CAMBRIDGE SYSTEMATICS

MAG Internal Truck Travel Survey and Truck Model Development Study

final

report

prepared for

Maricopa Association of Governments

prepared by

Cambridge Systematics, Inc.

with

NuStats
Northwest Research Group

December 2007

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Table of Contents

List of Tables

List of Figures

1.0 Introduction

Goods movement forecasting and predicting future truck volumes are often a necessary pre-requisite for the development of regional transportation plans. Large metropolitan areas face increasing demands to produce transportation plans that reflect the rapid growth in freight flows, both in terms of transportation programming and regulation. Truck movements are a major consideration for the economic vitality of the region, congestion and travel demand management, air quality conformity analysis, and road infrastructure improvements. The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, enacted in 2005) includes freight as a planning factor for both metropolitan and statewide transportation planning.

The Maricopa Association of Governments (MAG) is a Council of Governments that serves as the regional agency for the metropolitan Phoenix area. MAG has continuously maintained and updated truck volumes forecasts. The major input required for both analysis and forecasting of the freight movements and truck volumes is based on regional truck studies and surveys. MAG maintains and develops a variety of forecasting tools for the purposes of regional transportation planning. MAG regional travel forecasting model is the main instrument for the future traffic volumes forecasting. It includes, as a major component, truck volumes forecasting submodel. The submodel, also referred to as the Phoenix Urban Truck Travel Model, was originally developed in 1992 for the Arizona Transportation Research Center, Arizona Department of Transportation (ADOT). This model was one of the first urban truck models in the U.S., and paved the way for many other urban truck models. It also has been used as a key reference and a case study in the Federal Highway Administration's (FHWA) Quick Response Freight Manual (QRFM).

Rapid growth in the region required an update and recalibration of the truck model in order to reflect emerging travel realities and address new planning challenges. The purpose of this study was to update the current internal truck travel model with the help of new internal truck travel surveys. Collecting truck travel data internal to a region is integral to updating regional truck travel models. However, internal truck travel surveys are too few and far in between, and little is known as to what works and what does not when designing surveys and collecting data. That is, there is a lack of significant research into what increases the effectiveness of truck data collection. This study used an innovative approach for collecting data using a combination of methods and sampling techniques.

Cambridge Systematics led the MAG truck model update that involved collecting internal truck travel data. Truck trip diaries, led by NuStats, are used for sectors that generate multi-stop tours that are short haul in nature. These surveys are designed to collect truck travel information that includes origin and destination information, stop locations and land use types at stops, trip lengths and number of trips by truck type and sector, and time-of-day distributions of truck trips. Operator surveys or establishment surveys, led by Northwest Research Group (NWRG), are used for sectors that generate truck traffic that are long haul in nature. These surveys were conducted by phone and were designed to collect information on the number of inbound and outbound truck trips at each facility or establishment, and the distribution of truck trips by trip distance and time of day.

This report also provides a review of the current truck model, methodology for the surveys, analyses of the survey data along with key findings and lessons learned during the survey tasks, model development methodology, and model calibration and validation results.

2.0 Model Development Process

This chapter provides the following two-part description of the truck travel model review task.

1. **Review of Existing Truck Model.** The results of the model review are documented here, including the methodology for model improvements and addressing data needs for correcting specific deficiencies and completing the survey plan required for the survey task (Task 3).
2. **State-of-the-Practice and State-of-the-Art Truck Travel Modeling Techniques.** This section includes a separate discussion on state-of-the-practice and state-of-the-art travel modeling for goods movement and commercial trucks. This section also includes a discussion of the pros and cons of each available technique.

Following the truck travel model review sections, this section also provides a set of recommendations for the model improvements specific to the MAG internal truck model.

