicle miles traveled or number of trips. Many states collect data on annual mileage that could be used to estimate vehicle miles traveled, but these data were not available in our sample datasets from California and New York. While registration databases are potentially a rich source of data for our purposes, most states currently do not process these data in a way that would provide the information on vehicle type that is necessary for use in urban transportation planning models. Registration data was obtained for California and New York; the California data was used to identify most vehicle types (8) in our study and the New York data was used to identify some of the vehicle types (5). Vehicle registration data also can be purchased from R.L. Polk & Co, a privately owned consumer marketing information company.
- **Vehicle Miles of Travel –** The Highway Performance Monitoring System (HPMS) estimates vehicle miles of travel by functional classification, area type and to a limited degree, vehicle class (autos, single unit and combination trucks). Traffic count information collected by local, regional and state agencies also can be used to estimate the reasonableness of vehicle miles of travel in urban transportation planning models at the end of the modeling process.
- **Vehicle Classification Counts –** The Federal Highway Administration (FHWA) identifies 13 classes of vehicles that are used by state and local transportation agencies for vehicle classification counts across the country. These classes include autos, trucks, and buses and can be used to evaluate the reasonableness of the estimates of commercial vehicles in urban transportation planning models at the end of the modeling process.

Recommendations for Future Research and Data Development

The project team identified a number of areas of future research and data development, based primarily on gaps in the data required to support the development of advanced commercial vehicle models. These data collection recommendations are designed to support the development of traditional four-step transportation planning models and state-of-the-art tour-based transportation planning models. In this way, the recommendations will support both current practice and future planning models.

The areas of future research and data development are summarized in three categories: vehicles by type, establishment surveys and forecasting. It is very difficult to definitively classify personal and commercial vehicles based on their use, rather than their registration. Personal vehicles that are used for commercial purposes and commercial vehicles that are used for personal reasons are estimated based on data from the Vehicle Inventory and Use Survey (VIUS, 2000), but it would be useful to collect specific data on these classifications. In addition, since many commercial vehicles are automobiles and buses rather than trucks, commercial vehicles should be classified by vehicle type (autos, trucks and buses) for use in urban transportation planning models. Current registration data contains this information, but is not processed for this purpose in most states.

The most significant improvement in data collection for commercial vehicles would be establishment surveys to support the estimation of the following types of vehicles: manufacturing and industrial (for urban freight vehicles); retail and services (for business and personal service vehicles); construction (for construction vehicles); government (for safety, utility, and public service vehicles); education (for school buses); transportation (for shuttle services, taxi, paratransit, and rental vehicles); and other industries (for package, product, and mail delivery vehicles).

The establishment surveys should be standardized or adapted for unique types of establishments, as much as possible to improve the usefulness for model estimation. All of the surveys should include a complete day's travel diary information for a sample of vehicles in the establishment.

The current proposed methods for forecasting commercial vehicle travel are necessarily limited by the expected forecast data that would be available to a metropolitan planning organization. These methods could be expanded to provide more accurate assessment of future commercial vehicle travel as these future data sources become available. The current proposed methods for forecasting commercial vehicle travel also are unable to estimate micro-level transportation impacts. Specific techniques to estimate micro-level transportation impacts would be more appropriate, but should be developed after the regional-level impacts are better understood.

Data needs were further identified specifically for each vehicle category. All of the recommended methods for estimating commercial vehicles in urban transportation planning models (Aggregate Demand analysis, Network-based Quick Response Method, and Model Estimation Methods) use existing model forms and are not expected to require any future research to support these efforts. Other methods, such as activity-based or tour-based models, would advance the methods proposed in this project, but are beyond the scope of this initial effort, which was primarily aimed at developing Network-based Quick Response Methods that could be adapted or transferred by metropolitan planning agencies. Tour-based models should be considered during the development of any locally specific models using the Model Estimation Methods described here and could be developed using the same data recommended here to support the Model Estimation Methods.

1.0 Introduction

1.1 Purpose

The purpose of this report is to identify methods, parameters, and data sources that can be used to estimate and forecast commercial vehicles in each of the commercial vehicle categories defined in the prior tasks of this project for urban transportation models. The three primary goals of this report are:

1. To summarize these methods, parameters, and data sources by groups of commercial vehicle categories, based on the primary purpose of the vehicle;
2. To identify the data which are available for calibration and validation; and
3. To identify future research or data collection needed to improve the methods of estimating and forecasting commercial vehicles.

The purpose of this phase of the project was not to estimate the parameters for use in urban transportation planning models, but rather to identify the variables and parameters that would be most appropriate. In many cases, the project team was able to estimate the magnitude of these parameters using the data sources developed as part of the project, but these estimates are based on limited data and not intended to be used directly in urban transportation planning models. The estimates are provided as indicators of the approximate size of the parameters and are expected to be replaced with actual parameters estimated from robust datasets in the second phase of the project.

1.2 Approach

The process of developing methods, variables, parameters, and data sources for each commercial vehicle category began with an identification of data sources that would address the following needs:

- Sociodemographic data that would support the estimation of production and attraction trips, generally from U.S. Census data;
- Average mileage, fleet size, and VMT evaluated in the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, November 2003);
- Data on vehicle type, generally derived from vehicle registration data;
- Data on trips per vehicle and trips by time of day, generally derived from commercial vehicle survey datasets; and
- Data on vehicle occupancy, where applicable, for commercial vehicles moving people, but not for commercial vehicles moving goods or providing services.

These data were then analyzed to describe the travel behavior characteristics that are appropriate for three different methods of estimating commercial vehicles:

1. **The Aggregate Demand Method**, which estimates fleet size, trips, and VMT by commercial vehicle category directly from regional estimates of demographic data (such as population and employment) using national default parameters;
2. **The Network-based Quick Response Method**, which estimates trips, origin and destinations and routes for each type of commercial vehicle using zonal estimates of demographic data and roadway networks using national default parameters; and
3. **The Model Estimation Method**, which estimates trips, origin and destinations, and routes for each type of commercial vehicle using zonal estimates of demographic data and roadway networks using parameters derived from local survey data.

After the methods, parameters, and data sources were analyzed for each commercial vehicle category, the parameters and data sources appropriate for analyzing groups of commercial vehicles based on their primary purpose were identified. There are three primary purposes, including specific commercial vehicle categories, as follows:

1. Vehicles moving people, including school buses, shuttle services, taxis (private transport), paratransit vehicles, and rental cars;
2. Vehicles moving goods, including package, product, and mail delivery vehicles; urban freight vehicles; and construction vehicles; and
3. Vehicles providing services, including safety vehicles, utility service vehicles, public service vehicles and vehicles used for business and personal services.

Finally, the individual commercial vehicle categories and the groups of categories were studied to identify these categories with the greatest overall impact on urban transportation models.

1.3 Impact on Urban Transportation Models

Many of the commercial vehicle categories defined for this project have a negligible impact on VMT; school buses, fixed shuttle services, private transportation, and paratransit vehicles each total less than one percent of VMT. It may, therefore, be reasonable to estimate these commercial vehicles using the Aggregate Demand Method or to estimate these commercial vehicles as a group (all vehicles moving people) using the Network-based Quick Response Method. If a particular study focuses on areas such as central business districts or airports that are more greatly impacted by these types of vehicles, then more robust techniques may be considered.

The commercial vehicles with the largest impact on VMT are urban freight distribution vehicles, business and personal service vehicles, rental cars, and public service vehicles. To more accurately capture the impacts of these commercial vehicles on congestion and air quality in the transportation planning models, network-based quick response or Model Estimation Methods should be used.

The commercial vehicles with some (but still not significant) impact on VMT are the package, product, and mail delivery vehicles, the construction transport vehicles, and the safety and utility vehicles. Their impact may be estimated using Aggregate Demand Methods or Network-based Quick Response Methods, depending on the characteristics of the urban area under consideration. Network-based techniques are desirable, but not necessary, for these categories, given their low overall impact on congestion.

The overall impact of commercial vehicles ranges from three to 25 percent of the total VMT for the urban areas in the project team's evaluation. This percent indicates that commercial vehicles should be considered directly in urban transportation planning models, at a minimum with the Aggregate Demand Methods, but preferably with Network-based Quick Response Method or Model Estimation Methods.

1.4 Outline of this Report

This report contains six sections. Section 2.0 presents the overview of the three forecasting methods and the recommended methods by vehicle category. Each of the methods was applied to 12 categories of commercial vehicles and the travel behavior characteristics were summarized.

Twelve categories of commercial vehicles were organized into three groups based on what is being carried – people, freight, or services – and what economic, demographic, and land use factors influence them. Section 3.0 describes these three groups of commercial vehicles and presents their travel behavior characteristics.

Section 4.0 presents the data available for calibration and validation of commercial vehicle models. These data are divided into three groups: registration records, VMT, and vehicle classification counts. Each is described in a separate subsection and its applicability for calibrating and validating commercial vehicles is discussed.

Section 5.0 presents recommendations for future research. Several of the 12 commercial vehicle categories prove difficult to estimate using the Aggregate Demand Method, Network-based Quick Response Method, and Model Estimation Method described in other sections. This section discusses the problems the project team faced, lists additional data needed in forecasting the commercial vehicle categories, and suggests how these problems can be solved. Finally, Section 6.0 presents the references for the report.

2.0 Methods for Estimating and Forecasting Commercial Vehicle Travel

2.1 Overview of Methods

The methods, variables, parameters, and data sources used for estimating commercial vehicle travel must be related to the appropriate level of planning application and the resources that are available to a metropolitan planning organization (MPO). The project team identified numerous sets of commercial vehicle forecasting approaches that could be used to evaluate different categories of vehicle types and meet MPOs' varying needs and levels of travel model complexity. These methods fall into three categories ranging from simple applications requiring limited data inputs to more advanced techniques to produce more spatial and temporal detail for a more specific range of commercial vehicle types:

1. **Aggregate Demand Methods** that apply national default parameters to regional data to produce regional estimates of fleet size, trips, and VMT for each commercial vehicle category. These methods would produce estimates of VMT from aggregate data but would not distribute these over a network or provide VMT for a specific area or roadway. These methods can be used for emissions analysis and for better aggregate validation of planning models.
2. **Network-based Quick Response Methods** that apply national default parameters to zonal and network data to produce zonal and link-based estimates of fleet size, trip origins and destinations, volumes, and VMT for each commercial vehicle category. These methods would produce estimates of VMT over a network and for specific areas and roadways. These methods also could be defined as the *application* of four-step planning models. These methods can be used to determine the effects on congestion and for better network validation of planning models.
3. **Model Estimation Methods** that apply locally derived parameters to zonal and network data to produce zonal and link-based estimates of fleet size, trip origins and destinations, volumes, and VMT for each commercial vehicle category. Although the Model Estimation Methods can include more sophisticated models based on a wider variety of data inputs because they are developed from local data, they also may be modifications of the Network-based Quick Response Methods (based on the four-step planning process) which use local data.

MPOs analyze various types of performance measures, including mobility, safety, reliability, and environmental impacts. These analyses are performed at the regional or county level, at the corridor or TAZ level, and at the intersection or link level, depending on the purpose of the analyses they carry out. To meet MPOs' varying needs, the project team divided the analyses levels into the following three groups:

1. **Macro** analyses that include county, city, or regional-level analysis. MPOs perform travel demand modeling, ozone precursor studies, and conformity analysis of LRTP and TIP.
2. **Meso** analyses that include subarea TAZ or corridor-level analysis. MPOs perform operational analysis, ITS studies, TDM studies, and TSM studies.
3. **Micro** analyses that include link or intersection-level analysis. MPOs perform site impact analysis, carbon dioxide hotspot analysis, congestion management studies, and intersection analysis.

Both the Aggregate Demand and the Network-based Quick Response Methods have been developed to address the macro analyses, with the difference being that Network-based Quick Response Methods would be more useful for commercial vehicle categories that have larger impacts on congestion or air quality. The Model Estimation Methods are primarily for the meso level of analysis because it is more useful to use local data when considering subarea- or corridor-level analyses. This report does not present a method to address the micro level of analyses, leaving this subject instead for future research.

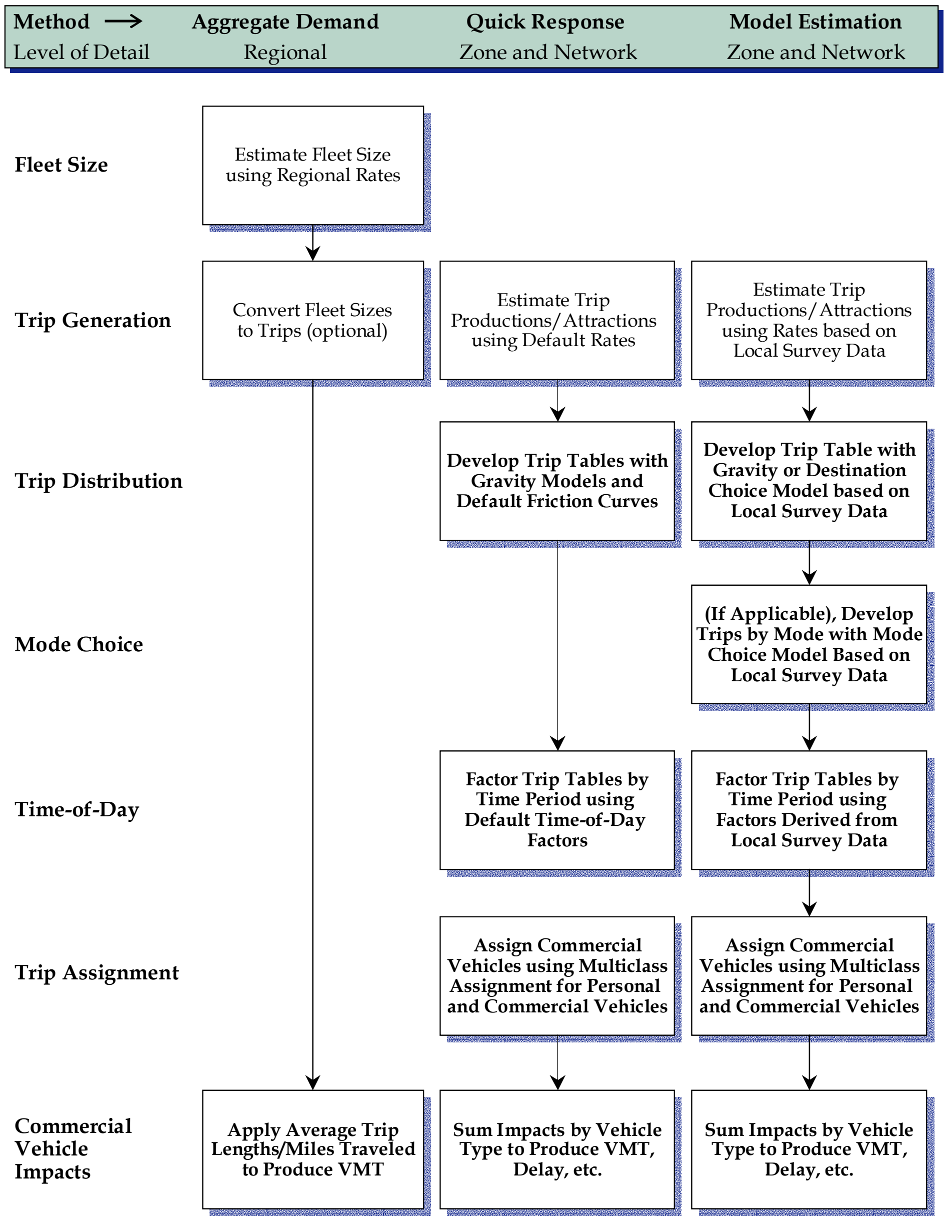
Figure 2.1 presents the modeling process for the Aggregate Demand Methods, Network-based Quick Response Methods, and Model Estimation Methods. This figure shows, in the form of a flow chart, the steps necessary to estimate impacts for commercial vehicles in urban transportation models. The Aggregate Demand Method provides a means to estimate regional impacts using nationally derived parameters and regional demographic estimates. The Network-based Quick Response Method and Model Estimation Methods are both based on applying four-step planning modeling techniques to estimate trips, origins and destinations, time periods, and volumes for commercial vehicles traveling in an urban area. These modeling processes would be applied to each category of commercial vehicle or to a group of categories. The mode choice component of the Model Estimation Method is included to represent the possibility of estimating commercial passenger vehicles for residents and visitors through the mode choice modeling process.

Aggregate Demand Methods

Daily Vehicle Mileage

At the simplest level, MPOs may be served best if the fleet size rate by land use, employment, or any other readily available data can be provided, along with the miles traveled per vehicle per day for each category of commercial vehicle. These rates and miles traveled can be used to estimate VMT. The primary advantage of this approach is that it extends the typical commercial vehicle forecasting procedures used by MPOs to a broader range of commercial vehicle and trip types. This technique is primarily applicable at a regional (macro) level of detail.

Figure 2.1 Modeling Process for Three Methods to Estimate Commercial Vehicle Travel in Urban Transportation Models



This is a simple procedure for using national average vehicle rates and miles traveled to project commercial vehicle fleet sizes in the MPO's jurisdiction. It assumes the availability of demographic projections (population, employment, tourists visiting, etc.) for the year under consideration. Using existing data, the number of vehicles for a particular category of commercial vehicle is calculated as follows:

$$FleetSize_c = VehicleRate_c \times SocioeconomicData$$

where:

- $FleetSize_c$ = Number of commercial vehicles of category **c**
- $VehicleRate_c$ = Number of commercial vehicles of category **c** per unit variable(s)
- SocioeconomicData = Data such as population/employment/tourists, set by category **c**

The number of commercial vehicles can be estimated using the above equation. The miles traveled per vehicle per day for commercial vehicle categories are available from a variety of sources, identified in the Task 3 report. Hence, it is possible to estimate the VMT for commercial vehicle categories, as follows:

$$DailyVMT_c = VMTperVehicle_c \times FleetSize_c$$

where:

- $DailyVMT_c$ = Total Daily Vehicle Miles Traveled for commercial vehicles in category **c**
- $FleetSize_c$ = Number of commercial vehicles of category **c**
- $VMTperVehicle_c$ = Average vehicle miles traveled per vehicle for commercial vehicles of category **c**. This may be calculated as the average number of trips per day * the average trip length in miles.

These procedures are documented separately for each commercial vehicle category in Section 2.2.

Annual Vehicle Mileage

Some of the sources of data on mileage for specific commercial vehicle categories report annual vehicle mileage rather than daily vehicle mileage. This method uses these data to estimate daily vehicle miles using the same equation to determine fleet size, but then estimates daily mileage as follows:

$$DailyVMT_c = (AverageAnnualMileage_c \div OperatingDays_c) \times FleetSize_c$$

where:

- $DailyVMT_c$ = Total Daily Vehicle Miles Traveled for commercial vehicles in category **c**
- $FleetSize_c$ = Number of commercial vehicles of category **c**
- $AverageAnnualMileage_c$ = Average annual vehicle miles traveled per vehicle for commercial vehicles of category **c**.
- $OperatingDays_c$ = Average number of operating days of commercial vehicles of category **c**, as presented in Table 2.1.

Table 2.1 Number of Days in a Year by Vehicle Category

Commercial Vehicle Category	Number of Days per Year	Assumption
School Bus	180	Weekdays from September to June
Fixed Shuttle Services	365	Every day
Private Transportation	365	Every day
Paratransit	365	Every day
Rental Cars	365	Every day
Package, Product and Mail Delivery	306	Weekdays and Saturdays, excluding holidays
Urban Freight Distribution, Warehouse Deliveries	306	Weekdays and Saturdays, excluding holidays
Construction Transport	260	Weekdays, excluding holidays
Safety Vehicles	365	Every day
Utility Vehicles	260	Weekdays, excluding holidays
Public Service Vehicles	260	Weekdays, excluding holidays
Business and Personal Services	306	Weekdays and Saturdays, excluding holidays

Network-based Quick Response Methods

The Network-based Quick Response Method applies a simplified four-step planning model where the parameters are derived from national data as default parameters. The method uses national average vehicle rates to develop trips produced and attracted by commercial vehicles, distributing these trips using the gravity model method, and assigning these trips to a planning model network to produce VMT. This procedure is applicable for either regional- (macro) or corridor- (meso) level detail, since the data is developed at a TAZ level and applied to a transportation planning network.

For the purposes of this simplified four-step planning model, the project team assumes that commercial vehicle travel does not include trips from outside the region. This assumption is based on the understanding that long-haul movement of commercial vehicles (i.e., tractor-trailers) carrying freight would be estimated using commodity flow forecasting methods separately from this process to estimate commercial vehicles within an urban area. So the simplified four-step planning model process does not include any external travel. If this process is applied at a corridor level, then trips from the region that pass into, out of, or through the study area must be included as external travel.

The simplified four-step planning model process can be applied by individual vehicle category or by group of commercial vehicles. The parameters, methods, and data sources for these models are described in Sections 2.2 and 3.0 by category and by group, respectively. The *Quick Response Freight Manual* (Cambridge Systematics, 1996) provides a similar approach for the development of commercial vehicle trips carrying freight, which is the second group of commercial vehicles.

Model Estimation Methods

The Model Estimation Method estimates the parameters of a trip-based or tour-based planning model from local survey data. Model Estimation Methods rely on more detailed data sources than Network-based Quick Response Methods. The surveys required are establishment surveys for specific industries, as described below:

- Manufacturing and Industrial (for urban freight vehicles) account for up to five percent of total VMT and 20 percent of all commercial vehicles;
- Retail and Services (for business and personal service vehicles) account for up to seven percent of total VMT and 28 percent of all commercial vehicles;
- Construction (for construction vehicles) account for up to one percent of total VMT and five percent of all commercial vehicles;
- Government (for safety, utility, and public service vehicles) account for up to six percent of total VMT and 23 percent of all commercial vehicles;
- Education (for school buses) account for up to one percent of total VMT and two percent of all commercial vehicles;
- Transportation (for shuttle services, taxi, paratransit, and rental vehicles) account for up to five percent of total VMT and 19 percent of all commercial vehicles; and
- Other Industries (for package, product, and mail delivery vehicles) account for up to one percent of total VMT and three percent of all commercial vehicles.

This results in commercial vehicles contributing up to a maximum of 25 percent of total VMT.

The four-step planning model components may be similar in structure to the Network-based Quick Response Methods, or they may be developed to be more sophisticated if the data supports this. These models are more resource-intensive than the Network-based Quick Response Methods, but provide greater flexibility in terms of capabilities and accuracy for a specific region. Model Estimation Methods developed for macro-level analysis can be used for meso-level (corridor) analysis, but only if the regional models already are developed.

Methods for Future Research

A number of modeling methodologies currently being researched will advance the state-of-the-art for forecasting commercial vehicles. These are described briefly below.

Tour-Based Models

Tour-based models estimate the number of "tours" that an individual commercial vehicle will make from when the vehicle leaves the garage to when it returns to the same garage. A number of individual trips typically comprise each tour.

Model estimation requires a tour-based commercial vehicle survey; these are the same type of establishment surveys recommended for use in developing the four-step models. The surveys should include public and private establishments (retail, service, manufacturing, and government). If establishments include movement of people (rental cars, taxis, etc.), then this could cover all commercial vehicles.

Tour-based models are estimated by type of establishment (such as manufacturing and construction, etc.). These establishment models predict the number and types of vehicles (light, medium, heavy), the purpose of each trip on a tour (service, goods, other, return to establishment) and the location of the stops for every trip on a tour. These methods can account for a mixture of vehicles providing service and moving goods as well as empty vehicles returning to the establishment directly. One example of this type of tour-based model was estimated for retail and service delivery vehicles in Calgary, Alberta (Hunt, et al., 2003).

Supply Chain Models

Supply chain models estimate the supply chain from distributor to warehouses to retailer to buyer. These supply chains can then be converted into the number of commercial vehicles required to support the supply of goods from the distributor to the buyer, including any intermediate storage locations. Supply chain models only represent the movement of goods and possibly services but would not be appropriate to model the movement of people in commercial vehicles. Supply chain models are typically estimated by type of supply chain (just-in-time, inventory, etc.) and product. One example of this type of supply chain model is the GoodTrip model developed for the City of Groningen, Netherlands (Boerkamps, et al., 2000).

Integrated Models

Integrated models estimate the personal and commercial vehicles from an integrated model of land use and demographics. In this definition, integrated models would include personal travel, commercial travel, and forecasting of households and businesses within a single modeling framework. These models will predict the movement of people, goods, and services by design. These integrated models can predict the demand and supply of each vehicle type – for example, the demand for school buses as a function of the number of children in each household and the supply for school buses as a function of the size and population of the school district. Integrated models also can predict the location and need for new schools as a function of the growth in households and changes in lifestyles (i.e., decisions to have children). One example of this type of integrated model is the Oregon 2nd Generation Land Use Transport Model (Oregon Department of Transportation, 2002).

2.2 Methods by Vehicle Category

While similar methods may be used for each of the 12 individual vehicle categories, their application varies based on available data and expectations for certain causal relationships with demographic variables. These models are intended to estimate commercial vehicles directly, rather than the persons or goods traveling in these vehicles. In the description of the Network-based Quick Response Method, trips and tours refer to the number of trips or tours that the commercial vehicle is required to make to transport people, goods, or services. In cases where tours are more appropriate (such as school buses and mail delivery), these would use tours instead of trips to estimate the travel behavior, then either used directly to estimate vehicle miles traveled or converted to trips for assignment.

This description of methods by vehicle category is limited to the Aggregate Demand and Network-based Quick Response Methods. The procedures for the Network-based Quick Response Methods are similar to those in the Model Estimation Methods, except that the parameters for the Model Estimation Method are developed using local survey data and statistical model estimation practices. In addition, the Model Estimation techniques could accommodate advanced methods not covered by this evaluation.

Identification of the data sources used to determine estimates of travel behavior characteristics for each method are provided in Appendix A for reference. These data sources also are discussed in greater detail in a companion report (Cambridge Systematics, November 2003).

A description of the method is provided for each travel behavior characteristic, along with an estimate of the travel behavior wherever possible. These estimates are made based on available data and sometimes represent very limited datasets. In all cases, the number of urban areas (or cities) is identified with the estimate in the tables so that the limitations on the calculation of the estimates is understood. The estimates are not intended to represent national default parameters, except in a few cases where the data includes enough sample cities to be considered statistically accurate.

In the discussion of time-of-day characteristics, the following time periods were defined to summarize data across all vehicle categories:

- The a.m. peak period: between 6:00 and 9:00 a.m.;
- The midday time period: between 9:00 a.m. and 3:00 p.m.;
- The p.m. peak period: between 3:00 and 6:00 p.m.; and
- The nighttime period: between 6:00 p.m. and 6:00 a.m.

School Buses

School buses were defined as non-personal transportation vehicles that carry elementary, middle, and high school students. School buses operate on fixed routes, predominately on local streets and the distribution is affected by the location of school age children. Some school districts do not provide school bus service, some districts provide it only for their elementary schools, and some districts provide it only for students crossing major roadways. Still other districts provide service based on a minimum distance of travel or to achieve a racial balance. While this makes estimating and forecasting school bus trips more complicated, there are several good data sources for school bus fleets. These also were discussed in the *Literature Review* report (Cambridge Systematics, January 2003) and the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, November 2003).

Aggregate Demand Method

The Aggregate Demand Method estimates school bus fleet size and VMT using regional estimates of the population under 18, the total number of elementary, middle, and high school students, and/or other national default parameters. The project team matched each school district's boundary with Census 2000 data blocks and extracted population under 18, elementary, middle, and high school students, and educational employees.

Table 2.2 summarizes the resulting travel behavior characteristics. It includes estimates of fleet size and VMT calculated from a statistical analysis of the data from SchoolBusFleet.com and the population and student data for the same area from the Census 2000 database (U.S. Census Bureau, 2004). The percent of VMT was estimated and presented in the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, November 2003).

Table 2.2 Travel Behavior Characteristics for School Buses Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of school-age students, and population under age 18.	0.004 school bus per school-going student ranging from 0.003 to 0.015 (data from 100 school districts).
Trip/Tour Length	School buses make several round trips each day to serve different schools within a district. Average mileage is calculated from annual miles traveled assuming 180 days of operation per year.	83 miles per day per bus ranging from 22 miles per day to 192 miles per day (data from 88 school districts).
Vehicle Miles Traveled	School buses represent a larger share of VMT in local and collector streets and streets around schools than on major arterials.	0.15 percent of total VMT on all roads, based on data from 100 school districts.

Network-based Quick Response Method

Data from 100 school districts on the SchoolBusFleet.com web site can be used to estimate regressions for school bus fleet size and regional VMT on a national basis. The project team collected demographic data for these cities from the Census database. Table 2.2 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method. School bus trips start from school, follow fixed routes, then return to school. In some cases, school bus trips start from school, go to a specific destination, and then return to school (field trips). As a result, it is not possible to estimate trip productions and attractions separately.

Regarding trip distribution, only 0.15 percent of total VMT on all U.S. roads are attributed to school buses, but the figure varies significantly from highways to local streets. In terms of vehicle types, most of the buses are large, although there are many small buses and buses with lifts, as shown in Table 2.3.

No data are available for time-of-day analysis. However, morning peak period is more or less the same as the commuter peak period, and most of the buses are garaged by 4:00 p.m.

Students begin and end their trip at home, but school buses begin and end their routes at school or at a garage. The accurate representation of school bus routing and district definition would require substantial data collection and network coding, but these can be approximated using school district boundaries, school locations and Census demographic data.

The project team could find no studies related to time-of-day distribution. Data might be collected for time of distribution of school buses. In terms of assignment, further data collection is needed to develop proper assignment procedures.

Table 2.3 Travel Behavior Characteristics for School Buses Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Regression models can be used with variables for residence (population under 18, school-age children, households) and/or educational employees. Most school bus trips start from school and finish at school. Some school trips start from school and go to other places (field trips).
Distribution	School buses are distributed through local streets, with origins and destinations at school. Some buses are garaged at the contractor's facility or at the driver's residence and deadhead to the start of the route.
Vehicle Type	There are three types of school buses, large, small, and small with lifts. In the 100 top school districts (Schoolbusfleet.com), there are 79 percent large buses, 16 percent small buses and five percent small buses with lifts.
Time of Day	School buses run from 7:00 a.m. to 4:00 p.m. with the a.m. peak from 7:00 to 9:00 a.m. and p.m. peak from 2:00 to 4:00 p.m.
Vehicle Occupancy	Vehicle occupancy varies from one to 50 depending on district. Average 14 students (Pearson, 1997).
Assignment	School buses generally run on fixed routes using local streets.

Shuttle Services

Shuttles are available at most airports in the United States, serving either fixed routes between hotels and airports or operating as on-demand services from various geographic locations to airports. Shuttle services also serve major intermodal terminals other than airports (such as rail stations). Shuttles serve both residents and non-residents of any urban area and fleet sizes can be a function of population size, level of tourism, and the options (or lack thereof) for alternative modes. In addition, the presence of rail transit can have a significant impact on the use of shuttle services.

There are some cities where there are direct tradeoffs with rental cars, shuttle services and taxis to serve the travel needs of the non-resident population. For example, Seattle would have higher rates for shuttle services and lower rates for taxis and rental cars than the average, but other cities like Tampa have lower rates for shuttle services and higher rates for taxis and rental cars than the average. This is apparent in the airport survey data collected (Appendix D of Cambridge Systematics, November 2003). For example, shuttle services in Seattle are 60 percent of total trips compared to Tampa where shuttle services are 30 percent of total trips while rental cars are 27 percent in Seattle and 64 percent in Tampa.

Aggregate Demand Method

The Aggregate Demand Method estimates fleet sizes and VMT using model area estimates of total population and factors developed from the *Airport Ground Access Planning Guide*. The project team tried to estimate fleet sizes and VMTs using number of tourists and hotel rooms, but these two variables are not statistically significant with the available data. The *Guide* provides enough data to estimate vehicle trips but not fleet sizes. A summary of the travel behavior characteristics is provided in Table 2.4.

Table 2.4 Travel Behavior Characteristics for Shuttle Services Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size cannot be derived with the available data.	
Trip/Tour Length	Shuttle services primarily provide transport for visitors and residents to and from airports. Round trip mileage can be short with many trips per day, or longer with fewer trips per day.	Average daily miles of travel per trip is 14.7 miles (data from 28 cities). Note that average mileage per day is not available since we do not have fleet sizes.
Vehicle Trips	Vehicle trips can be estimated as a function of population, number of tourists, and number of hotel rooms.	0.0002 trips per person (data from 28 cities).
Vehicle Miles Traveled	Shuttle services typically represent a small percentage of overall VMT but contribute to a potentially large share of VMT at airports.	0.02 percent of total VMT in an urban area. The daily average VMT is 11,518. (data from 28 cities).

Network-based Quick Response Method

Airport shuttle data derived from the *Airport Ground Access Planning Guide* can be used to estimate travel behavior characteristics for the Network-based Quick Response Method. Table 2.5 presents a summary of these characteristics.

Table 2.5 Travel Behavior Characteristics for Shuttle Services Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for demand (population and tourists).
Distribution	Shuttle trips typically originate at airports and are destined to tourist destinations, hotels and residences. These shuttle services would include fixed-route and demand-response vans (i.e., Super Shuttle) that serve both residents and visitors, as well as courtesy vans.
Vehicle Type	Vehicle types include minivans, SUVs, and minibuses.
Time of Day	Shuttle services are available during the entire period that airports remain open. There are 24.1 percent of shuttle vehicle trips for a.m. peak, 14.8 percent for p.m. peak, and 61.2 percent for midday (data from the Denver CV survey).
Vehicle Occupancy	Vehicle occupancy can be estimated from survey data to estimate person trips per vehicle. There are three to 10 persons per vehicle (data from Boston Logan Airport).
Assignment	Most shuttle service vehicles are permitted on the entire roadway system and are concentrated around airports.

From the data available, production and attraction of shuttle trips were found to be best represented by the population within an area. Contrary to expectations the number of tourists and hotel rooms was not a useful variable in estimating vehicle trips. Both production and attractions are based on a sample of 28 cities.

Trip distribution may be performed using a gravity model. An average trip length of 14.7 miles was determined using the statistics provided in the *Guide*.

Private Transport (Taxi)

Private transport is represented by taxis, which are present in most urban areas in the U.S. Taxis serve both residents and non-residents of any urban area and fleet sizes can be a function of population size, level of tourism, and the options (or lack of options) for alternative modes. Specifically, the presence of rail or significant shuttle services to airports can affect the use of taxis in the region. In addition, some cities ban "hailing" of taxis, which greatly reduces their use. Taxi service is on-demand, so can cover the entire urban area, but is typically concentrated in areas of high employment, around intermodal terminals, and at tourist attractions.

There are some cities where there are direct tradeoffs with rental cars, shuttle services and taxis to serve the travel needs of the non-resident population. For example, Minneapolis has more service for shuttles and less service for taxis and rental cars than the average, but St. Louis has more service for taxis and rental cars than the average. This is apparent in the airport survey data collected (Appendix D of Cambridge Systematics, November 2003). For example, shuttle services in Minneapolis are 40 percent of total trips compared to St. Louis where shuttle services are 26 percent of total trips while taxis are 36 percent in St. Louis and 22 percent in Minneapolis.

A few models specifically estimate taxis around the globe and a few models in the U.S. address taxis as part of the four-step modeling process. In most urban transportation planning models, the resident-based taxi trips are accounted for in the overall trip-making, but taxis are not specifically separated out in the mode choice models, except in a few cases.

Aggregate Demand Method

The Aggregate Demand Method estimates taxi trips and fleet size using regional estimates of employment and hotel rooms and nationally derived default parameters. Taxi trips are estimated for each city using the national averages for trips per taxi for different fleet size categories. These parameters can be derived by expanding the *Taxi Fact Book* to include the number of workers and hotel rooms for 270 cities. Current estimates of these parameters are based on a smaller sample of cities.

A summary of the travel behavior characteristics is provided in Table 2.6. This summary includes estimates of fleet size, trips, and VMT calculated from a statistical analysis of the data in the Taxi Fact Book, combined with demographic data. The percent of VMT was estimated and presented in the *Magnitude and Distribution of Commercial Vehicle Travel* report (Cambridge Systematics, Inc., November 2003).

Table 2.6 Travel Behavior Characteristics for Taxis Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of employment and hotel rooms. Density also may be a factor.	0.003 taxis per worker + 0.012 taxis per hotel room (data from 28 cities).
Trip/Tour Length	Taxi trips have a wide range of mileages and may not represent the complete daily mileage of the taxi due to empty taxi trips and cruising that occurs. Average mileage is calculated from annual mileage information assuming 365 days of operation per year.	149.5 average miles traveled per day, nine average miles per trip (data from 270 cities).
Vehicle Trips	National average = 16.5 trips per taxi from *Taxi Fact Book*. Varies by fleet size, 1-24 = 20.2 trips per taxi, 25-99 = 17.1, and 100+ = 16.2.	16.5 trips per taxi per day (range is 16.2 to 20.2).
Vehicle Miles Traveled	Taxis represent a potentially large share of VMT in central business districts and at airports but a small overall contribution to total VMT.	0.20 percent of total VMT in an urban area (data from 13 cities).

Network-based Quick Response Method

The 270 cities reported in the *Taxi Fact Book* can be used to estimate regressions for fleet size and regional VMT on a national basis. The project team collected demographic data for a portion of these cities for use in evaluating taxi trips. Table 2.7 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method.