2.1 Review of Existing Truck Model

The existing truck model, also known as the Phoenix urban truck travel model, was developed in 1992 for the Arizona Transportation Research Center, ADOT. This model was one of the first urban truck models in the U.S., and paved the way for many other urban truck models in the country. This model has also been used as a key reference and a case study in the FHWA's Quick Response Freight Manual (QRFM)[1]. The MAG Transportation and Planning Office (TPO), the metropolitan planning organization (MPO) for the Phoenix area, provided technical monitoring of the project. The primary objectives of the project were to conduct a travel survey of commercial vehicles operating within the Phoenix metropolitan area, and to use the data collected in this survey to develop commercial vehicle trip generation, distribution, and traffic assignment models. The models were designed to be incorporated into MAGTPO's UTPS-based travel model system, which was then used to predict highway and transit system usage throughout the metropolitan area.

Overview of Model Methodology

As noted above, the trip generation and distribution components of the MAG truck model are for internal commercial vehicle trips; that is, internal-to-internal

[1] The Federal Highway Administration, Quick Response Freight Manual, 1998.

movements only. The model consists of three commercial vehicle class trip tables (24-hour) that are factored into three time periods just before the traffic assignment step in the MAG travel demand model. The three vehicle classes are defined in terms of gross vehicle weight (GVW) ratings: light (less than 8,000 lbs), medium (8,000 to 28,000 lbs), and heavy (more than 28,000 lbs).

The internal truck model estimates trip tables using a traditional trip generation and distribution modeling approach. Trip ends are generated based on rates computed by land use. The rates are trips per employee and/or household and use traffic analysis zone (TAZ)-level socioeconomic data as the input to trip generation. There are separate rates for each truck class and each employment type at the trip end (including households). Trip distribution uses a gravity model with separate gravity models for each truck class.

Once the trip tables are developed, they are factored from 24-hour tables to period tables based on factors derived from hourly classification count data. Trucks are then assigned using a simultaneous multi-class equilibrium assignment procedure. The trip generation and distribution model was originally developed in FORTRAN language and later on converted to EMME/2. The EMME/2 model has now been converted over to TransCAD software.

Critical Data and Modeling Issues/Concerns

The model was one of its kind at the time and represented a major step forward in truck modeling. However, upon review of the documentation of the existing truck modeling process, we identified a number of issues that clearly need to be addressed in future updates and model development. The most critical issues identified are described below:

- The surveys were all done using trip diaries, but the recruitment and response rates were all very low. Though the trucks were classified by GVW class, there was no stratification by business sector. That is, target sample sizes were not estimated by business sector, which precluded the ability to determine if the surveys captured all kinds of commercial vehicles serving different industry sectors. The only distinction made to the data collection approach was recruiting vehicles operated by the U.S. Postal Service, and this was based on truck trip activity.
- The sampling frame for the surveys was the Department of Motor Vehicles (DMV) registration database, which has many pitfalls. The most critical ones are that the vehicle records are often not keyed in correctly, and use of these records will involve a lot of data mining to extract the information that is truly needed for the survey sample. The DMV database consists of trucks that are owned or registered, but there are usually a large number of trucks that are leased or rented by various companies in different sectors. That is, a significant portion of the actual users or drivers are not listed, and hence does not provide a good sampling source. Also, based on our prior experiences in other areas, the registration database will likely have a large number of

records that are no longer operating in the area and a large number of duplicate records. Apart from all of these issues, the process to acquire the database is both time consuming and bureaucratic.

- A significant portion of the internal truck trip generation in any urban area is created by the service industry and the Utility sector; that is, trucks that do not deliver goods. Since no stratification scheme was employed in the survey planning process, it is uncertain if this particular sector has been adequately captured. Also, due to the overlapping nature of these types of truck trips with other industry types, additional adjustments should be made to avoid duplication.
- There have been significant changes in industry logistics practices over the last decade that have resulted in new inventory management practices, a greater use of value-added warehouse and intermediate handling functions, and changes in the configuration of distribution networks. All of these have had a profound impact on the nature of truck trip patterns in the Warehouse and Distribution sector. The warehouse industry includes central warehouses for business enterprises, public warehouses, and storage establishments. In addition to this economic sector, many companies operate their own private warehouse and distribution facilities that are typically associated with the Wholesale Trade industry sector. These sectors have been crudely represented in the existing model, because no survey data collection was focused on this component of the model. So it is entirely possible that this has resulted in the underestimation of truck traffic at warehouse and distribution facilities.
- Trip generation rates for the model were based on sampling vehicles registered in the Phoenix metropolitan area. Internal truck trips are also made by vehicles registered outside of the region. An adjustment for this element of the vehicle population needs to be incorporated in the sample expansion methodology, or an alternative approach to sampling and population estimation needs to be incorporated in the data collection effort.
- The trip distribution models were calibrated based on the trip length frequency distributions derived from the trip diaries. Due to the sampling approach, these distributions were available only by GVW class and not by business sector. As there is evidence that the length of trips vary significantly across different sectors, the models would benefit from calibration by sector as well, provided there is enough data to do this.
- In the existing MAG urban travel modeling process, a number of special generators are included; these are the Sky Harbor International Airport in Phoenix and the Arizona State University's main campus in Tempe. But while these two generators are accounted for in the generation of passenger trips, neither these nor any special generators are included in the truck trip generation process.

- The existing model was calibrated to observe the vehicle miles traveled (VMT), and no screenline counts were used during validation. Validation should also include summaries by facility type, truck type, and area type.
- Axles per commercial vehicle factors are used to convert the trucks to passenger car equivalents (PCE) during the traffic assignment process. In subsequent model validation processes, these factors were modified to get better validation results against observed counts. The variation of PCE factors due to congestion and highway grade was not considered.
- The applicability of existing volume-delay functions developed for auto traffic, as applied to trucks, needs to be re-examined. Different speed/capacity relationships may need to be accounted for in the truck model if there are lane restrictions in the region that trucks encounter. The various roadway geometric configurations can impact the vehicular flow characteristics in a significant way.
- The external truck trips in the existing model are based on an external vehicle trip survey, and are included in the modeling process after the internal trips were distributed. Though this study focuses only on internal-internal trips, attempts are made to include the external truck trips into the gravity model based distribution process.

Trip Generation Model Improvements

One of the biggest issues in the internal model methodology is the data and methods of estimating trip generation. In 2002, the National Cooperative Highway Research Project (NCHRP) published Synthesis Report 298 on truck trip generation. This report critiques all of the available methods for estimating truck trip generation models. It also rates and presents data from numerous studies in North America that can be used to evaluate the reasonableness of the trip rates in the MAG model, and can provide guidance on techniques for improving estimation of these rates.

Our past experience suggests that typically the most significant problems in an internal truck model are associated with light trucks (less than 8,000 lbs) and maybe associated with specific land uses and their trip generation characteristics. These problems usually stem from trips generated at residential, retail trade, wholesale trade, construction, and service businesses. This suggests that data collection efforts be targeted at trucks that are involved in most of the aforementioned businesses in order to improve trip generation results for these sectors.

A separate model for trucks in the Service sector will be developed to estimate all other truck traffic that does not carry freight. Developing a separate model has proven challenging in other areas because it is expensive to collect enough data from surveys for these sectors, which makes it very hard to update or calibrate the Service sector model. Cambridge Systematics has collected data as part of the FHWA research on accounting for commercial vehicles in urban transportation models[2] that identified the magnitude and distribution of service vehicles in four categories: 1) safety, 2) utility, 3) public service, and 4) business and personal. These data and techniques will be used to develop the service industry trip generation model.

The existence of trip chains is important in the internal model, and they are not explicitly accounted for in the existing truck model. New tour-based modeling techniques are being applied to truck modeling in other parts of the world. Cambridge Systematics believes it is premature to include these techniques in the MAG model, and the budget is not sufficient to estimate these models.

Cambridge Systematics will evaluate the grouping of industries for the purposes of modeling trip generation to determine if more appropriate industry groupings would yield better results. We will also investigate the opportunity to introduce new trip types in the estimation of trip generation. The existing modeling structure uses vehicle weight classes as classification scheme for trip types, and estimates trip generation by weight class as a function of land use at trip ends. Alternate classification schemes will be explored, such as the FHWA axle and body classes, because the counts are going to be collected using the FHWA classification scheme. In addition to this, a third dimension will be added to the trip generation model to support estimation of trip rates by economic sector (manufacturing trips, warehouse and distribution trips, local pickup and delivery trips, and service trips).