Taxi trips as a function of population and hotel rooms represent trip origins. Taxi trips as a function of employment and tourist attractions represent trip destinations. These trip rates can be estimated from the 270 cities in the *Fact Book*, combined with Census Bureau data on population and employment and hotel rooms obtained from tourist bureaus in each city. Estimates of trip origins are derived from a linear regression of taxi trips as a function of population and hotel rooms, based on data from 28 cities (limited by the available data on hotel rooms). Estimates of trip destinations are derived from a linear regression of taxi trips as a function of employment, based on data from 134 cities (limited by the available data on employment).

Table 2.7 Travel Behavior Characteristics for Taxis Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for resident (population, households) and non-resident (hotel rooms). There are 0.02 daily taxi trips per person + 0.08 taxi trips per hotel room (based on data from 28 cities). Cross-classification or regression models also can be used with variables for employment by type, households, and tourists at major destinations and intermodal terminals (such as airports). There are 0.06 daily taxi trips per worker (based on data from 134 cities).
Distribution	Taxis are distributed widely throughout the region, but are most common in areas of higher employment, in the vicinity of tourist destinations, and at airports/rail/bus stations.
Vehicle Type	Most taxis are passenger autos, with some passenger vans.
Time of Day	Taxis operate at all times of day, especially during daytime hours (both peak and off-peak). Peak time for taxis is 7:00 a.m. to 1:00 p.m., with 50 percent of trips in this time period (data from 260 taxi trips).
Vehicle Occupancy	In this application, taxi trips are vehicle trips and do not require conversion for use in trip assignment. There are 1.3 passengers per trip (based on 270 cities).
Assignment	Taxis drive on all routes, particularly major arterials and freeways.

Taxi trips can be distributed using a gravity model with friction curves estimated from travel survey data on taxis. Taxi trips from the travel survey data are plotted to represent the trip length frequency of all taxi trips. The friction curve is then estimated to produce a similar trip length frequency for estimated taxi trips. The taxi trips in the *National Highway Travel Survey* and Florida surveys are a source for this estimation process, but the sample size may require expansion with other surveys for reliable statistical estimation. Estimates of average mileage and miles traveled are from the *Taxi Fact Book* (Taxicab, Limousine and Paratransit Association, 2002).

One source of data on time of day is the *National Highway Travel Survey*, with 260 taxi trips in the U.S. This source includes only resident taxi trips and should be supplemented with data from non-resident taxi trips to ensure a more representative sample. Vehicle occupancy is derived from the *Taxi Fact Book* and represents 270 cities.

Another means of estimating taxi trips for residents and non-residents would be to incorporate taxis as a modal option in existing mode choice models. This process assumes that the trip generation model includes taxi trips (most existing urban area models do so) and that there is a separate trip generation model for visitor (non-resident) trips. These trips are distributed by trip purpose along with other resident and non-resident trips. The mode choice models for resident and non-resident trips include taxi as a separate modal option. As is the case with mode choice models for transit, a large enough sample of taxi trips in the household survey is needed to adequately separate out these trips in the mode choice model. This has been done in the Houston-Galveston, Cleveland, Las Vegas, and New York mode choice models. In the Las Vegas model, there is a separate resident and non-resident (visitor) modeling process, so taxis are represented as a mode in the mode choice model for each of these models. The primary drawback of this approach is that it only predicts taxi trips when a passenger is in the taxi, which will not represent the empty taxi trips.

Paratransit and Social Service Vehicles

Paratransit and social service vehicles serve primarily disabled and senior populations. Since the mid-1980s, the number of paratransit and social service systems across the United States has increased significantly (Bearse, P., et al., 2003). In 198 cities with fewer than 400,000 inhabitants, paratransit trips increased from 6.0 million in 1984 to 16.9 million in 1995 (J. Fitzgerald et al., 2000). Unfortunately, very little research has been done concerning paratransit and no models have been developed to estimate the demand for these trips.

Aggregate Demand Method

The Aggregate Demand Method estimates paratransit fleet size, total trips and vehicle miles using the regional estimates of total population over the age of 60 and total employment. These parameters were derived using data from 220 cities. A summary of the travel behavior characteristics is provided in Table 2.8.

Table 2.8 Travel Behavior Characteristics for Paratransit Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of population greater than 60 years of age.	0.008 paratransit vehicle per population over 60 (data from 220 cities).
Trip/Tour Length	Paratransit vehicles are demand responsive so the average miles are dependent upon demand. The average mileage is calculated from the annual miles assuming 365 days of operation per year.	24 average miles (range one to 58 miles) traveled per day, five average miles per vehicle trip (data from 316 cities).
Vehicle Trips	National average of trips per paratransit vehicle is provided in the National Transit Database.	5.1 daily trips per paratransit vehicle with a range from one to 27 (data from 220 cities).
Vehicle Miles Traveled	Paratransit and social service vehicles' share of VMT is negligible.	0.01 percent of total VMT in an urban area (data from 220 cities).

Network-based Quick Response Method

The team used NTD data for 220 cities and estimated the regression coefficients for trips. Because the NTD data do not include population and employment data, paratransit data was matched with Census Bureau data to obtain total population, population over the age of 60, and employment data. Table 2.9 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method.

Table 2.9 Travel Behavior Characteristics for Paratransit Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for residence (population over the age of 60, total population, households). There are 0.006 daily paratransit trips per person over the age of 60 (data from 220 cities) Cross-classification or regression models also can be used with variables for employment by type. There are 0.0002 daily paratransit trips per employee (data from 220 cities).
Distribution	Paratransit vehicles are distributed throughout the region, but are concentrated in areas with a higher percentage of elderly and fewer transit services. Paratransit trips can be distributed with a gravity model.
Vehicle Type	Most vehicles are vans or van conversions, but some larger buses are also in paratransit service.
Time of Day	Paratransit vehicles operate seven days a week without any specific peak periods.
Vehicle Occupancy	Vehicle occupancy for paratransit vehicles depends on the type of services. Demand responsive services may have one passenger, while fixed-route services may have many.

Rental Cars

Rental cars form one of the most important categories of commercial vehicles in urban areas. About two percent of the total VMT on U.S. roadways is from rental cars (Cambridge Systematics, November 2003). However, very limited data are available on this category. While some aggregated statistics are available from different sources, the project team found no specific studies related to rental car demand analysis, fleet size, or VMT. Almost without exception, rental car companies do not release data on their fleet size and mileage. Only Hertz Rent-A-Car provided this information for 13 cities in response to the project team's request, but on the condition the data not be published directly. Based on Hertz's data and other available data, the total U.S. rental car fleet size, average mileage per vehicle, and other statistics for selected cities were estimated.

There are some cities where there are direct tradeoffs with rental cars, shuttle services and taxis to serve the travel needs of the non-resident population. For example, New York City would have lower rates for rental cars and higher rates for taxis than the average because of the limitations for driving and parking that are inherent on New York City streets, but other cities with lower densities and inexpensive parking (such as Florida cities) will likely have higher rates for rental cars and lower rates for taxis than the average. This is apparent in the airport survey data collected (Appendix D of Cambridge Systematics, November 2003). For example, rental cars in Orlando are 46 percent of total trips compared to New York (JFK) where rental cars are three percent of total trips while taxis and on-demand services are six percent in Orlando and 45 percent in New York (JFK).

Similar to the taxis, rental cars operated by residents are captured by household-based models in the trip generation model, but not typically separated out as rental car trips in the mode choice model. Since rental cars for residents probably have similar distributions as vehicles owned by the household, it is reasonable to incorporate these into urban transportation planning models this way, except that it will be important not to double-count resident-based rental car trips when including rental cars as commercial vehicles. These can be excluded from the household-based planning model estimates (which is very straight-forward) or excluded from the rental car data (which is done by surveying only non-residents).

Aggregate Demand Method

The Aggregate Demand Method can be used to estimate the rental car fleet size, the number of trips, and VMT using the regional estimates of population, employment, and the number of hotel rooms. A summary of the travel behavior characteristics is provided in Table 2.10.

Table 2.10 Travel Behavior Characteristics for Rental Cars Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of population, employment, and hotel rooms in an urban area. Number of tourists also may be a factor.	0.7 rental cars per hotel room (based on data from 13 cities).
Trip/Tour Length	Rental car companies reported an average of 80 miles per day per vehicle, compared to 43 miles per day from VIUS, based on annual mileage reported.	Average mileage per rental car per day ranges from 43 to 80 miles (from the Vehicle Inventory and Use Survey and sample rental car companies).
Vehicle Trips	This requires rental car or visitor survey data to estimate number of trips.	2.2 daily trips per rental car (Orlando Trip Log Data).
Vehicle Miles Traveled	Rental cars represent a large share of VMT in urban areas and at airports.	Two percent of total VMT ranging from 0.8 percent to 4.3 percent (data from 13 cities).

Network-based Quick Response Method

Rental car trips can be divided into three groups: business-related, social-recreational, and other, with other trips being a very small proportion of the total (less than 10 percent in the Florida surveys). Most business trips start at the airport and go to business districts or employment centers. Business-related rental car trips can be estimated from airport surveys. Recreational rental car trips usually start from airports or car rental sites and go to tourist or recreational areas. All rental car trips also can be estimated from rental car surveys.

Data for 13 cities were used in conjunction with population, employment, and hotel room data from the U.S. Census Bureau to estimate rental car fleets. Table 2.11 shows the recommended methods for estimating rental car data using the Network-based Quick Response Method and the estimated parameters.

Table 2.11 Travel Behavior Characteristics for Rental Car Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for residents (population, households) and non-residents (hotel rooms). There are 0.005 daily trips per person + 0.8 daily trips per "population/square miles" (data from 13 cities).
Distribution	Rental cars are distributed throughout the region, but are concentrated in areas of tourist destinations, airports, and central business districts.
Vehicle Type	Most vehicles are passenger autos, but many medium and heavy vehicles are also in this category. Cars are 76 percent, pickups are four percent, SUVs are nine percent, vans are eight percent, medium and heavy vehicles are three percent (from the California DMV data).
Time of Day	Rental cars operate seven days a week. There is six percent in the a.m. peak, 39 percent at midday, 11 percent in the p.m. peak, and 44 percent at night (from Florida District 5 survey trip log data).
Vehicle Occupancy	Vehicle occupancy depends on the purpose of trips. Vehicle occupancy for recreational trips is higher than for business trips. There are 3.4 person per vehicle (Florida District 5 trip log data).
Assignment	Rental cars drive on all routes.

Package, Product, and Mail Delivery Vehicles

Package, product, and mail delivery vehicles can be classified as either public or private. The United States Postal Service (USPS) represents the public section of this category, while there are numerous private carriers.

Package, product, and mail delivery represents approximately one percent of total VMT for an urban area (Cambridge Systematics, November 2003). Mail is typically delivered during daytime hours in smaller vehicles (SUV-sized to large vans and parcel trucks), while bulk distribution of mail is performed by heavier vehicles (tractor-trailers and combination trucks) during nighttime hours.

Aggregate Demand Method

The Aggregate Demand Method estimates package, product, and mail delivery trips using model area estimates of total population, households, and employment factors developed from USPS data and the four commercial vehicle surveys.

A summary of the travel behavior characteristics is provided in Table 2.12.

Table 2.12 Travel Behavior Characteristics for Package, Product, and Mail Delivery Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates[1]
Fleet Size	Fleet size can be estimated as a function of population, households, and employment. The presence of a major private or public distribution center will greatly impact the fleet size for the urban area.	Fleet size = 0.005 per number of area employees (62 percent private and 38 percent public).
Trip/Tour Length	There is a wide range of miles traveled per day from different sources reflecting the broader geographic coverage from private sources.	Average ranging from 19 miles per day (public) to 163 miles per day (private).
Vehicle Trips	Average number of trips estimated from commercial vehicle survey data from Detroit, Atlanta, Denver, and the Piedmont Area in North Carolina.	Average daily number of trips per vehicle is 4.0, with a range of 2.1 to 7.5 daily trips per vehicle (data from four cities).
Vehicle Miles Traveled	Package, product and mail delivery typically represents a small percentage of overall VMT. Private VMT is approximately twice as large as public VMT.	Daily VMT = 0.2 per number of employees (70 percent private and 30 percent public.

[1] Estimates are based on USPS data for seven cities (public) and commercial vehicle survey data from four cities (private).

Network-based Quick Response Method

Delivery trip data derived from multiple commercial vehicle surveys can be used to estimate travel behavior characteristics for the Network-based Quick Response Method. Table 2.13 presents a summary of these characteristics.

Table 2.13 Travel Behavior Characteristics for Package, Product, and Mail Delivery Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for area residents (population). There are 0.01 daily trips per employee (private). Cross-classification or regression models also can be used with variables for area workers. There are 0.02 trips per household (private).
Distribution	Delivery trips are distributed throughout the entire study area, but may be more concentrated in areas of high employment, where there are higher incidences of private delivery vehicles. Delivery trips are expected to be tours rather than individual trips, measured by the number of delivery locations.
Vehicle Type	Vehicle types may range from passenger autos to combination tractor-trailers. Public vehicle types are 95 percent light-duty, three percent medium-duty, and two percent heavy-duty (data from USPS).
Time of Day	Package, product, and mail delivery is performed mostly during the day by smaller delivery vehicles. These lighter vehicles are more numerous than the heavier vehicles that carry the mail to/from distribution centers, often at night. Seventy-two percent of all trips occur between 9:00 a.m. and 3:00 p.m. (data from three commercial vehicle surveys).
Assignment	Most delivery vehicles are permitted on the entire roadway system, with the exception of some heavy vehicles that may be excluded from certain roads.

From the data available, estimation of delivery trips was found to be best represented by the number of households within an area. Although population and household are highly correlated, contrary to expectations, population was not a useful variable in estimating vehicle trips. This may be due in part to high populations in apartment buildings or other housing clusters that have multiple delivery boxes located in one place, requiring only one trip to satisfy a larger number of people. Estimates of delivery trips also can be based on the number of employees for the cities with commercial vehicle survey data. Because these estimates are based on a sample of only four cities, more data is required to develop better estimates.

Delivery trips begin and end at distribution centers and travel either on fixed routes or on-demand route systems. An average mileage of 16 miles was determined from the commercial vehicle survey data (for private delivery vehicles).

Urban Freight Distribution and Warehouse Delivery Vehicles

In urban areas, vehicles deliver goods to warehouses and distribution centers, and transport these goods from the warehouses and distribution centers to their final (or next) destination. Passenger, light-duty, and heavy-duty vehicles are all used to perform these operations, depending on the goods being transported.

Aggregate Demand Method

The Aggregate Demand Method estimates urban freight trips and fleet sizes using regional population estimates combined with derived default parameters. The *Quick Response Freight Manual* contains two types of Aggregate Demand Methods, the first based on historical trends and the second based on forecasts of economic activity. The historical trends Aggregate Demand Method uses two years of historical data to create an annual growth factor. The economic activity method assumes that the demand for transport of a specific commodity is directly proportional to an economic indicator variable that measures the demand for the commodity. With this assumption growth factors for economic indicator variables can be developed. The economic activity method requires base- and forecast-year data for the economic indicators and base traffic by commodity.

Outside of the *Quick Response Freight Manual*, commercial vehicle survey data can be used for estimates using the Aggregate Demand Method. Table 2.14 outlines some basic travel behavior characteristics of Urban Freight based on the available commercial vehicle surveys.

Table 2.14 Travel Behavior Characteristics Based on Commercial Vehicle Surveys for Urban Freight Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates[1]
Fleet Size	Fleet size can be estimated based on population. Total employment does not appear to be as significant as population.	0.02 vehicles per person based on commercial vehicle surveys.
Trips/Tours	Average mileages are typically longer than other commercial vehicles (except taxis), based on annual VIUS data assuming 306 days of operation per year.	Average 12.7 miles per trip; 65 miles per day per vehicle.
Vehicle Trips	Average daily number of trips estimated from commercial vehicle survey data from Detroit, Atlanta, Denver, and Piedmont Area in North Carolina.	Average daily number of trips per vehicle is 5.1 from four surveys with a range of 3.2-6.6 trips per vehicle.
Vehicle Miles Traveled	Urban freight represents a larger percentage of overall VMT than most other types of commercial vehicles.	4.4 percent of total VMT based on commercial vehicle surveys.

[1] Estimates are based on commercial vehicle survey data from four cities.

Network-based Quick Response Method

The *Quick Response Freight Manual* (Cambridge Systematics, 1996) outlines procedures for calculating trip generation and trip distribution. Trip generation rates provided by the *Manual* are shown in Table 2.15. These are intended to capture all commercial vehicles carrying goods and providing services, so they are higher than rates that are calculated only for urban freight vehicles. Nonetheless, they may be scaled to provide comparisons for the urban freight category of commercial vehicles. Updated trip generation rates (NCHRP Synthesis 298, 2002) also can be used to assess truck trip generation of urban freight vehicles.

The *Manual* uses a traditional gravity model to distribute the total origins and destinations estimated from the trip generation process. Friction factors are estimated using exponential factors with -0.08 for four-tire, -0.1 for single-unit trucks, and -0.03 for combination trucks.

Table 2.15 *Quick Response Freight Manual* Trip Generation Rates

Generator	Trip Rates
Agriculture, Mining, and Construction	1.573 trips per worker
Manufacturing, Transportation, Communications, Utilities, and Wholesale Trade	1.284 trips per worker
Retail Trade	1.206 trips per worker
Office and Services	0.514 trips per worker
Households	0.388 trips per household

Source: *Quick Response Freight Manual.*

Urban freight trip data derived from multiple commercial vehicle surveys can be used to estimate travel behavior characteristics for the Network-based Quick Response Method. Table 2.16 presents a summary of these characteristics.

Table 2.16 Travel Behavior Characteristics Based on Commercial Vehicle Surveys for Urban Freight Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for area workers with 0.17 daily trips per worker. Cross-classification or regression models also can be used with variables for area residents (population and households) with 0.10 daily trips per person.
Trip Distribution	Urban freight vehicles are distributed throughout the system with higher concentrations in areas of high total employment and industrial employment.
Vehicle Type	The majority of urban freight is carried by light-duty vehicles, but will vary depending on the commodity being transported. See Table 2.17 for details.
Time of Day	Urban freight trips mostly occur during business hours. There is seven percent in the a.m. peak, 60 percent in the midday, 23 percent in the p.m. peak and 10 percent at night (data from three commercial vehicle surveys).
Trip Assignment	Some urban freight vehicles may be restricted from certain parts of the road network.

From the survey data available, urban freight trips was found to be best represented by the population or employment within an area. Because these trips were based on a sample of only four cities, more data is required to develop better estimates.

Trip distribution may be performed using a gravity model. An average trip length of 12.7 miles per trip was determined from the commercial vehicle surveys.

As illustrated in Table 2.17, light duty vehicles make up the majority of trips made by urban freight vehicles. Heavy duty vehicles make up the second largest number of trips.

Table 2.17 Percent of Urban Freight Vehicle Types Based on Trips from Commercial Vehicle Surveys

Vehicle Type	Atlanta	Denver	Detroit	Triad	Weighted Average
Heavy	18.56%	31.02%	17.21%	41.42%	25.16%
Medium	2.58%	8.89%	24.18%	27.00%	8.01%
Light	78.86%	60.09%	58.60%	31.58%	66.82%

Construction Transport Vehicles

Construction transport vehicles are used primarily for hauling materials and equipment to a construction site. These vehicles are usually heavy trucks; the numbers of these trips can vary depending on the duration, scale, and type of construction project with which they are associated.

The construction transport commercial vehicle category is the most site-specific of all of the categories identified. The origin end of these trips is relatively fixed. Producers of construction materials and equipment tend to have set locations and varying productions of trips. The demand for these trips varies both in terms of location and need, depending upon the construction project.

Aggregate Demand Method

The Aggregate Demand Method estimates construction transport trips and fleet sizes using regional estimates of population, combined with derived default parameters. The magnitude of these trips will vary from city to city, depending on differences in local growth rates. The distribution of the construction transport activity within the region also will vary. Ideally, two sets of factors should be developed for these trips, one for activity during the construction season and one for activity outside of the construction season. It may even be useful to consider regional differences in construction activity relative to weather conditions (such as cold weather climates). Table 2.18 describes the travel behavior of this category of vehicle.

Table 2.18 Travel Behavior Characteristics for Construction Transport Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Average number of vehicles estimated from commercial vehicle survey data from Detroit, Atlanta, Denver, and Piedmont Area in North Carolina.	Fleet size = 0.009 per number of area employees (data from four cities).
Trip/Tour Length	Average mileage for construction trips is based on commercial vehicle survey data collected for an average day. Range is 31 to 58 miles per vehicle per day, with smaller cities quoting less mileage on average.	Average 43 daily miles per vehicle per day and 12.6 miles per trip (data from 13 cities).
Vehicle Trips	Average number of trips estimated from commercial vehicle survey data from Detroit, Atlanta, Denver, and Piedmont Area in North Carolina.	Daily average number of trips per vehicle is 4.1, with a range of 1.8–4.8 daily trips per vehicle (data from four cities).
Vehicle Miles Traveled	VMT is under two percent of overall VMT. This number will increase around construction sites.	Average percent VMT is 0.6 percent, with a high of 1.4 percent and a low of 0.02 percent (data from 13 cities).

Network-based Quick Response Method

The Network-based Quick Response Method uses national or other available default values for estimating the effects of construction transport vehicles within urban areas. Most of the default values shown in Table 2.19 are derived from commercial vehicle surveys for Atlanta, Denver, Detroit, and the Triad cities (Greensboro, High Point, and Winston-Salem, North Carolina).

Table 2.19 Travel Behavior Characteristics for Construction Transport Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for area residents (population and households). There are 0.04 daily trips per worker (data from four cities). Cross-classification or regression models also can be used with variables for area workers. There are 0.02 daily trips per person (data from four cities).
Distribution	Distribution of construction trips will vary depending on the types of construction activities and are concentrated around areas of new growth.
Vehicle Type	Light-duty trucks make up the majority of vehicle types. See Table 2.20 for details
Time of Day	The highest percentage of construction trips occurs between 9:00 a.m. and 3:00 p.m. There are eight percent in the a.m. peak, 21 percent in the p.m. peak, 61 percent in the midday and 10 percent at night (data from four cities).
Assignment	Heavy construction vehicles will tend to stay on higher functionally classified roadways until they approach their trip ends.

The rate of change of population or employment may prove to be a stronger indicator of construction activity than the actual number of population or employment, since construction only occurs when population changes.

As illustrated in Table 2.20, light-duty vehicles make the majority of trips from the construction transport commercial vehicle group. Heavy-duty vehicles make up the second largest number of trips. Light-duty vehicles make the most trips, possibly because they not only transport construction materials and equipment, but also account for business and personal service trips made from the construction site.

Table 2.20 Percent Construction Transport Vehicle Types Based on Trips from Commercial Vehicle Surveys

Vehicle Type	Atlanta	Denver	Detroit	Triad	Weighted Average
Heavy	33.21%	34.38%	24.49%	88.89%	35.56%
Medium	0.80%	28.46%	36.55%	7.41%	14.49%
Light	65.99%	37.16%	38.96%	3.70%	49.95%

Safety Vehicles

Safety vehicles include both publicly and privately operated vehicles, such as police cars, fire trucks, ambulances, tow trucks, tow truck wreckers, snow plows, and sanders.

Aggregate Demand Method

The Aggregate Demand Method estimates fleet size for safety vehicles based on a number of demographic factors:

- Government employment;
- Jobs per person (employment to population ratio); and
- Percent of government employment (from total employment).

A summary of the travel behavior characteristics is provided in Table 2.21. This summary includes estimates of fleet size, trips, and VMT, calculated from a statistical analysis of the data available combined with demographic data. The estimate of trips per vehicle was derived from the Detroit commercial vehicle survey. The percent of VMT was estimated and presented in the *Magnitude and Distribution of Commercial Vehicle Travel* report.

Table 2.21 Travel Behavior Characteristics for Safety Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of government employment, total employment, and population.	0.0006 per total population + 80 per the percent of government employment (data from five cities).
Trip/Tour Length	There is a wide range of mileages for this category due to differences in vehicle use. Mileages are estimated from VIUS data, assuming 365 days of operation per year, from Detroit survey data on tow trucks and snow plows and from samples of police departments.	The average mileage in this category varies from 22-31 miles per day for police cars to 47-100 miles per day for tow trucks or nine miles traveled per tow truck trip on average.
Vehicle Trips	Trips per vehicle can be derived from commercial vehicle surveys, including public and private safety vehicles.	5.4 daily trips per vehicle (based on Detroit data for private vehicles).
Vehicle Miles Traveled	Safety vehicles represent a small share of total VMT and a small share of service-related commercial vehicle VMT (7 percent).	0.4 percent of total VMT (based on data from five cities).

Network-based Quick Response Method

Only five cities in the project team's collection of data on commercial vehicles include safety vehicles, and only one city includes vehicle trips and mileages. Further data is needed to more accurately evaluate travel behavior for safety vehicles. Table 2.22 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method, based on data from the Detroit commercial vehicle survey.

Safety trips can be estimated as a function of government employment and some combination of other types of employment. The Detroit commercial survey has tow trucks and snow plows in a wide variety of industries, probably because many of these are privately owned and operated. This survey does not include government vehicles, so it cannot be used to estimate trips by public safety vehicles. Estimates of trips could likely be based on population and some estimate of crash statistics, which could be constructed from the network as a level of service variable. Additional data are required to develop these quick response parameters.

Table 2.22 Travel Behavior Characteristics for Safety Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description of Methods
Trips/Tours	Cross-classification or regression models can be used with variables for acreage and employment. Government employment is the most likely variable, but this was not available for testing in Detroit. Accident statistics also may be a significant variable, but may not be available.
Distribution	Safety vehicles are distributed widely throughout the region and could be distributed with a gravity model. Vehicles that are cruising will have different distribution characteristics than vehicles that are dispatched on demand.
Vehicle Type	Most safety vehicles are passenger autos (49 percent). The remainder are primarily fire trucks (27 percent) and tow trucks (21 percent) with a small percentage of ambulances (three percent). These are derived from vehicle registration for four cities. There are 49 percent light-duty vehicles, 51 percent medium-/heavy-duty.
Time of Day	Safety vehicles operate at all times of day, but with greater frequency during peak periods. There are 63 percent of trips in peak hours, 26 percent of trips in midday, and 11 percent at night (based on Detroit survey).
Assignment	Safety vehicles drive on all routes and the distribution of traffic by facility type is expected to be similar to the distribution for the full population.

Safety vehicle trips can be distributed using a gravity model with friction curves estimated from commercial vehicle surveys of safety vehicles. Safety vehicle trips from the commercial vehicle survey data are plotted to represent the trip length frequency of all safety trips and then the friction curve is estimated to produce a similar trip length frequency for estimated safety trips. The safety vehicles in the Detroit survey are one source for this estimation process, but additional surveys are needed for reliable statistical estimation. Estimates of average mileage are derived from a combination of the Vehicle Inventory and Use Survey (VIUS) data and the Detroit survey to produce a national average. (VIUS provides data on the physical and operational characteristics of the nation's truck population.)

There are two types of trip patterns for safety vehicles: cruising (police patrols and highway tow trucks) and emergency response (fire and ambulance trucks). Cruising vehicles are either uniformly distributed within an area or along specific routes (such as highways). Emergency response vehicles make trips on demand to specific locations, which are randomly distributed within the service area. The tow trucks are more likely to be active during peak hours (both for cruising and emergency response) because of the higher likelihood of accidents from higher volumes, leading to an overall increase in safety vehicles traveling during peak periods.

The Detroit commercial vehicle survey provides time-of-day data for 132 safety vehicle trips. The survey includes only private sector safety vehicles and should be supplemented with data from government sources to ensure a more representative sample.

Utility Vehicles

Utility vehicles include publicly and privately operated vehicles such as garbage trucks, public utility trucks, hazardous waste trucks, water/irrigation trucks, and vehicles used for maintenance, electrical, and plumbing services. The private sector vehicles used for maintenance, electrical and plumbing services have been included in this category rather than business and personal services because of the similarity in trip-making characteristics to the public utility vehicles. They are classified based on the industry or land use (utilities) being served or on the cargo (electrical) being carried or on the purpose (fuel/service vehicle).

Aggregate Demand Method

The Aggregate Demand Method estimates fleet size for safety vehicles based on a number of demographic factors:

- Government employment;
- Population; and
- Dummy variables for cities without public vehicles included in their commercial vehicle survey data (such as Detroit and Atlanta).

A summary of the travel behavior characteristics is provided in Table 2.23. This summary includes estimates of fleet size, trips, and VMT, calculated from a statistical analysis of the data available combined with demographic data. The estimate of daily trips per vehicle was derived from the commercial vehicle surveys, which did not include public utility vehicles. The percent of VMT was estimated and presented in the Task 3 report, *Magnitude and Distribution of Commercial Vehicle Travel.*

Table 2.23 Travel Behavior Characteristics for Utility Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of population.	0.001 per population (data from six cities).
Trip/Tour Length	National average miles traveled are derived from VIUS data, based on 260 days of operation per year. Local average mileage is derived from commercial vehicle survey data for three cities and is much lower than the VIUS estimate, probably because it only includes private utility vehicles.	60 daily miles traveled on average per vehicle from VIUS, 22 daily miles traveled per vehicle from CV surveys (average 6.4 miles per trip).
Vehicle Trips	Daily trips per vehicle can be derived from commercial vehicle surveys, including public and private utility vehicles.	3.5 daily trips per vehicle (data from three cities).
Vehicle Miles Traveled	Utility vehicles represent a small share of total VMT and a small share of service-related commercial vehicles (6 percent).	0.3 percent of total VMT (data from six cities).

Network-based Quick Response Method

Only six cities in the project team's collection of data on commercial vehicles include utility vehicles, and only three cities include data on vehicle trips and mileages. These three, in turn, only represent private utility vehicles. Further data are needed to more accurately evaluate travel behavior for utility vehicles. Table 2.24 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method, based on data from the Detroit commercial vehicle survey.

Table 2.24 Travel Behavior Characteristics for Utility Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with variables for population, acreage and employment. Government employment is the most likely variable, but this was not available for testing in Detroit.
Distribution	Utility vehicles are distributed widely throughout the region and could be distributed with a gravity model. There are likely higher concentrations of utility vehicles in areas of high employment.
Vehicle Type	Most utility vehicles are trucks (43 percent), with the remainder passenger autos (30 percent) and garbage trucks (27 percent) (data from four cities).
Time of Day	Utility vehicles operate at all times of day, but more frequently during the normal working hours. There are 55 percent in the p.m. peak, 41 percent in the midday, four percent at night (data from three cities).
Assignment	Utility vehicles operate on all facilities.

Public Service Vehicles

Public service vehicles include publicly operated vehicles such as city, county, state, and Federal government vehicles, as well as vehicles used to serve schools and colleges.

Aggregate Demand Method

The Aggregate Demand Method estimates fleet size for public service vehicles based on two demographic factors: government employment and population.

A summary of the travel behavior characteristics is provided in Table 2.25. This summary includes estimates of fleet size, trips, and VMT, calculated from a statistical analysis of the data available combined with demographic data. A source of data for trips per vehicle is unavailable because none of the commercial vehicle surveys include government vehicles. The percent of VMT was estimated and presented in the *Magnitude and Distribution of Commercial Vehicle Travel* report.

Table 2.25 Travel Behavior Characteristics for Public Service Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of population.	0.005 per population (data from four cities).
Trip/Tour Length	Public service vehicles have low rates of mileage on average because they are not always in use every day, but on demand by government and education employees. National average miles traveled are derived from VIUS data, based on 260 operating days per year.	29 average miles per day (data from four cities in California).
Vehicle Trips	Daily trips per vehicle can be derived from a government vehicle survey.	
Vehicle Miles Traveled	Public service vehicles represent a larger share of total VMT in capital cities (3.6 percent) than in other cities (0.6 to 1.2 percent).	1.6 percent of total VMT (data from four cities).

Network-based Quick Response Method

Only four cities in the project team's collection of data on commercial vehicles include public service vehicles, and none include data on vehicle trips and mileages. One of the four cities is a capital city, which has very different travel characteristics for public service vehicles than a non-capital city. Further data is necessary to more accurately evaluate travel behavior for public service vehicles. Table 2.26 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method, based on data from the Detroit commercial vehicle survey.

Table 2.26 Travel Behavior Characteristics for Public Service Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description of Methods
Trips/Tours	Cross-classification or regression models can be used with total and government employment. There are 0.06 per government employment or 0.01 per total employment (data from three cities).
Distribution	Public service vehicles are distributed widely throughout the region but are more concentrated in areas of government and education employment.
Vehicle Type	All public service vehicles are light-duty vehicles, based on the definition of vehicles in this category from the registration records.
Time of Day	Public service vehicles operate primarily during weekday business hours and probably have a relatively uniform distribution during these hours. The project team found no data on time of day for public service vehicles.
Assignment	Public service vehicles operate on all facilities.

Business and Personal Service Vehicles

Business and personal service vehicles include those used by realtors, door-to-door salespersons, and others who do not have a fixed business address. Business and personal service vehicles are seldom included in travel demand models due to the inherent difficulty in separating out business-related trips from other trips in traditional household surveys. The number of business and personal service vehicles will be a function of the level of employment in out-of-office services, the population of the urban area, and land use.

Aggregate Demand Method

The Aggregate Demand Method estimates business and personal service trips and fleet sizes using regional estimates of population combined with derived default parameters, as shown in Table 2.27.

Table 2.27 Travel Behavior Characteristics for Business and Personal Services Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated from population. Total employment does not appear to be as significant as population.	0.02 vehicles per person (data from eight cities).
Trip/Tour Length	These average mileage and range are derived from three commercial vehicle surveys and the national average from the VIUS.	Average mileage is 46 miles per vehicle per day (or 15 miles per trip) and ranges from 27 to 78 miles per day (data from three cities and national average from the VIUS).
Vehicle Trips	Average number of daily trips estimated using commercial vehicle survey data from Detroit, Atlanta, and Denver.	Daily average number of trips per vehicle is 3.0 with a range of 1.8–5.1 daily trips per vehicle (data from three cities).
Vehicle Miles Traveled	Business and personal services is the largest percentage of overall commercial VMT.	3.6 percent of total VMT (data from seven cities).

Network-based Quick Response Method

Business and personal trip data derived from multiple commercial vehicle surveys can be used to estimate travel behavior characteristics for the Network-based Quick Response Method. Table 2.28 presents a summary of these characteristics.

From the survey data available, production of business and personal trips was best represented by the employment within an area. Estimates of trip attractions are based on the population within an area. Because both productions and attractions are based on a sample of only three cities, more data is required to develop better estimates.

Trip distribution may be performed using a gravity model. An average trip length of 15.3 miles was determined using the VIUS data and 12.7 miles was determined using the commercial vehicle surveys.

Table 2.28 Travel Behavior Characteristics for Business and Personal Services Using the Network-based Quick Response Method

Travel Behavior Category	Description of Methods
Trips/Tours	Cross-classification or regression models can be used with population and employment variables. There are 0.03 daily trips per worker or 0.01 daily trips per person (data from three cities).
Distribution	Business and personal service vehicles are distributed widely throughout the region, with a focus on non-CBD areas. Business and personal service trips can be estimated using the gravity model or destination choice.
Vehicle Type	Business and personal service trips are generally made in passenger autos, pickup trucks, minivans or SUVs; they may be available from the DMV. There are 32 percent cars, 26 percent pickups, 16 percent vans, nine percent SUVs and 17 percent medium and heavy trucks.
Time of Day	Business and personal trips occur throughout the workday, with half taking place between 9:00 a.m. and 3:00 p.m. There are 11 percent in the a.m. peak, 53 percent at midday, 22 percent in the p.m. peak, and 14 percent at night (data from three cities).
Assignment	Business and personal service trips are likely to be uniformly distributed among freeways, arterials and local streets.

3.0 Summary by Vehicle Group

For some specific types of analysis, commercial vehicles can be organized into three groups based on what they transport and what economic, demographic, and land use factors influence the magnitude and distribution of commercial vehicle trips in a metropolitan area. The three groups of vehicles, along with the detailed set of commercial vehicle categories, are provided below:

- **Commercial passenger vehicles** include school buses, shuttle services, rental cars, taxis, and paratransit vehicles. Growth of this category depends on the growth of population and employment.
- **Freight vehicles** include mail delivery, trash collection, warehouse delivery, construction, and parcel pickup and delivery vehicles. This category has received considerable attention in recent years. Urban goods movement, like longer-haul freight movement, is gaining a larger share of the on-road vehicle load. Growth of this category of commercial vehicles depends on the growth of population and employment in specific markets.
- **Service vehicles** are used by police officers, firefighters, plumbers, cleaning crews, utility maintenance workers, and a variety of retail and service-related professionals. As the United States transitions from a manufacturing-oriented economy to a service-oriented economy, the number of service-related commercial vehicle trips continues to grow faster than the number of trips made for almost any other purpose. The rate of this growth is related to the growth of population and employment.