Trip Distribution Model Improvements

The main improvement to the internal trip distribution model should be the incorporation of a more robust database on trip length frequency distributions for estimation of the model parameters. These will be developed based on a more extensive and representative sample of trip diaries and operator surveys that will be collected.

A second improvement to the trip distribution model that should be investigated is the development of multiple gravity models for trip distribution based on new trip types. Currently, the model uses different trip length frequencies for the estimation of gravity models by weight class, but it ignores the logical links (or lack thereof) among land uses for trips of different types (e.g., it is currently just as likely that a trip from a manufacturing facility will be attracted to a residence as a warehouse and distribution facility, trip lengths and attractions being equal). For the service industry, attempts will be made to derive the average daily trip lengths for these vehicles from other studies across the nation. It is also possible

[2] Cambridge Systematics, Inc., *Accounting for Commercial Vehicles in Urban Transportation Models*, prepared for the Federal Highway Administration, February 2004.

that, because freight from different sectors can get mixed, doing distribution by sector can be hard if it is part of a tour. In this case, the trip distribution will be done based on truck type only, and not by trip type or sector.

With regard to special generators, incorporation of the Phoenix Airport and Arizona State University trip generation techniques into the model will be evaluated, as will methods to forecast trip distribution patterns. Other generators such as intermodal terminals or large distribution centers will also be considered if these trip patterns are very different from the rest of the businesses.

Assignment Model Improvements

Time-of-Day Factoring

The 1992 truck model documentation indicated that the time-of-day distribution in the model was derived from the trip diary surveys. Although it is acceptable to use these distributions as a cross-check, it is usually not recommended to use these factors to divide the daily commercial vehicle trips into different time periods. Instead, hourly traffic count data has proven to reflect the time-of-day patterns better. Also, the count data includes a much broader range of sites by location and type of facility than the survey data. The time-of-day distribution in the counts normally does not exhibit significant variation by location or by type of facility, and so it is recommended that the count data be used to adjust the time-of-day factors for the internal model. Since the traffic count data will be based on the FHWA classification scheme, a correlation technique will need to be developed to derive time-of-day factors by GVW ratings. But if we decide to follow the FHWA scheme for modeling, then the derivation of these factors will be a straightforward process. The factors will not be distinguished by trip type or sector.

PCE Factors

The original MAG truck model used axles per commercial vehicle data from the unexpanded survey data to compute adjustment factors to account for passenger car equivalents in the traffic assignment process. But this model was changed subsequently, and the existing model does not use any PCE factors.

Volume-Delay Functions

Volume-delay functions used in the traffic assignment should be reviewed and updated in order to enhance the traffic assignment results. The trucks will be assigned along with autos using multi-class assignment procedures. Several sensitivity tests need to be conducted to examine the use of alternative volume delay functions, developed as part of the process for autos and trucks, as well as facility-specific delay functions. Ideally, different time penalties and values of time need to be introduced to enable the development of different vehicle impacts for each vehicle type, in contrast to the existing process where the impact in final speed is the same for trucks and autos.

2.2 State-of-the-Practice and State-of-the-Art Truck Travel Modeling and Survey Techniques

The state of the practice and state of the art in freight modeling has advanced significantly since the development of the MAG truck model in 1992. Prior to developing the modeling framework for the new MAG model, it is useful to review existing literature on freight and truck travel modeling. This reveals conceptual frameworks that may be useful in the current effort, as well as pitfalls that should be avoided. In the recent past, Cambridge Systematics conducted extensive reviews of both the state-of-the-practice and the state-of-the-art modeling techniques as part of another study.[3] The ensuing sections provide a brief description of the various techniques identified in those reviews.

The modeling techniques can be classified broadly into the following eight categories based on objective, methodology, and data requirements:

1. Link-based factoring;
2. Origin-destination (O-D) factoring;
3. Freight truck models;
4. Four-step commodity models;
5. Economic activity models;
6. Hybrid models;
7. Logistics/supply chain models; and
8. Tour-based models.