Table 3.1 presents the percentage range of total VMT and VMT per vehicle per day by passenger, freight, and service vehicles for selected cities (Cambridge Systematics, November 2003). Of these three groups, service vehicles contribute the highest percentage of VMT, 5.9 percent (ranging from 1.4 percent to 12.7 percent). Freight vehicles are second, at 3.5 percent (ranging from 1.0 percent to 6.9 percent), followed by passenger vehicles at 2.4 percent (ranging from 1.0 percent to 5.4 percent). In terms of VMT per vehicle per day, passenger commercial vehicle trips are longer than freight and service vehicle trips.

Table 3.1 Range of Vehicle Miles Traveled Across Selected Urban Areas

Vehicle Type	Range of VMT across Selected Urban Areas			VMT per Vehicle per Day
	Minimum	Maximum	Average	
Passenger	1.0%	5.4%	2.4%	66 miles
Freight	1.0%	6.9%	3.5%	50 miles
Service	1.4%	12.7%	5.9%	41 miles
Total	**3.4%**	**25.0%**	**11.8%**	**48 miles**

3.1 COMMERCIAL PASSENGER VEHICLES

Five of the 12 categories of commercial vehicles transport passengers:

- School buses;
- Shuttle services;
- Taxis;
- Paratransit services; and
- Rental cars.

About 2.4 percent of total vehicle miles traveled in urban areas in the United States each year are attributable to vehicles in these five categories. Rental cars, which make up 80 percent of vehicles in the commercial passenger group, account for fully 2.0 percent of total VMT in the United States, while school buses, taxis, and shuttle and paratransit services account for about 0.4 percent of VMT.

No specific urban transportation models include the "commercial passenger vehicle" as a separate trip purpose. However, several metropolitan planning organizations have attempted to include specific categories of these commercial vehicle in their models. The Las Vegas model is the only one that considers taxis as a separate mode in the mode choice model and assigns them to the highway network. The Tucson and Houston-Galveston models predict school bus travel, but do not assign or evaluate these trips. The San Francisco model includes mode choice for rental cars, taxis, and airport shuttles. The Portland model includes shuttle services and taxis in the mode and destination choice models. The Sacramento model includes airport trips as a separate trip purpose. In addition, a number of models deal separately with the development of trip tables for taxi trips (sometimes combined with 'truck' trips) and their assignment to the network using procedures akin to the Network-based Quick Response Methods presented in Section 2.0. Also, all urban models based on local survey data can be presumed to include rental cars used by residents with all trips made using privately owned passenger cars.

Very little research has focused on paratransit vehicles and no models have been developed to estimate the demand for these trips. Similarly, although rental cars contribute a significant percentage of VMT on U.S. roads, the project team could find no models that estimate the demand for rental cars specifically. A few visitor models (San Francisco, Honolulu, and Las Vegas) predict the mode share of auto trips, but the percentage of these trips attributable to rental cars is not considered.

Data Sources

To analyze the commercial passenger vehicle group, the project team created a dataset by combining data on school buses, shuttle services, rental cars, taxis, and paratransit vehicles. Data were derived from:

- School bus data were derived from the Schoolbusfleet.com web site.
- Shuttle Service data were derived from the Airport Ground Access Planning Guide.
- Paratransit data were derived from the National Transit Database's paratransit database.
- Taxi data were derived from the Taxi Fact Book.
- Very limited data were available on rental cars. The project team obtained fleet size and mileage data from Hertz. The project team also collected T.F. Green and Walker Field airport rental car surveys, an Orlando area survey, and a California Department of Motor Vehicles survey.

Data for four cities, Los Angeles, San Francisco, Detroit, and Portland (Oregon), were compiled and analyzed. Demographic data, including total population and total employment for each city, were derived from the 2000 Census.

Aggregate Demand Method

The Aggregate Demand Method estimates fleet size, number of trips, and VMT based on total population and total employment. A summary of these travel behavior characteristics is provided in Table 3.2.

Table 3.2 Travel Behavior Characteristics for Commercial Passenger Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description of Methods	Estimates
Fleet Size	Fleet size can be estimated as a function of population. Data from Los Angeles, San Francisco, Detroit, and Portland (Oregon) were used to develop this factor.	0.008 per total population (data from four cities).
Trip/Tour Length	Mileage for commercial passenger vehicles range from 149 miles per day for taxis to 18 miles per day for shuttle services. Group averages should take into account the weighted average of individual vehicle types in this category.	58 average miles per day.
Trips	Daily trips per vehicle can be derived from DMV data. Data from the above four cities were analyzed.	Average 2.7 trips per vehicle (weighted average of school bus, rental car, taxi, paratransit and shuttle service vehicles).
Vehicle Miles Traveled	Passenger commercial vehicles represent a range of 1 to 5 percent of total VMT (Cambridge Systematics, November 2003) and 20 percent of the commercial vehicle VMT.	2.4 percent of total VMT (based on data from 11 cities)

Network-based Quick Response Method

Passenger trips is a function of population or employment. These trips are generally occurring at airports, hotels, tourist attractions, and businesses, so employment is used as a proxy for these generators, but employment in specific industries could provide a more direct link to these passenger trips. The project team estimated trip rates based on four cities. However, population and employment data for most of the cities are available from Census Data (United States Census Data, 2000) and trip rates can be estimated and passenger trips can be distributed using a gravity model with a friction curve borrowed from non-home-based trips. Since 80 percent of commercial passenger vehicles are rental cars, and 76 percent of rental cars are sedans (as opposed to pickup trucks or sport utility vehicles), more than 60 percent of commercial passenger vehicles are sedans.

Most commercial passenger vehicles operate during weekday business hours and the distribution among the time periods is probably fairly flat. Table 3.3 presents a summary of the travel behavior characteristics for commercial passenger vehicles using the Network-based Quick Response Method.

Table 3.3 Travel Behavior Characteristics for Commercial Passenger Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with total employment or population. Data discussed in Section 2.2 were combined and a regression equation was developed for total daily trips.
Distribution	Passenger vehicles are distributed widely throughout the region and could be distributed with a gravity model.
Vehicle Type	Of total vehicles, 66 percent are car, 13 percent are bus, three percent are pickup, eight percent are SUV, seven percent are van, and three percent are other medium and heavy vehicles (DMV data).
Time of Day	Passenger vehicles operate primarily during weekday business hours and probably have a relatively uniform distribution during these hours. No data could be found on time of day for passenger vehicles.
Assignment	Passenger vehicles operate on all facilities. However, school buses operate mostly on local streets.

3.2 Freight Vehicles

Three of the 12 categories of commercial vehicles transport goods:

- Package, product, and mail delivery vehicles;
- Urban freight distribution and warehouse delivery vehicles; and
- Construction transport vehicles.

About 3.5 percent of the total vehicle miles traveled each year in urban areas in the United States are attributable to vehicles in these three categories. Urban freight vehicles alone contribute 2.7 percent of total urban area VMT, while package delivery and construction vehicles each contribute less than 0.2 percent. This category does NOT include the related movement of intercity freight to, from, or through urban areas, which is forecast using other techniques.

Urban transportation models typically include "commercial freight vehicles" in a goods movement model. Some of these goods movement models are vehicle-based truck models (Atlanta, Chicago, San Francisco, Buffalo, and Phoenix), some are commodity-based models (Portland) and some are hybrid models (Seattle and Los Angeles). These truck models include trucks from the commercial service vehicles category as well as intercity freight trucks traveling to, from or through an urban area. Most of these models identify trucks by weight class or type (light-, medium-, and heavy-duty) rather than by purpose (package delivery, urban freight, and construction).

Data Sources

To analyze the commercial freight group, the project team created a dataset combining data on package delivery, urban freight and construction vehicles.

- Package delivery data were derived from three sources: California DMV data on parcel delivery trucks for Los Angeles, San Francisco, San Diego, and Sacramento; USPS data on package and mail delivery for seven urban areas (Atlanta, Denver, Detroit, Greensboro, Houston, Orlando, and Portland); and, the commercial vehicle surveys that included package and product delivery trucks for six urban areas (Atlanta, Denver, Detroit, Greensboro, Winston-Salem, and High Point.)
- Urban freight vehicle data were derived from two primary sources: California DMV data and commercial vehicle survey data from the six urban areas listed above.
- Construction vehicle data also were derived from the same two sources: California DMV data and commercial vehicle survey data from the six urban areas.
- Data for three cities, Detroit, Denver and Atlanta, as well as combined data for the Triad cities of Greensboro, High Point and Winston-Salem, North Carolina, were compiled and analyzed. Demographic data, including total population and total employment for each city, were obtained from the 2000 Census.

Aggregate Demand Method

The Aggregate Demand Method estimates fleet size, number of trips, and VMT based on total population and total employment. A summary of these travel behavior characteristics is provided in Table 3.4.

Table 3.4 Travel Behavior Characteristics for Commercial Freight Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates[1]
Fleet Size	Fleet size can be estimated as a function of population and employment. The presence of a major private or public distribution center will greatly impact the fleet size for the urban area.	0.05 per total employment (data from four cities).
Trip/Tour Length	Mileage ranges from 43 to 66 miles per day by category and also is consistent across cities, with lower mileages in smaller cities.	Average mileage is 50 miles per vehicle per day or 11 average miles per trip (data from 11 cities).
Trips	Trips per vehicle can be derived from a commercial vehicle survey.	Average 4.6 daily weekday trips per vehicle.
Vehicle Miles Traveled	Freight commercial vehicles represent a range 1 to 7 percent of total VMT (Cambridge Systematics, November 2003) and 30 percent of commercial vehicle VMT.	3.5 percent of total VMT (data from 11 cities).

[1] Estimates are based on commercial vehicle survey data from Atlanta, Denver, Detroit and the Triad cities.

All types of vehicles are used to move freight. Four-tire vans and light trucks are used primarily to pick up and deliver packages and to transport workers and their tools to and from construction sites. Commercial vehicles moving freight represent the vast majority of heavier commercial trucks in urban areas. Single unit, medium-sized trucks are used in the local delivery of urban freight and supplies to construction sites. Combination tractor trailer trucks are used to move heavy goods, and for trips to and from distribution centers. Fleet size is primarily a function of employment and population.

The number of trips for the commercial vehicle categories moving freight averages from four to five per vehicle per weekday day, based on available commercial vehicle surveys. However, it is assumed that for local delivery the definition of a "trip" is actually a chain consisting of many short-distance trips to homes, retail stores, or offices.

Network-based Quick Response Method

Commercial vehicle freight trips are a function of population or employment. Although the project team estimated trip rates based on data from four cities, population and employment data are available in the Task 3 Report for more than 300 cities. Using total commercial vehicle freight trips from available sources along with the Task 3 report data, trip rates can be estimated. Also, commercial freight trips can be distributed using a gravity model with a friction curve borrowed from non-home-based trips, as shown in Table 3.5.

Table 3.5 Travel Behavior Characteristics for Commercial Freight Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used to predict daily trips attracted using total employment or population. There are 0.23 per total employment or 0.12 per total population (data from four cities).
Distribution	Commercial freight vehicles are distributed widely throughout the region and could be distributed with a gravity model.
Vehicle Type	Obtain results from registrations or commercial vehicle surveys. Estimates do not include public mail delivery vehicles because these were not included in the commercial vehicle surveys. Of commercial freight vehicles, 25 percent are four-tire trucks or vans, 59 percent are medium trucks, and 16 percent are heavy combination trucks.
Time of Day	Obtain results from commercial vehicle surveys. Of total trips, 50 percent occur during the midday period; 18 percent during the p.m. peak; five percent during the a.m. peak; and eight percent during the night (data from four commercial vehicle surveys).
Assignment	Freight vehicles operate on all facilities. However, some urban areas restrict the line-haul portion of the trip to certain streets.

Trip generation rates for commercial vehicles moving freight are primarily based on the number of employees and persons in an urban area. Based on the data from the four cities, commercial vehicle productions can be estimated as 0.23 trips per employee and the corresponding attractions as 0.12 trips per person. While the attraction of trips for commercial vehicles moving freight can best be explained by the number of persons, these trips are usually not to homes, but to offices and retail stores whose location is highly correlated with population.

Trip distribution for commercial vehicles moving freight is highly concentrated in areas with high employment. While the package delivery category has a slightly shorter average mileage, there is little difference between the distribution and average mileage among the construction and the urban freight categories. The construction and package delivery categories average approximately 12.5 and 8.7 miles per trip, respectively. Urban freight averages 14.1 miles per trip based on commercial vehicle surveys. (Again, it is assumed that the definition of a "trip" is actually a chain consisting of many short trips to homes, retail stores, or offices.)

Commercial freight vehicles travel most frequently between 9:00 a.m. and 3:00 p.m., and to a lesser extent in the p.m. peak period. The percentage of daily commercial freight VMT in the average hour within the p.m. peak period is seven percent, compared to an average of 10 percent per hour during the midday hours. Travel is less frequent during the a.m. peak period (an average of two percent of the daily VMT per hour) and during the night (an average of one percent of the daily VMT per hour).

The assignment of commercial vehicles moving freight is permitted on the entire roadway system for travel in the vicinity of the establishments and homes they are serving. Some limitations based on vehicle size may apply for certain line-haul portions of travel removed from the origin or destination.

3.3 SERVICE VEHICLES

Four of the 12 commercial vehicle categories are vehicles providing services:

- Safety vehicles;
- Utility vehicles;
- Public service vehicles; and
- Business and personal service vehicles.

Public service vehicles are publicly owned. Business and personal service vehicles are privately owned. Safety and utility vehicles may be either publicly or privately owned.

About 5.9 percent of the total vehicle miles traveled in the urban areas in the United States each year is attributable to vehicles in these three categories. Business and personal service vehicles alone contribute 3.6 percent of the total VMT in urban areas across the nation, while public service vehicles contribute 1.6 percent of the total VMT and safety and utility vehicles contribute 0.4 percent each.

Urban transportation models currently do not include any commercial service vehicles specifically, although some models have identified a commercial vehicle trip purpose that is based on a fixed factor of personal non-home-based travel. Some truck models also include delivery and service vehicles that are four-tire commercial vehicles, based on the inclusion of these vehicles in the *Quick Response Freight Manual* (Cambridge Systematics, 1996).

Data Sources

To analyze the commercial services group, the project team created a dataset combining data on safety, utility, public service, and business and personal service vehicles.

- Safety vehicles were derived from two sources: 1) California DMV data on police, fire, and rescue vehicles and tow trucks for Los Angeles, San Francisco, San Diego, and Sacramento; and 2) the Detroit commercial vehicle survey, which includes snow plows and tow trucks.
- Utility vehicles were derived from two sources: 1) California DMV data on utility cars and trucks; water and irrigation trucks; and garbage trucks for Los Angeles, San Francisco, San Diego, and Sacramento; and 2) three commercial vehicle surveys that included utility and maintenance vehicles for the Detroit, Atlanta and the Triad cities regions.
- Public service vehicles were derived from a single source: California DMV data on city, county, state, Federal, other and school and college cars for Los Angeles, San Francisco, San Diego, and Sacramento.
- Business and personal service vehicles were derived from two sources: 1) California DMV data on "other commercial cars," armored, panel and

pickup trucks, vans and step vans for Los Angeles, San Francisco, San Diego, and Sacramento; and 2) three commercial vehicle surveys that included vehicles used for office, professional, or personal services in the Detroit, Atlanta, and Denver areas.

Data for four cities, Los Angeles, San Francisco, San Diego, and Sacramento, were compiled and analyzed because these were the only four cities with a comprehensive assessment of all commercial service vehicles. Demographic data for each city, including total population and employment by type (government, utility, business and personal services and total), were derived from the 2000 Census.

Aggregate Demand Method

The Aggregate Demand Method estimates service vehicle fleet size based on two demographic factors: total employment (possibly stratified by type) and population. A summary of the travel behavior characteristics is provided in Table 3.6. This summary includes estimates of fleet size, number of trips, and VMT calculated from a statistical analysis of the available data combined with demographic data. The only comprehensive data source (including both public and private sector data) is the motor vehicle registration data, so only these data are used in estimating rates of travel by commercial service vehicles. These data do not show trips per vehicle, so the commercial vehicle surveys are used to provide data on this variable for private sector vehicles only. The percent of vehicle miles traveled was estimated and presented in the *Magnitude and Distribution of Commercial Vehicle Travel* (Cambridge Systematics, November 2003).

Table 3.6 Travel Behavior Characteristics for All Commercial Service Vehicles Using the Aggregate Demand Method

Travel Behavior Category	Description	Estimates
Fleet Size	Fleet size can be estimated as a function of population, based on data from the DMV.	0.05 per population (data from four cities).
Trip/Tour Length	Average mileages are consistent across different cities and categories, ranging from 29 to 49 miles per day. National average miles traveled were derived from VIUS data. Average mileage was derived from commercial vehicle survey data.	41 average miles traveled per day, average trip length is 14 miles (data from eight cities).
Trips	Trips per vehicle can be derived from a commercial vehicle and government vehicle survey. Trips per vehicle estimates were derived for private vehicles only from commercial vehicle surveys in Atlanta, Detroit, Denver, and the Triad cities.	Three daily trips per vehicle (data from four cities).
Vehicle Miles Traveled	Service vehicles range from five percent to 13 percent of total VMT for four cities (San Diego, Sacramento, San Francisco, and Los Angeles), based on DMV and VIUS data (Cambridge Systematics, November 2003) and represent 50 percent of total commercial vehicle VMT.	5.9 percent of total VMT (data from four cities).

Network-based Quick Response Method

Data on public and private service vehicles were available for only four cities: Los Angeles, San Francisco, San Diego, and Sacramento. No data was available for the number of vehicle trips or mileages for these four cities because the DMV data for those cities contains only fleet size. Data on vehicle trips and mileages are available from commercial vehicle surveys for private sector service vehicles for the cities of Atlanta, Denver, Detroit and the Triad cities. Additional data are necessary to more accurately evaluate travel behavior for all service vehicles. Table 3.7 presents a summary of the travel behavior characteristics for the Network-based Quick Response Method.

Table 3.7 Travel Behavior Characteristics for All Commercial Service Vehicles Using the Network-based Quick Response Method

Travel Behavior Category	Description
Trips/Tours	Cross-classification or regression models can be used with employment variables Government, utilities and business and personal services employment are the most likely variables. Trip rates are based on data from the DMV and the Bureau of the Census. There are 0.1per total employment or 0.05 per population (data from four cities).
Distribution	All service vehicles are distributed widely throughout the region and could be distributed with a gravity model. National average miles traveled were derived from VIUS data. Average trip length was derived from commercial vehicle survey data.
Vehicle Type	Service vehicles are primarily light duty vehicles, dominated by public service, business, and personal service types (all light duty vehicles), based on data from the DMV. Some safety and utility vehicles are medium and heavy duty trucks (fire trucks, ambulances, utility trucks, etc.). Of commercial service vehicles, 91 percent are light duty vehicles and nine percent are medium/ heavy duty trucks (based on data from four cities).
Time of Day	The majority of private service vehicles operate between 9:00 a.m. and 3:00 p.m., based on private service vehicles from the commercial vehicle surveys. The project team believes that the majority of public service vehicles also operate in this period. Of total trips, 11 percent occur in the a.m. peak, 23 percent in the p.m. peak, 53 percent in midday, and 14 percent at night (data from three cities).
Trip Assignment	Service vehicles operate on all facilities.

4.0 Calibration and Validation Data

The term "model calibration" is the process of adjusting parameter values until predicted travel matches observed travel demand levels in the given region. The term "model validation" is the process of comparing the model predictions with information other than that used in estimating the model. Model calibration and validation data should be obtained from different sources than the data used in estimating model parameters. As a result, one needs to identify unique sources of data that can support model calibration and validation. For the purpose of this report, calibration and validation data are those data that can be used to compare with model predictions to determine the reasonableness of the model parameters. Model calibration and validation data also are used as a means to adjust the model parameter values so that model predicted travel match observed travel in the region. This is especially important when applying nationally derived model parameters to a specific region.

4.1 Registration Records

State vehicle registration databases often indicate whether registered vehicles are used for commercial purposes. These databases typically show vehicle weight classes, but not service use. Service use can be inferred based on vehicle make/model, weight class, owner, and possibly other data. However, this requires considerable data processing. Many states' databases also do not include odometer readings.

Vehicle registration databases that are maintained by a state can yield useful information on the number of commercial vehicles existing within a particular geographic area. For example, the California Energy Commission has been working with the California Department of Motor Vehicles (DMV) and other agencies since the late 1990s in an effort to clean, organize, and analyze the State's vehicle data. The California DMV employed all key words from the 120-character owner field of each record in the database that reveal any potential business use information. The Energy Commission divided the DMV data into two main groups: 1) light vehicles and 2) medium and heavy vehicles. It further divided the light vehicle category by use, and the medium and heavy vehicle category by body type.

Based on the use and body-type subcategories, the project team was able to map the registration data to the 12 categories of commercial vehicles, as shown in Table 4.1. No vehicle types in the California DMV database correlate to the following commercial vehicle categories in this study: Shuttle Service: Airports, Stations; Private Transportation: Taxi, Limos, Shuttles; and Paratransit: Social Services, Church Buses.

Table 4.1 California DMV Vehicle Types by Commercial Vehicle Category

Commercial Vehicle Category		California Light Duty Vehicles	California Medium and Heavy Duty Vehicles
1	School Bus		Bus
5	Rental Cars	Daily Rental	
6	Package, Product and Mail Delivery: USPS, UPS, FedEx, etc.		Parcel Delivery
7	Urban Freight Distribution, Warehouse Deliveries		Auto Carrier, Beverage Cargo Cutaway, Dromedary, Logger, Multiple Bodies, Refrigerated, Stake or Rack, Tandem, Tank, Tractor Truck, Tractor Truck Gas
8	Construction Transport		Boom, Concrete Mixer Crane, Cutaway, Dump, Flat Bed/Platform, Motorized Cutaway
9	Safety Vehicles: Police, Fire, Building Inspections, Tow Trucks	Govt. – District – Fire Govt. – District – Police	Ambulance Fire Truck Tow Truck Wrecker
10	Utilities Vehicles (Trash, Meter Readers, Maintenance, Plumbers, Electricians, etc.)	Govt. – District – Utility Govt. – District – Water/Irrigation	Garbage Utility
11	Public Service (Federal, State, City, Local Government)	Govt. – City Govt. – County Govt. – State Govt. – Federal Govt. – District – School Govt. – District – College Govt. – District – Transit Govt. – District – Other	
12	Business and Personal Services (Personal Transportation, Realtors, Door-to-Door Sales, Public Relations)	Other Commercial	Armored Truck, Panel, Pickup, Step Van, Van
	Not Categorized	Personal	Chassis and Cab, Conventional Cab, Forward Control, Gliders Incomplete Chassis, Tilt Cab, Tilt Tandem, Unknown, Motorized Home

Source: California Department of Motor Vehicles registration data processed by the California Energy Commission.

The project team recommends that other states explore and develop the same kind of multi-year cooperative arrangement that exists in California so that, over time, vehicle registration data can be used to support transportation planning – including, but not limited to, the movement of commercial vehicles.

The California DMV data has a large category of "other commercial" light duty vehicles that the project team assigned to the business and personal services categories. Since not all "other commercial" vehicles are being used for commercial purposes, this category was factored to exclude the business and personal service vehicles used for personal activities, based on the VIUS estimates of the use of these vehicles. The team cross-tabulated VIUS Business and Personal Services category vehicles by business use and personal use and determined that in California 22 percent of total vehicles (both personal and commercial) are used for commercial purposes. Accordingly, "other commercial" vehicles in the California DMV data were multiplied by 0.22 to obtain the numbers of Business and Personal Services vehicles as shown in Table 4.2.

Table 4.2 Business and Personal Services Vehicles in California Cities

	San Francisco	Los Angeles	San Diego	Sacramento
"Other Vehicles" from California DMV Database	687,169	1,474,911	242,156	210,271
Factors from VIUS Database	0.22	0.22	0.22	0.22
Business and Personal Services Vehicles	152,263	321,445	50,488	43,984

Registration data, such as that collected by the California DMV, is the best source of fleet size statistics. Table 4.3 presents the California DMV data on fleet size for four California urban areas that could be used for calibration or validation of urban area commercial vehicle models.

Vehicle registration and new vehicle data also may be purchased from R.L. Polk & Co., a privately owned consumer marketing information company. Polk develops custom reports for customers, providing data by ZIP code, Metropolitan Statistical Area, county, state, or for the entire United States.

Vehicle registration data for New York State are available at their web site (New York State Department of Motor Vehicles, 2001). These data are not as detailed as the California DMV data. The number of vehicles by type are summarized for five cities in New York State in Table 4.4.

4.2 Vehicle Miles of Travel

An independent regionwide estimate of VMT, based on traffic counts and roadway miles, can be used to validate the base-year assignment of commercial vehicles produced by a travel demand model. These traffic counts are collected in most urban areas as part of the ongoing transportation planning process and are used to validate the passenger portion of urban travel demand models. In addition to any counts that might be undertaken for planning purposes, state departments of transportation are required to include Annualized Average Daily Traffic Counts and mileage for all roadways, based on a statistical sample, for each urban area as part of their annual HPMS submittal. The HPMS VMT can be summarized by functional classification of highways and by area type and compared to the urban area model volumes by functional classification and area type. When using HPMS estimates of VMT, it is important to understand that VMT is for all roadways, including local roads. Travel demand models, in contrast, generally do not include these local roads so this comparison should consider an adjustment for them to allow for a comparison of the total observed and estimated VMT.

Table 4.3 Fleet Size across Selected Cities in California

Commercial Vehicle (CV) Category	San Francisco		Los Angeles		San Diego		Sacramento	
	# of CV	%	# of CV	%	# of CV	%	# of CV	%
School Bus	1,510	0.03%	5,259	0.05%	1,267	0.06%	1,011	0.07%
Rental Car	89,805	1.78%	88,217	0.83%	12,107	0.61%	9,913	0.69%
Package, Product, Mail	470	0.01%	449	0.00%	41	0.00%	42	0.00%
Urban Freight	22,484	0.44%	69,617	0.65%	8,510	0.43%	10,651	0.74%
Construction	22,561	0.45%	36,318	0.34%	6,939	0.35%	8,798	0.61%
Safety Vehicles	5,090	0.10%	11,149	0.10%	3,364	0.17%	7,090	0.49%
Utility Vehicle	7,552	0.15%	19,488	0.18%	2,729	0.14%	5,108	0.36%
Public Service	38,094	0.75%	83,219	0.78%	13,111	0.66%	36,710	2.56%
Business and Personal Services	152,263	3.01%	321,445	3.01%	50,488	2.55%	43,984	3.07%
Total Commercial Vehicles	885,120	17.50%	1,806,460	16.90%	292,652	14.80%	291,849	20.34%
Total Vehicles	5,057,355	100%	10,688,810	100%	1,977,794	100%	1,434,670	100%

Table 4.4 Fleet Size across Selected Cities in New York State

Commercial Vehicle (CV) Category	Bronx		Kings		Queens		New York		Albany	
	# of CV	%	# of CV	%	# of CV	%	# of CV	%	# of CV	%
Bus	624	0.2%	2,101	0.4%	19	0.3%	230	0.1%	72	0.0%
Taxi	5,394	2.0%	11,844	2.5%	175	2.5%	6,720	2.6%	325	0.2%
Trailer	1,561	0.6%	2,424	0.5%	57	0.8%	932	0.4%	8,981	4.2%
Ambulance	63	0.0%	642	0.1%	2	0.0%	135	0.1%	42	0.0%
Motorcycle	2,395	0.9%	4,831	1.0%	77	1.1%	5,374	2.1%	4,465	2.1%
Moped	80	0.0%	253	0.1%	4	0.1%	887	0.3%	146	0.1%
Rental Vehicles	334	0.1%	2,246	0.5%	78	1.1%	207	0.1%	2,236	1.0%
Total Commercial Vehicles	17,317	6.4%	38,420	8.2%	662	9.3%	21,885	8.5%	39,430	18.2%
Total Vehicles	269,577	100%	470,290	100%	7,086	100%	257,531	100%	216,133	100%

Generally, traffic counts are collected and VMT is calculated either for all vehicles or for vehicles classified by axle configuration. Traffic count information is predominately collected by Automatic Traffic Recorders (ATR) and thus will rarely include any other classification of commercial vehicles. That information will typically be based on a visual identification of commercial markings on the vehicle or a visual observation of the commercial registration plate.

HPMS estimates of percentages of single unit and combination trucks, based on ATRs, can be used to develop VMT for these types of trucks. Not all commercial vehicles are included in these classes, and intercity freight trucks that are excluded from the definition of urban commercial vehicles are responsible for a considerable portion of the truck travel on higher functional classes. Nevertheless, HPMS estimates of truck VMT can be used to validate commercial vehicle models. It should be noted, however, that the HPMS values for trucks are based on statistical samples. Thus, the "observed" truck VMT is in reality an estimate.

Based on accepted standards for model validation, modeled regional VMT should generally be within five percent of observed VMT (Barton-Aschman Associates and Cambridge Systematics, 1997). When the regional models are used to track VMT for air quality purposes, the Environmental Protection Agency requires that estimates be within three percent. However, these estimates are for the total of all vehicles irrespective of vehicle type. If commercial vehicles generally represent 13 percent of total VMT, and if a travel demand model's estimate of commercial VMT is within five percent of that value, it would be consistent with the overall validation standards.

The accepted standards of total VMT by functional class are shown in Table 4.5. As described in Section 2.2, the mix of commercial vehicles by functional class will vary considerably by vehicle category. For example, school buses travel almost exclusively on local or collector roads, while urban freight vehicles travel principally on the arterial system. Thus, commercial vehicles cannot be expected to have the same distribution by functional classification as shown for all vehicles in Table 4.5. However, the table shows the variability of usage of the functionally classified roads by urban area size and this variability by urban size also can be expected to occur for the commercial vehicles portion of travel.

Table 4.5 Urban Area VMT by Facility Type

	Urban Area Population		
Facility Type	Small (50-200K)	Medium (200K-1M)	Large (>1M)
Freeways/Expressways	18-23%	33-38%	40%
Principal Arterials	37-43%	27-33%	27%
Minor Arterials	25-28%	18-22%	18-22%
Collectors	12-15%	8-12%	8-12%

Source: Christopher Fleet and Patrick De Corla-Souza, *Increasing the Capacity of Urban Highways: The Role of Freeways*, presented at the 69th Annual Meeting of the TRB, January 1990.

In addition to validating modeled VMT to observed VMT by functional class, it is customary to use measures such as VMT per person or per household to assess the reasonableness of urban models. Reasonable ranges of total VMT per household are 40–60 miles per day for large urban areas and 30–40 miles per day for small urban areas (Barton-Aschman, 1997). If one applies the 13 percent of total VMT that is estimated for commercial VMT in this report to these household ranges, then the VMT per household for commercial vehicle demand would represent five to eight miles per day for large urban areas and four to five miles per day for small urban areas.

4.3 Vehicle Classification Counts

Travel demand models are validated by comparing observed versus estimated traffic volume on the highway network and by comparing summations of volumes at both cordons and screenlines. Vehicle classification counts have been used to validate the auto and truck volumes, but this is not directly useful to validate commercial vehicles by category, since many categories contain both autos and trucks. Nonetheless, it is one of the only sources to verify the reasonableness of traffic volumes based on the inclusion of commercial vehicles into the transportation planning models.

As described in the Task 3 Report, vehicle classification count data, which classifies vehicles according to the 13-axle-based classes of the FHWA, is generally available from state departments of transportation for sampled sets of streets and highways. For the 13 classes, the information includes counts by location, by hour of the day, and by date. In summary format this information generally presents truck volumes (defined as FHWA Classes 5 through 13, six tires and above) and occasionally includes buses (FHWA Class 4). Four-tire pickup trucks, vans, and sport utility vehicles (FHWA Class 3), are almost always included with passenger cars.

The project team expects that the Network-based Quick Response Methods for developing commercial vehicle models will include methods to convert commercial vehicle trip tables into assignments of commercial vehicles by type (auto and truck at a minimum). These vehicle classification counts can be used to compare the observed auto and truck counts (and shares by vehicle type) with the estimated auto and truck volumes (and shares) produced by the urban area model. These vehicle assignments will include both personal and commercial vehicles, derived from both personal and commercial models, so calibration adjustments deemed necessary from these comparisons may be required for either the personal or commercial models or both. The project team does not recommend that vehicle classification counts be used to evaluate individual count locations, but that they be summarized by functional class, area type, or screenline.

5.0 Recommendations for Future Data Development

While evaluating the magnitude and distribution of commercial vehicles and identifying methods, parameters and data sources that can be used to forecast these vehicles in urban transportation planning models, the project team has uncovered a number of areas for future data development. These areas are determined primarily by the gaps in the data and the need for data sources to support the development of advanced commercial vehicle models. Once the data development has been undertaken, research and evaluation of these new data sources can provide a more robust evaluation of the methods for estimating commercial vehicle travel for urban transportation planning models.

The team's recommendations for future data development are designed to support the three methods of estimating commercial vehicle travel in urban area planning models: Aggregate Demand, Network-based Quick Response, and Model Estimation techniques. Future research should focus on collecting data for specific commercial vehicle categories, based on a level of priority. The priority levels are determined based on the overall impact on VMT of a particular vehicle category and the current availability of data (or lack thereof) for that vehicle category. The recommendations are designed to support the development of traditional four-step transportation planning models and/or tour-based transportation planning models. Tour-based modeling techniques should be considered when evaluating Model Estimation techniques, but are considered to be beyond the scope of this initial work effort.

The remainder of this section outlines recommendations on the identification of vehicle by type, a discussion of establishment surveys for each vehicle category, limitations for forecasting and priorities for data to support individual vehicle categories. All of the recommendations are designed to support the evaluation of commercial vehicle travel from a national perspective and would support the development of national default model parameters for commercial vehicle models. The discussion of issues related to establishment surveys and forecasting also apply to the evaluation of commercial vehicle travel from a local perspective and would support the development of local model parameters for commercial vehicle models.

5.1 Identification of Vehicles by Type

Personal and Commercial Vehicles

Based on the definition of commercial vehicles established for this study (all vehicles being used for commercial purposes), it is very difficult to clearly identify personal and commercial vehicle travel using existing datasets. Vehicle registration data, when augmented by significant levels of additional processing, provides the best available identification of personal and commercial vehicle fleet sizes, based on whether the vehicle is registered for personal or commercial use. However, in the Business and Personal Services category, a personal vehicle may be used for commercial purposes (for example, real estate agents and door-to-door salesmen) and a commercial vehicle may be used for personal use (for example, a construction worker using the company truck after hours). The VIUS shows that 88 percent of business and personal services vans, pickup trucks, and sport utility vehicles are being used for personal use.

Household and establishment surveys do not typically classify vehicles as personal or commercial vehicles. It is assumed that all vehicles in a household survey are personal and that all vehicles in an establishment survey are commercial. It may be desirable to modify establishment surveys to specifically determine whether the vehicle is being used for personal or commercial purposes.

Autos, Buses, and Trucks

Contrary to popular belief, many commercial vehicles are automobiles and buses rather than trucks. The vehicle registration databases provide a distribution of vehicles by type for each commercial vehicle category in this study, but these databases are not currently available in most states. In order to compare commercial vehicle models with ground counts, it will be necessary to classify all commercial vehicles by type (autos, buses and trucks) and preferably to separate trucks by weight (light, medium and heavy duty). Most commercial vehicle models to date are aimed at quantifying trucks and therefore do not include commercial vehicles moving people and public sector commercial vehicles providing services. These vehicles are primarily autos, vans, and buses.

5.2 Establishment Surveys

Further research is needed to design and collect surveys to support the estimation of commercial vehicles by category using advanced modeling methods. Seven types of surveys are identified, in order of priority for supporting the model development modeling methods (based on the percent of total VMT contributions from each vehicle type). All are establishment surveys and are intended to include the commercial vehicles used by both public and private establishments.

The surveys would collect data on commercial vehicle movements, including the type and size of vehicle, number of trips, purpose of the trip, products carried, service provided, and origin and destination characteristics. The following industries would require surveys and these are presented in order of priority:

- Retail and services (for business and personal service vehicles);
- Manufacturing and industrial (for urban freight vehicles);
- Transportation (for shuttle services, taxi, paratransit, and rental vehicles);

- Government (for safety, utility, and public service vehicles);
- Construction (for construction vehicles);
- Other Industries (for package, product, and mail delivery vehicles); and
- Education (for school buses).

The surveys could be standardized or adapted for unique types of establishments, although the project team recommends standardizing these surveys as much as possible to improve the usefulness for model development. All of the surveys should include a complete day's travel diary information for a sample of vehicles in the establishment. In the transportation industry, it will be important specifically to identify shuttle services, taxis, paratransit, and rental car companies to ensure that enough samples in these categories are represented. In all industries, it will be important to design the survey to capture all 12 categories of commercial vehicles.

5.3 Forecasting

The current proposed methods for forecasting commercial vehicle travel are necessarily limited by the expected exogenous forecast data that would be available to a metropolitan planning organization. These methods could be expanded to provide more accurate assessment of future commercial vehicle travel as these future data sources become available. For example, school bus travel could be a function of the geographic coverage of the school district and enrollment, but school districts change over time to accommodate growth; these changes are not currently part of the regional forecasting activities.

The current proposed methods for forecasting commercial vehicle travel also are unable to estimate micro-level transportation impacts. These impacts can be estimated for specific categories of commercial vehicle travel from the network-based approaches identified in the Network-based Quick Response Method or model development modeling techniques, but significant effort will be needed if these techniques were developed only for a micro-level analysis (and not for a macro- or meso-level analysis). Specific techniques to estimate micro-level transportation impacts would be more appropriate, but should be developed after the regional-level impacts are better understood.