State-of-the-Practice Models

Link-Based Factoring Techniques

Link-based factoring techniques begin with existing truck volumes on a facility, on a modal network link, or at a freight-related terminal. Factors are developed to estimate changes in truck volumes due to changes in transportation service on the facility, or on an alternative facility of the same or different mode. For example, to develop truck counts in a future year, observed truck counts on a specific highway are increased by three percent per year. The three-percent value may

[3] Fischer, M. J., M. L. Outwater, L. L. Cheng, D. N. Ahanotu, and R. Calix, *An Innovative Framework for Modeling Freight Transportation in Los Angeles County*, prepared for the Los Angeles County Metropolitan Transportation Authority by Cambridge Systematics, Inc., January 2005.

be derived from historical truck volume growth, or based on another surrogate variable such as employment or economic growth. This simplified method permits existing data to be applied rapidly, and is usually intended for short-term forecasts. Many assumptions are needed to make these methods work, and the range of applicability is limited. The Quick Response Freight Manual, developed for the FHWA, describes methods of applying growth factors to traffic volumes that are applicable to urban highways. Only two model components are required for the simplified method: 1) observed link traffic volumes, and 2) methods to factor these flows.

Origin-Destination Factoring

Origin-destination (O-D) factoring forecasts truck flows by factoring a base year truck O-D table of truck flows and assigning the new truck O-D tables to the highway network. This method differs from the link-based method; in that, truck volumes are not directly observed, but produced by assigning a truck O-D table to a highway network. A variation on this approach is the factoring of commodity flow tables that provide tonnage flows by commodity between origins and destinations, splitting these flows among the available modes (using a mode choice model or fixed modal shares from the base year), and converting the truck flows to truck trips. The commodity O-D factoring approach is frequently used for statewide freight models, which generally focus on long-haul freight movement. Long-haul movement is well characterized in commodity flow datasets, such as the Commodity Flow Survey[4] and the Global Insight (formerly known as Reebie) TRANSEARCH database[5].

Three model components are required for the O-D factoring forecast method: 1) a base year O-D trip table for trucks (or a commodity flow table), 2) growth factors for the table, and 3) methods to assign the truck table to the highway network. The growth factors can be based on economic output, employment, or other growth indicators at the zonal level. The growth rates are often developed by using simple economic models. They are then applied to the base year O-D truck trip tables using iterative proportional fitting techniques to balance production and attraction growth rates. The iterative proportional fitting technique commonly used in transportation planning is known as Fratar factoring. Software to implement this technique is usually available in travel demand model

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[4] The Commodity Flow Survey is a survey conducted by the U.S. Bureau of the Census every five years based on a survey of establishments. The resulting database provides commodity flows at the national, state, and metropolitan level. Commodity flows are reported in tons, ton-miles, and value; and by mode.

[5] TRANSEARCH is a proprietary commodity flow database that provides information on tons moved by mode. Origin-destination information is provided at the county level. Reebie Associates originally developed TRANSEARCH, and the database is often called Reebie data. Reebie Associates was acquired by Global Insights in 2006.

packages (CUBE, TRANPLAN, TP+, EMME/2, and TransCAD). Methods to assign truck tables to the highway network depend on the availability of other data, and are not limited by the O-D factoring models.

Base year O-D truck trip tables can be estimated in a variety of ways, depending on the availability of data. One approach that has been used with some success is the origin-destination matrix estimation (ODME) process. This method utilizes observed truck counts and partial O-D data (usually from O-D surveys) to estimate a truck trip table. Nonlinear programming techniques are used to estimate a trip table that, when assigned to the network, minimizes the difference between predicted and observed truck volumes. The partial O-D data and best judgment estimates for the unknown O-D information are used to construct a "seed" table. The nonlinear programming process then adjusts the trip table to obtain the best fit with the truck count data. The base year table produced from the ODME method can then be factored to a forecast year using the methods described previously. ODME models for trucks have been developed in the New York City region by List and Turnquist.[6] The ODME process is available as a standard module in the CUBE and TransCAD travel demand model packages.