5.4 Data Need Priorities by Vehicle Category

All of the vehicle categories have specific future data needs that were identified and prioritized during the course of the evaluation. These data need priorities are described in the following sections. Priorities are based on the overall impact that a particular vehicle category has on VMT (higher VMT categories receive a high priority) and on the availability of data for the category (categories will little or no data receive a higher priority). The priorities by category are summarized below:

- High Priority – Business and Personal Services, Urban Freight Distribution, Rental Cars and Public Service Vehicles.
- Medium Priority – Construction Transport, Safety and Utility Vehicles.
- Low Priority – Package, Product and Mail Delivery, Private Transportation (Taxis), School Bus, Shuttle Services, and Paratransit.

Interestingly, the vehicle categories in the greatest need of better data sources (business and personal services, rental cars, public service, safety and utility vehicles) are also those that rank high- or medium-priority based on their overall impact on VMT.

All of the recommended methods for estimating commercial vehicles in urban transportation planning models (Aggregate Demand analysis, Network-based Quick Response Method, and Model Estimation Methods) use existing model forms and are not expected to require any future research to support these efforts. Other methods, such as activity-based or tour-based models, would advance the methods proposed in this project, but are beyond the scope of this initial effort, which was primarily aimed at developing Network-based Quick Response Methods that could be adapted or transferred by metropolitan planning agencies. Tour-based models should be considered during the development of any locally specific models identified as Model Estimation Methods in this report; these could be developed using the same data recommended here to support the Model Estimation Methods.

High-Priority Data Needs

Business and Personal Services

Retail and service surveys of establishments are needed to obtain information regarding fleet size, number of trips, origins and destinations, departure times, and mileages for business and personal services. It also would be useful to collect data on how vehicles are registered, to allow for a better interpretation of vehicle registration data for vehicles used for business and personal services (i.e., those that are registered as commercial but used for personal activities and those that are registered as personal but used for commercial activities).

Urban Freight

Urban freight is the movement of freight within the urban area, but does not include trips to, from, and traveling through the area. Current commercial vehicle surveys collect comprehensive data on this category of commercial vehicle trips. Urban freight trips are more likely to be short-haul trips made using medium- and light-duty vehicles. Methods for modeling urban freight vehicles in urban transportation planning models are currently based on the *Quick Response Freight Manual*. However, the trip rates developed in the *Manual* represent all goods movement and service-related commercial trucks in an urban area and these trucks have very different behavior. In addition, trucks include all freight, of which urban freight is only part of the total. What is referred to as freight in the *Manual* includes long-haul trips that are primarily heavy vehicles, which are often modeled using national and international commodity flow data.

Comprehensive business surveys should be conducted to determine the fleet size and composition of vehicles maintained at an establishment. Businesses that are likely to be urban freight generators or destinations such as warehouses, distribution centers, and manufacturing employers need to be identified and contacted for follow-up surveys. Follow-up surveys should determine vehicle fleet size and composition and include trip activity diaries with numbers of trips, products carried, origins and destinations, mileages, time of travel, and costs.

Rental Cars

Among commercial vehicles, rental cars have the largest impact on VMT, accounting for two percent of total VMT nationwide. However, very limited data are available on rental cars. The project team could find no specific studies related to rental car demand, fleet size, or VMT analysis.

The only comprehensive source of data for rental cars is the augmented California DMV database. The California Energy Commission processed California DMV datasets and identified the rental cars from the master list of rental companies. Processing DMV data and extracting information about rental cars is very expensive and time-consuming, and there is no indication that other states have done this kind of processing.

Rental car trips can be divided into three types: 1) business-related trips, 2) recreational car trips, and 3) home-based trips. Most business trips start at the airport and go to business districts or employment centers. Business-related rental car trips can be estimated from airport surveys. Recreational rental car trips usually start from airports or car rental centers and go to tourist or recreational areas. In order to more accurately predict the impact of rental cars on the urban transportation network, data on rental cars also is needed. These data can be collected by surveying rental car companies, which collect information on miles traveled, number of vehicles, and cost, and by asking rental car drivers to provide information on number of trips, trip purpose, origins and destinations, and time of travel.

Public Services

The primary data source for public service vehicles is the augmented Department of Motor Vehicles registration database. These data are only useful to identify fleet size and do not contain any data on miles traveled, origins and destinations, time of travel, and cost. Some states maintain miles traveled as part of their registration database. Data on number of trips, origins and destinations, services provided, departure times, and costs should be collected using an establishment survey of public service agencies. These data are necessary to support both the Network-based Quick Response Method and Model Estimation Methods of estimating commercial vehicle models.

Medium-Priority Data Needs

Construction Transport

Trip data for construction transport vehicles are adequately collected by existing commercial vehicle surveys. Vehicle fleet data are available through the commercial vehicle surveys and for select cities in California from the California DMV. Other than these data sources, data are limited for construction transport vehicles.

Similar to urban freight vehicles, construction transport vehicle research should begin with a comprehensive business survey. From this survey, firms that produce or maintain construction materials and/or equipment or have fleets of transport vehicles can be identified. Travel diaries sent to these firms can be used to determine the characteristics of the trips.

A business survey also will identify construction companies. These companies, like suppliers of construction material and equipment, can provide fleet information and trip characteristics, as well as data regarding construction sites. Details from a construction site survey could include the type of project, the length of project, the number of workers on site, and the number of shipments received at site.

A construction site classification should be developed. Construction project types are as numerous as they can be different from each other. For example, trip rates associated with housing construction, office building construction, and highway reconstruction all would be expected to vary. Composite trip rates could be developed from the different classifications for all construction site types.

Safety Services

The primary data source for safety vehicles is the augmented Department of Motor Vehicles registration database. These data are only useful to identify fleet size and do not contain any data on miles traveled, origins and destinations, time of travel, and cost. Some states maintain miles traveled as part of their registration database.

Travel data for safety service vehicles are currently limited to data collected in one commercial survey (Detroit) that included only snow plows and tow trucks. Similar travel diary data on police, fire, and rescue vehicles should be included in these surveys. This will require administering travel diary surveys to both public and private establishments for a comprehensive assessment of the number of trips, origins and destinations, services provided, departure times, and costs. If these safety vehicles are estimated as a separate category, we recommend that data on average annual or daily mileage be collected and used to estimate VMT rather than collecting travel survey data, but if these vehicles are combined into a commercial services category, it would be important to include travel surveys for safety vehicles in this group.

Utility Services

The primary data source for utility vehicles is the augmented Department of Motor Vehicles registration database, which contains both public and private utility vehicles. According to these data, 24 percent of utility vehicles are publicly owned. Unfortunately, the registration data are only useful to identify fleet size and do not contain the necessary travel information found in commercial vehicle surveys.

Low-Priority Data Needs

Package, Product, and Mail Delivery

Data for public package, product, and mail delivery are maintained by the USPS. Data on routes, miles traveled, time of travel, and number of vehicles should be available in their entirety for accounting for public delivery vehicles in urban models through the Freedom of Information Act of 1966. Data that are normally withheld for privacy reasons should be obtainable due to the aggregate level of detail used in travel demand models.

Fleet size, fleet composition, and VMT by vehicle type for all urban areas should be obtained from the USPS. Special attention should be given to urban areas which contain major distribution centers. Population, household, and employment data are maintained at the five-digit and three-digit ZIP code levels by the U.S. Census. These data are available through the Census web site (www.census.gov) and should be obtained for all urban areas that USPS data are available. From these data, statistically valid public package, product, and mail delivery Network-based Quick Response Method procedures can be estimated for urban areas. With this vast database, procedures for specific urban area sizes and geographic locations could be developed, as well as more advanced modeling procedures.

Data on private package, product, and mail delivery are only available through a limited number of existing commercial vehicle surveys. More specific and complete data are therefore required to develop better models. Large service providers such as United Parcel Service and FedEx maintain detailed information similar to the USPS, but these data have historically been very difficult to obtain. Travel diary surveys of vehicles in package, product, and mail firms should be conducted to collect data on number of trips, mileages, origins and destinations, time of travel, and travel costs.

The team reviewed three commercial surveys that contained the necessary travel data for private utility vehicles. If these surveys were administered to public and private establishments, then a comprehensive assessment of the number of trips, origins and destinations, services provided, departure times, and costs would allow evaluation of the Model Estimation Methods for utility service vehicles.

Private Transport (Taxi)

Currently, the *Taxi Fact Book* is the only source of data on taxi and limousine services. These data are robust and provide useful information for the Network-based Quick Response Methods, but do not contain data on tours that individual taxis make. This makes it difficult to differentiate between taxi travel behavior in center cities and suburban areas, where the mileages are expected to be very different.

The Model Estimation Method for estimating taxi trips would be based on travel diary surveys of taxi companies. These models would estimate taxi trips (both empty and full taxi trips) as necessary components of taxi-related travel. Trips would be based on locations where taxis pick up passengers, such as hotels, employment centers, and airports, and on locations where taxis drop off passengers, such as residences, hotels, and employment centers. The travel diary surveys would provide data on number of trips, average mileage, number of passengers, travel cost, and time period of travel to support these elements of the model.

School Bus

The existing data for school buses (Schoolbusfleet.com from *School Bus Fleet* magazine) cover public school buses for the 100 largest school districts only, and include no travel diary information. These data are appropriate for Aggregate Demand analysis, but do not provide the necessary trip information for the Network-based Quick Response Method or model development modeling techniques.

School bus trips fall into two categories: trips made to transport students between home and school and school-based other trips. Home school trips follow fixed routes, beginning and ending at school bus garaging sites. School-based other trips begin and end at school and go to various recreational or educational destinations.

In urban models, school bus travel patterns are similar to public transit systems and more complicated to code than other vehicle patterns. The standard four-step modeling procedures for estimating trip generation, distribution, and assignment cannot estimate all aspects of school bus patterns accurately. In their pick-up mode, school buses travel in a loop starting from a garaging facility, making a series of pick-up stops at different residential locations, and then proceeding to school to drop off the students. Next, the same bus may repeat this pick-up/drop-off process for a different school before returning to a garaging facility. They travel mostly on local and collector roads on regularly scheduled routes and cannot detour to avoid congestion. Most automobiles, in contrast, follow a path well approximated by an equilibrium assignment not suitable for school buses.

Further research is needed to develop either the quick-response or an model development procedure to include school buses in urban models, but the Aggregate Demand Method is considered adequate for estimating school buses, given their low overall impact on the transportation system. There are two other options for including school buses in urban models. The first is to develop a trip chain model which will consider school bus trips as a loop from a garaging facility or school to different residential locations and then back to the same or a different school. For school-based other trips, it will be necessary to collect data from school districts and to estimate trips per student, trips per teacher, or any other variables. This method would require travel surveys of school districts to identify the travel patterns of home school and school-based bus trips. Travel times for buses could be estimated using GIS techniques, rather than by building school bus networks of all routes and schedules. Even this method would only be able to construct generalized school bus tours. The actual school bus routes could be established based on the business practices of the school districts (opening and closing hours of various schools, eligibility requirements by distance from school, fee for service, etc.) which are beyond the scope of any model to consider.

Shuttle Services

Currently, the *Airport Ground Access Planning Guide* is the only source of data for shuttle services. Even this source is limited because it considers data from only 29 airports. No shuttle services outside of airports were considered and no data sources distinguished between fixed schedule and demand response shuttle services.

In order to more accurately predict the impact of shuttle services on the urban transportation network, agencies should obtain information on population and the number of tourists and hotel rooms in the area. In addition, agencies should have an accurate count of the total number of passengers at airports and other stations where shuttle services are provided. Agencies also should obtain information on the number of businesses providing shuttle services, the size of their fleets, their routes, the number of trips they make annually, and the average length of each trip.

In addition to the data requirements detailed above, it is recommended that agencies conduct travel diary surveys of a sample of shuttle service providers. This sample can be extrapolated to the expanded set of shuttle service vehicles to determine the trips for shuttle services. Once trips have been estimated, trip distribution can be estimated and shuttle service vehicles assigned to the transportation network using the same survey data.

There is clearly a correlation between shuttle services, taxis and rental cars within any urban area, where the demand for shuttle services and taxis will be in part based on the cost and need for rental cars. In cities where parking costs are high, transit services are good and the airport is located far from the central business district (such as New York), the taxi and shuttle services are more widely used than rental cars. In cities where the parking costs are low, transit services are not good and the airport is located closer to the central business district (such as Orlando, Tampa, Palm Springs, and San Jose), then rental cars are used more widely than taxis and shuttle services. We observed this correlation by reviewing the *Airport Ground Access Planning Guide* for mode splits to and from 29 airports, but expect that the correlation extends to other parts of the urban area as well.

Paratransit Services

Since the mid-1980s, the number of paratransit and social service systems across the United States has increased significantly. However, paratransit contributes only 0.006 percent of total VMT, which is insignificant compared to other categories of commercial vehicles.

The Federal Transit Administration (FTA) collects and disseminates data on the state of mass transportation via the National Transit Database (NTD) program. Over 600 of the nation's transportation providers submit data to the NTD annually. However, the FTA data include only those systems that receive FTA funds and are therefore required to report their data to FTA. Paratransit systems that do not receive FTA funds, such as church service buses, are not required to submit their data but may do so voluntarily.

The NTD database includes the number of paratransit vehicles, vehicle miles, vehicle hours, passenger miles, and passenger trip information. This is sufficient for estimating parameters for some of the Network-based Quick Response Method parameters, but is not sufficient for estimating parameters for the Model Estimation Methods. Based on this analysis, paratransit trip attractions are highly correlated to population over the age of 60 and total employment, which can be estimated from the NTD and the Census Bureau database. However, trips cannot be estimated using these data. The project team tried to correlate trips and employment, but the statistical fit (based on the R-square value) was not satisfactory. For estimating paratransit trips, data are needed on the destinations of paratransit users, such as specific types of employment (for example, government, education, and medical services). These parameters could be developed with travel surveys of paratransit vehicles, which identify number of trips, origins and destinations, trip departure times, and travel costs. It is possible that paratransit trips could be modeled using data from existing travel surveys, since most paratransit users are residents, but these samples may be too small or limited due to the fact that household surveys do not include group quarters, such as retirement or group homes.

5.5 SUMMARY

The future research and data development needs focus on filling the data gaps identified in the research on accounting for commercial vehicles in urban transportation models. While a significant amount of data was identified to support the development of model parameters for commercial vehicle in urban transportation planning models (that is planned in Phase II), it is also clear that a more consistent methodology for collecting data across vehicle categories would greatly enhance the accuracy and reliability of models developed from these data. Existing commercial vehicle surveys are very limited in understanding the travel behavior of commercial vehicles and exclude a significant number of commercial vehicle categories, but do contribute to our ability to understand simple trip characteristics of available commercial vehicle categories.

6.0 References

American Hotel and Lodging Association, *Lodging Industry Profile*, 2003. http://www.ahla.com/products_info_center_lip.asp.

Barton-Ashman Associates, Inc., *Piedmont Triad Area Commercial Vehicle Survey*, Prepared for the North Carolina Department of Transportation, January 1996.

Barton-Aschman Associates, Inc., and Cambridge Systematics, Inc., *Model Validation and Reasonableness Checking Manual: Travel Model Improvement Program*, Arlington, Texas, 1997.

Bearse, P., S. Gurmu, C. Rapaport, and S. Stern, *Paratransit Demand of Disabled People*, August 2003.

Boerkamps, J. and Binsbergen, A., *GoodTrip – A New Approach for Modeling and Evaluation of Urban Goods Distribution,* Delft University of Technology and the Netherlands Research School for Transport, 2000.

California Air Resources Board, *On-Road Motor Vehicle Activity*, May 1995. http://www.arb.ca.gov/research/resnotes/notes/95-9.htm.

California Energy Commission, processed California DMV Database, 2002.

Cambridge Systematics, Inc., *Accounting for Commercial Vehicles in Urban Transportation Models: Literature Review*, prepared for FHWA, January 2003. http://tmip.fhwa.dot.gov/clearinghouse/docs/accounting/.

Cambridge Systematics, Inc., Accounting for Commercial Vehicles in Urban Transport Models: Magnitude and Distribution, prepared for FHWA, November 2003.

Cambridge Systematics, Inc., Truck Trip Generation Data, National Cooperative Highway Research Program Synthesis 298, Transportation Research Board, 2002.

Cambridge Systematics, Inc., *Quick Response Freight Manual, Final Report,* prepared for the U.S. Department of Transportation and the U.S. Environmental Protection Agency, DOT-T-97-10, September 1996.

Federal Highway Administration, *Airport Ground Access Planning Guide,* 1996. http://ntl.bts.gov/DOC/AGAPP.html.

Fitzgerald, J., D. Shaunesey, and S. Stern, *The Effect of Education Programs on Paratransit Demand of People with Disabilities*, Transportation Research Part A: Policy and Practice, 34, 261-285, 2000.

Hunt, John Douglas, Stefan, Kevin J., and Abraham, John E., *Modeling Retail and Service Delivery Commercial Movement Choice Behavior in Calgary*, 10th International Conference on Travel Behavior Research, August 2003.

National Highway Traffic and Safety Administration, *Report to Congress, School Bus Safety, Crashworthiness Research*, prepared for the National Highway Travel Survey (NHTS), Research and Development, April 2002. http://www.nrd.nhtsa.dot.gov/departments/nrd-11/schoolbus/sbreportfinal.pdf.

National Transit Database, Federal Transit Administration web site. http://www.ntdprogram.com/NTD/ntdhome.nsf?OpenDatabase.

New York State DMV, Internet Office 2001. http://www.nydmv.state.ny.us/reginforce.htm.

NuStats International, Atlanta Area Commercial Vehicle Survey, Draft Final Report, 1996.

Oak Ridge National Laboratories, *National Highway Travel Survey Database*. http://nhts.ornl.gov/2001/index.shtml.

Oregon Department of Transportation, *Oregon Model Improvement Program,* http://www.odot.state.or.us/tddtpau/modeling.html#General%20Papers.

Parsons Transportation Group, *Commercial Vehicle Survey Report*, prepared for Denver Regional County of Governments, 2001.

Pearson, David, *Technical Memorandum on the Houston-Galveston Travel Surveys*, Texas Transportation Institute, Study No. 405090, March 1997.

San Diego City Schools, Transportation Department, *The Statistics of the Yellow School Bus.* http://transportation.sandi.net/stats.html.

SchoolBus.com, *School Bus Fleet Surveys Magazine*, October 2003. http://www.schoolbusfleet.com/stats.cfm.

Smith Travel Research Press Release, *Update of 30 Largest U.S. Hotel Markets for* Year-End 1998, February 9, 1999. http://www.hotelonline.com/News/PressReleases1999_1st/Mar99_STRmarkets.html.

Taxicab, Limousine and Paratransit Association, *Taxicab Division Fact Book*, 2002.

TEI Engineers and Planners, *Regional Study on Tourism/Commuter Trips,* prepared for the Florida Department of Transportation, District 5, April 2001.

T.F. Green Airport Authority, *Master Plan Update, T.F. Green Airport*, June 2001. http://www.landrum-brown.com/MasterPlans/PVD/PDFs/inventory-b.pdf.

United States Census Bureau, 2000 data, maintained by Laura K. Yax (Population Division), created January 25, 2002, last revised January 02, 2004. http://www.tetrad.com/pcensus/usa/census2000data.html.

United States Postal Service, USPS Data, June 2003.

Vehicle Inventory and Use Survey (VIUS), U.S. Census Bureau, SSSD, April 26, 2000. http://www.census.gov/econ/www/viusmain.html.

Walker Filed Airport Authority, *Walker Field Airport, Rental Car Revenues*, Grand Junction, Colorado, August 2003. http://www.walkerfield.com/Stats_PDF/AUTO0803.pdf.

Wilbur Smith Associates, *Commercial Vehicle Survey,* prepared for Southeast Michigan County of Governments, 1999.

Woods & Poole Economics, Inc., Employment Database, Woods & Poole Economics, Inc., 1794 Columbia Road N.W., Suite 4, Washington, D.C. 20009-2808, Phone: (800) 786-1915; Fax: (202) 332-6466, 2003.

Appendix A

Data Sources by Vehicle Category

Data Sources by Vehicle Category

Data sources used in the evaluation of methods and parameters are, in some cases, unique to each vehicle category and in other cases, used to support numerous vehicle categories. The data sources used to support the evaluation of each vehicle category are described individually in this section, even though some of these data source descriptions are redundant across categories.

School Buses

Every year in the United States, approximately 450,000 public school buses travel an estimated 4.3 billion miles to transport 23.5 million children to and from school and school-related activities, contributing about 0.3 percent of total VMT (National Highway Traffic and Safety Administration, 2002). Because most school buses travel on local and collector streets, the percentage of school bus VMT on those streets is much higher than the percentage of VMT on arterial roads and highways. School busing is the largest form of public transportation in the United States, with over 10 billion student rides provided annually (San Diego City Schools).

There are 23,900 school buses in the State of California. The average bus travels 13,000 miles each year (California Air Resources Board, 1995). Mileage accumulation rates (MAR) are higher for light heavy-duty buses (16,000 miles per year) than for heavy heavy-duty buses (12,500 miles per year). Contractor school buses exhibit considerably higher MARs (19,000 miles per year) than either public school buses (13,000 miles per year) or private school buses (9,200 miles per year). Thirty percent of total trip duration of school buses is spent idling. The California Air Resources Board estimated the statewide school bus population and VMT by counties as part of its air quality model.

In terms of data for analysis, *School Bus Fleet* magazine is one of the best sources of school bus statistics (SchoolBusFleet.Com). Each year it conducts a school district survey and a school bus contractor survey. The survey includes the number of buses on each route by size, number of students transported daily, total mileage, and total costs. However, data are collected for the top 100 school districts only.

Shuttle Services

The *Airport Ground Access Planning Guide* published by the Federal Highway Administration (FHWA) and Federal Aviation Administration (FAA) is the main source of data for airport shuttle fleet sizes (Federal Highway Administration, 1996). This document provides data for 28 cities, and has been designed to encourage regional and local planners to carry out site-specific analyses in a manner consistent with the planning process required for statewide and systemwide management systems. The planning process described in the *Guide* has been designed to maximize cooperation and collaboration between the airport authority and the state and MPOs responsible for the preparation of the congestion management system and the intermodal management system.

Smith Travel Research and tourist bureaus provided hotel room information for the 28 cities listed in the *Guide*. The Denver Commercial Vehicle Survey was used to obtain time-of-day distribution for shuttle services (Parsons Transportation Group, 2001). The Denver Survey defines shuttle services as trips whose purpose is to "Drop-off/pick-up" people.

Private Transport (Taxi)

The *Taxi Fact Book* is a good source of existing data on taxis for 270 cities in the United States (Taxicab, Limousine and Paratransit Association, 2002). For each city it provides summary data on population, total miles traveled, distance per trip, trips per taxi, passengers per taxi, and passengers per trip. These data were used to identify the fleet size, trips, and VMT for the regional estimates of taxi trips.

The *National Highway Travel Survey* includes 260 taxi trips made by residents in its current survey (NHTS, 2001). The survey shows that 24 percent of taxi trips are taken between 7:00 a.m. and 10:00 a.m., 26 percent are taken between 10:00 a.m. and 1:00 p.m., and the remaining trips are distributed evenly across the other hours of the day.

Hotel, airport, and attraction surveys collected by the Florida Department of Transportation contain trip records for 1,033 hotel visitors, 2,548 airport passengers, and 5,310 visitors to tourist attractions (TEI Engineers and Planners 2001). Each of these surveys shows taxi trips made by non-residents as a separate mode, resulting in 46 taxi trips to hotels, 181 taxi trips to airports, and 58 taxi trips to tourist attractions (for a total of 285 taxi trips).

Smith Travel Research and tourist bureaus provided hotel room information for the 28 cities listed in the *Airport Ground Access Planning Guide*. The 2000 Census was the source for demographic data on the number of workers in 134 cities. Additional cities can be obtained with additional work on the geographic boundaries of the taxi data compared to the Census data.

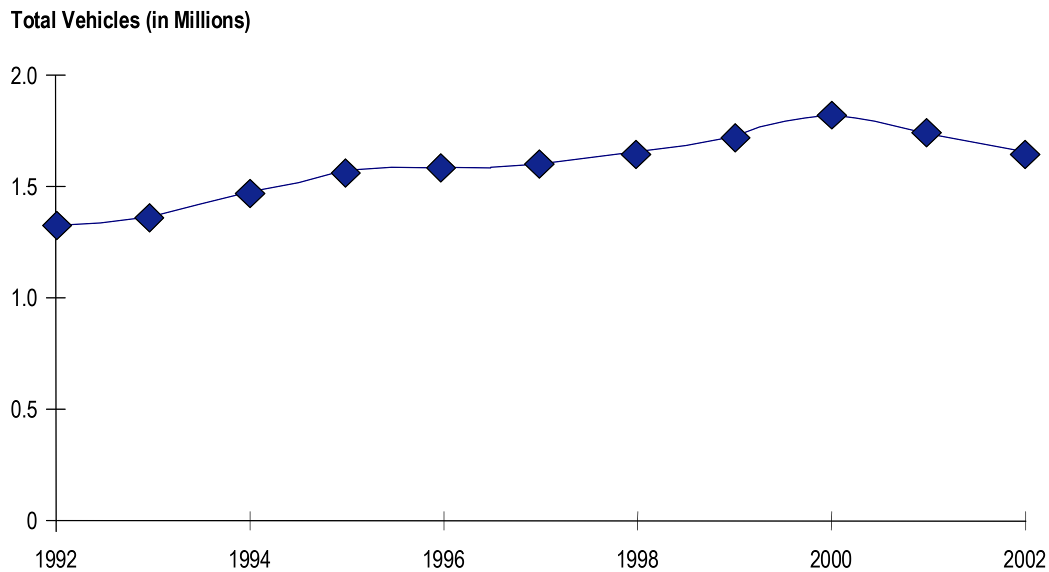
Paratransit and Social Service Vehicles

The National Transit Database (NTD), formerly Section 15 of the Federal Transit Act, is a valuable source of information on paratransit in the United States (National Transit Database, Federal Transit Administration). It provides data on transit agencies, modes of transport, the number of paratransit vehicles, VMT, and unlinked passenger trips. The project team obtained total population, population over the age of 60, and employment data from the U.S. Census Bureau database. Although the NTD database includes paratransit data from 315 cities, the team matched 220 cities and obtained household and employment data for further analysis.

Rental Cars

Following an increase in the number of rental cars in the United States from 1992 to 2000, companies began to trim the size of their fleets. In 2000, there were 1,829,000 rental cars in the United States, but by 2002 the number had declined to 1,643,000 (see Figure A.1).

Figure A.1 Total Rental Car Fleet Size in the United States
1992-2002



Correlating rental car fleet size with other variables, the project team found that hotel occupancy rates are directly related to the number of rental cars in the market. Nationwide hotel occupancy rates decreased between 2000 and 2002, as shown in Table A.1 (American Hotel and Lodging Association, 2003).

Table A.1 Average Hotel Occupancy Rates across the United States

Year	Hotel Occupancy Rate
2000	63.7%
2001	60.3%
2002	59.0%

Two published airport surveys include rental car data: the T.F. Green Airport survey (Rhode Island) and the Walker Field Airport (Grand Junction, Colorado) survey. The first was conducted for the Railway Industry Advisory Committee garage near the airport (T.F. Green Airport Authority, 2001). Nine rental car companies operate at the airport, among them Hertz, Budget, and Avis, which currently have 50 percent of the market share. These three companies operate 160 ready spaces inside the main parking garage and the remaining companies operate from satellite facilities along Route 1.

The Walker Field Airport Authority maintains rental car revenues by month for the last 12 years (Walker Field Airport Authority, 2003). Table A.2 shows the percentage of revenues by rental car companies. Although rental car fleet size may vary from the revenue data, these data are a general indication of rental car company market share at this airport.

Table A.2 Yearly Rental Car Revenues at Walker Field Airport

Rental Car Company	Revenue Share Percentage
Avis	24.4%
Budget	9.2%
Hertz	17.2%
National	25.4%
Thrifty	17.3%
Enterprise	6.5%

Florida District 5 (Orlando area) conducted a regional study on tourism and commuter trips (TEI Engineers and Planners, 2001). This study revealed that about 42 percent of the trips to hotels and airports in District 5 are rental car trips. The project team analyzed 5,545 rental car logs in Orlando, Volusia, Marion, and Brevard Counties to determine the time-of-day distribution. About six percent of the rental cars are rented in the a.m. peak, 39 percent at midday, 11 percent in the p.m. peak, and 44 percent at night. Florida rental car data also show that the average rental car occupancy rate is 3.4.

Data from the California Department of Motor Vehicles (DMV), published by the California Energy Commission, includes rental car statistics (California Energy Commission, 2002). These show that about 76 percent of all rental cars are sedans, four percent are pickup trucks, nine percent are sport-utility vehicles (SUV), eight percent are vans, and three percent are medium and heavy vehicles.

Based on the data from the California DMV, Hertz Rent-A-Car, T.F. Green Airport, and Walker Field Airport, the project team estimated the total fleet size and annual average mileage of rental cars in 13 cities, as shown in Table A.3.

Table A.3 Rental Car Data for 13 Cities

City Name	Fleet Size	Average Mileage per Car per Year
San Francisco	89,805	13,715
Los Angeles	88,219	15,054
San Diego	12,107	13,929
Denver	20,864	10,790
Orlando	20,356	12,051
Atlanta	19,124	12,926
Houston	16,448	13,368
Detroit	11,570	15,099

City Name	Fleet Size	Average Mileage per Car per Year
Portland, Oregon	8,241	13,960
Greensboro	2,734	14,540
Portland, Maine	2,194	13,010
Sacramento	9,913	13,495
Houston	8,291	14,039

Package, Product, and Mail Delivery Vehicles

The USPS is the main source for data on the public section of the package, product, and mail delivery category, and has provided data for seven cities: Atlanta, Denver, Detroit, Greensboro, Houston, Orlando, Portland. The average vehicle miles traveled per vehicle is 18.3 for light vehicles, 21.2 for medium-duty vehicles, and 103.7 for heavy-duty vehicles (most of the daily mileage for heavy-duty vehicles occurs in intercity travel at night). The average miles per day per vehicle for all these vehicles is 19.9.

Light-duty postal vehicles travel the fewest miles per day on average, but make up the majority of the total VMT. This is because light-duty vehicles constitute 95 percent of the USPS fleet. Heavy-duty vehicles have average mileages over five times greater than light-duty vehicles. Most likely, they make trips between distribution centers while light-duty vehicles are used on local delivery routes.

Data for private mail carriers are available through commercial vehicle surveys, although these do not specifically define package, product, and mail delivery vehicles or trips. The following four definitions are from the four commercial vehicle surveys reviewed by the project team:

1. **Atlanta Commercial Vehicle Survey –** Cargo is "printed matter" and purpose of the trip is either "delivery" or "pick-up."
2. **Denver Commercial Vehicle Survey –** Cargo is "packages" and purpose of the trip is "pickup/deliver a load."
3. **Detroit Commercial Vehicle Survey –** Cargo is "mail/small parcels/packages."
4. **Triad Area (North Carolina) Commercial Vehicle Survey –** Cargo is "mail/small packages/printed matter."

Data from larger private mail carriers would be very insightful and should be sought for future studies.

Urban Freight Distribution and Warehouse Delivery Vehicles

The *Quick Response Freight Manual* provides a basis for estimating Urban Freight commercial vehicles. The *Manual* identifies quick response parameters to predict all commercial vehicles, but this definition is not intended to include commercial vehicles carrying people. The *Manual* outlines procedures for producing trip tables that can be assigned to highway networks for three classes of commercial vehicles:

1. Four-tire commercial vehicles, including delivery and service vehicles;
2. Single unit trucks with six or more tires; and
3. Combination trucks consisting of a power unit (truck or tractor) and one or more trailing units.

Commercial vehicle surveys are another source of data for urban freight estimation. Truck surveys also may provide useful data, but do not provide a complete estimate of urban freight, as urban freight is not completely transported by "trucks."

Construction Transport Vehicles

Construction transport data are available primarily through commercial vehicle surveys, although these vehicle surveys do not specifically define construction transport vehicles or trips. The following definitions pertain to the four commercial vehicle surveys consulted by the project team:

1. **Atlanta Commercial Vehicle Survey –** Cargo is "lumber or wood" or "transport equipment."
2. **Denver Commercial Vehicle Survey –** Land Use is "construction" or "transportation, communications and other non-manufacturing industrial (on-site not office)."
3. **Detroit Commercial Vehicle Survey –** Industry is "construction" or "contractor" or "landscaping." Cargo is "lumber, wood products, other building materials," or "sand/gravel."
4. **Triad Commercial Vehicle Survey –** Land Use is "construction/gravel/landfill."

The California DMV data provides information on registered vehicle types for the cities of San Francisco, Los Angles, San Diego, and Sacramento. From this data construction vehicle fleet sizes can be estimated.

Safety Vehicles

The primary source of data on safety vehicles is the vehicle registration database maintained by every state government. The project team compiled data for four cities in California (San Diego, Sacramento, San Francisco, and Los Angeles) from data processed by the California Energy Commission (California Energy Commission, 2002). In this dataset, the following vehicle types were included in the safety services category:

- Government district – fire (light-duty vehicles);
- Government district – police (light-duty vehicles);
- Ambulance (medium- and heavy-duty vehicles);

- Fire truck (medium- and heavy-duty vehicles); and
- Tow truck wrecker (medium- and heavy-duty vehicles).

Commercial vehicle surveys are another source of data for safety vehicles. Of the four commercial vehicle surveys reviewed by the project team, only one (Detroit) contained data on safety vehicles (Wilbur Smith Associates, 1999). In Detroit, safety vehicles included the following vehicles based on their use:

- Plowing/snow removal vehicles; and
- Towing/road service vehicles.

The primary difference between the vehicle registration data and the commercial vehicle survey data is that the latter does not include government-related safety vehicles (fire trucks, ambulances, and police cars).

Demographic data for the analysis of safety vehicles, including total population and total employment for each city, was derived from the 2000 Census. Government employment also was tested as a variable and was derived from Woods and Poole data (Woods and Poole).

Utility Vehicles

The primary source of data on utility vehicles is the vehicle registration database maintained by every state government. The project team compiled data for four cities in California (San Diego, Sacramento, San Francisco, and Los Angeles) from data processed by the California Energy Commission (California Energy Commission, 2002). In this dataset, the following vehicle types were included in the utility services category:

- Government district – utility (light-duty vehicles);
- Government district – water/irrigation (light-duty vehicles);
- Garbage truck (medium- and heavy-duty vehicles); and
- Utility vehicle (medium- and heavy-duty vehicles).

Commercial vehicle surveys are another source of data for utility vehicles. Of the four commercial vehicle surveys reviewed, Atlanta, Detroit, and the Triad cities surveys contained data on utility vehicles. These surveys classify utility vehicles based on land use or industry (utility), cargo (electrical or tools/maintenance for office/government services), and purpose (maintenance). They do not include government-related utility vehicles, which represent 24 percent of total utility vehicles in the vehicle registration database.

Demographic data for the analysis of utility vehicles, including total population and total employment for each city, were derived from the 2000 Census. Government employment also was tested as a variable and was derived from Woods and Poole data (Woods and Poole, 2003).

Public Service Vehicles

The primary source of data on public service vehicles is the vehicle registration database maintained by some states. The project team compiled data for four cities in California (San Diego, Sacramento, San Francisco, and Los Angeles) from data processed by the California Energy Commission. In this dataset, the following vehicle types were included in the public services category:

- Government district – City (light-duty vehicles);
- Government district – County (light-duty vehicles);
- Government district – State (light-duty vehicle);
- Government district – Federal (light-duty vehicle);
- Government district – Other (light-duty vehicle); and
- Government district – School and college (light-duty vehicle).

Demographic data for the analysis of public service vehicles, including total population and total employment for each city, were derived from the 2000 Census. Government employment also was tested as a variable and was derived from the Woods and Poole data.

Business and Personal Service Vehicles

Commercial vehicle surveys and DMV data are reliable sources of data for business and personal services estimates. In this study, data were used from commercial vehicle surveys for Atlanta (NuStats, 1996), Denver (Parsons Transportation Group, 2001) and Detroit (Wilbur Smith, 1999) and California DMV data for Los Angeles, San Francisco, San Diego, and Sacramento. Census Bureau data were used to obtain population and employment information for those urban areas. Land use data also can be obtained from the Census Bureau to determine the magnitude and distribution of business and personal service vehicles. VIUS is another good source of data for business and personal services vehicles.

The following four definitions are from the four surveys reviewed by the project team:

1. **Atlanta Commercial Vehicle Survey** – Business and Personal Services is "driver need," Land Use is "office/government" with Vehicle Type not already classified as Package/Product and Mail Delivery or Public/Private Utilities.
2. **Denver Commercial Vehicle Survey –** Business and Personal Services classified for Land Use is "personal services (office and other buildings or outlets)" or "commercial and personal services (office and other buildings or outlets)."
3. **Detroit Commercial Vehicle Survey –** Business and Personal Services classified for Industry is "personal services" or "other professional services."
4. **VIUS –** Business and Personal Services is classified by Body Type and Major Use and Products Carried.