Three-Step Freight Truck Models

Freight truck models develop highway freight truck flows by assigning an O-D table of freight truck flows to a highway network. This is the class of truck model currently included in the MAG travel demand model. The O-D truck table is produced by applying truck trip generation and distribution steps to existing and forecast employment and/or other variables of economic activity for analysis zones. This method differs from O-D factoring in that the O-D table is estimated directly using trip generation rates/equations and trip distribution models at the TAZ level. The mode choice step is unnecessary since truck trips are estimated directly, and there is no need for the consideration of other possible modes for moving freight. The components required for this modeling technique include existing and forecast zonal employment data, methods to generate zonal freight productions and attractions by using freight truck trip generation rates, methods to generate truck O-D flows by applying trip distribution procedures to truck productions and attractions, and methods to assign the O-D freight truck flows to a highway network.

Freight truck models usually attempt to account for shipment of goods, including local delivery. Because these models are focused exclusively on the truck mode, they cannot analyze shifts between modes. Truck models are usually part of a comprehensive model that forecasts both passenger and freight movement, and consequently will often use a simultaneous assignment of truck trips with auto trips.

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[6] List, G. F., and M. A. Turnquist, *Estimating Truck Travel Patterns in Urban Areas*, Transportation Research Record 1430, 1995.

As noted above, freight truck models follow a three-step process of trip generation, trip distribution, and traffic assignment. Trip generation estimates the number of trips either produced in each zone or attracted to each zone, and is usually a function of socioeconomic characteristics of the zone (employment by industry, population, or number of households). Trip generation is accomplished using truck production and attraction equations, which coefficients are estimated based on local surveys or by using parameters borrowed from other sources such as the Quick Response Freight Manual. Trip distribution determines the connection between trip origins and trip destinations.

Trip distribution is generally accomplished using a gravity model similar to that used in a passenger model. In the gravity model, the number of trips that travel between one zone and another is a function of the number of trip attractions in the destination zone, and is inversely proportional to a factor measuring the impedance between the two zones. (The gravity model is usually related to the travel time between two zones (i.e., the longer it takes to get from one zone to another, the less attractive trips to that destination zone become).) Parameters in the gravity model can be developed from local surveys or borrowed from other sources, such as the Quick Response Freight Manual. The route that trucks use to get from origin to destination is a function of network characteristics, taking into account traffic conditions on each route.

Network assignment of the truck trips is usually based on a multi-class equilibrium highway assignment that includes passenger cars; in other words, the model looks for the shortest time path for all trips simultaneously. Freight truck models can take into account the different classes of trucks and their impact on congestion compared to automobiles (Large trucks cause more congestion, because they occupy more space than autos.). In addition, the networks can be coded so that any specific link can either allow only truck trips, or can exclude the use of truck trips.

Four-Step Commodity Flow Models

The four-step commodity flow model is similar in structure to the four-step passenger model. Both the four-step commodity flow models and the four-step passenger models require the development of a network and zone structure. Since a larger percentage of freight trips in an urban area are long haul than is the percentage of passenger trips that are long haul, a skeletal highway network external to the region is usually appended to a local passenger network to allow for assignment of these long-haul freight trips. Commodity models can analyze the impact of changes in employment, trip patterns, and network infrastructure.

The commodity-based "trip" generation model actually estimates the tonnage flows between origins and destinations. These flows are converted to vehicle trips after the mode choice step in the process. The trip generation models include a set of annual or daily commodity tonnage generation rates or equations by commodity group that estimate annual or daily flows as functions of TAZ or county population and disaggregated employment data.

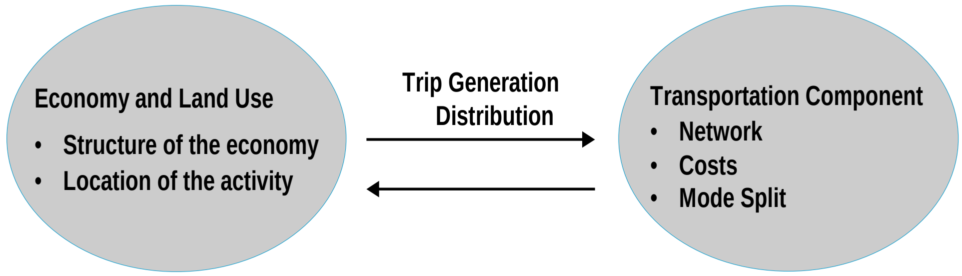
Base year commodity flow data at the zonal level are used to estimate the trip rates or trip generation equations. The O-D tables for these flows are typically estimated using gravity models similar to the trip distribution step in four-step passenger models. Trip distribution models are estimated separately for each different commodity group. The unit of flow in the O-D table is typically tons shipped. The distribution of freight is to a national system of zones, recognizing the large average trip lengths in this class of models. Mode split is a necessary component, because O-D patterns are developed for particular commodities rather than for trucks. Quite often, the mode split step simply assumes that the base year mode share of each commodity flow stays the same in the future. The conversion of commodity truck tonnage to daily freight truck trips uses the application of payload factors (average weight of cargo carried per vehicle load). Payload factors can be estimated on a commodity-by-commodity basis using locally collected survey data (e.g., roadside intercept surveys) or national surveys (e.g., the U.S. Census Bureau Vehicle Inventory and Use Survey). The assignment of truck freight will typically use either a freight truck only or multi-class assignment model.

Economic Activity Models

An economic activity model includes an economic or land use model as a step before the traditional four steps. Economic activity models are the freight equivalent of the integrated land use transportation models used in the analysis of urban passenger travel. They require specific data concerning the availability of land and the rules governing the development and location of certain industries, and an understanding of the interdependencies between industries.

Economic activity models estimate the flows of commodities between economic sectors and between zones. They assume that the zonal employment or economic activity is not directly supplied to the model, but is created by applying an economic or land use model. The modeling technique used for economic activity models is known as a spatial input-output (I-O) model. The spatial I-O model distributes household and economic activity across zones, uses links and nodes of a transportation network to connect the zones and model the transportation system, and then calculates transportation flows on the network. It uses a land use component to generate and distribute trips, and a transportation component to generate mode split and network assignments. The two sides of the model inform each other, resulting in a dynamic model, as shown in Figure 2.1.

Figure 2.1 Economic Activity Model Process



The model uses an I-O structure of the economy to simulate economic transactions that generate transportation activity. A spatial I-O model identifies economic relationships between industries and between industries and households, accounting for the geographic or spatial relationships associated with the economic relationships (origins and destinations of the economic flows). In future years, the spatial allocation of economic activity, and thus trip flows, is influenced by the attributes of the transport network in previous years. Thus, the model is dynamic with respect to land use and transportation. It differs from the four-step commodity class of models; in that, it uses an economic or land use model to forecast zonal employment or economic activity prior to the trip generation step. The freight component of the Oregon DOT's statewide travel demand model is an example of an economic activity model.

Hybrid Models

State-of-the-practice metropolitan truck models are hybrids that blend commodity flow modeling techniques with freight truck modeling techniques. Commodity flow databases tend to be relatively accurate for intercounty flows, but undercount intracounty flows because commodity flow databases rely, in part, on economic input-output data that ultimately are based on financial transactions between producers and consumers of goods. However, in an urban area, many truck moves are not easily traced to such transactions. Moves from warehouses and distribution centers, repositioning of fleets, drayage moves, parcel delivery, and the like are generally short-distance trips, in which there may not be an economic exchange of the goods from one party to another.

To compensate for the undercounting of the shorter-distance trips, local truck trips are generated based on local employment and economic factors using trip generation rates. These trips are usually generated at the zone level, and trip distribution uses methods such as gravity models. The trip rates are calibrated so that the truck traffic volumes that are generated from the combined commodity flow and locally generated truck trips match those from available truck counts. Several terms are used to refer to these two trip types, including commodity flow trips versus locally generated trips, external versus internal truck trips, and long-haul versus local truck trips.

State-of-the-Art Models

Research programs throughout North America and Europe are presently developing a new generation of freight models. Two techniques in particular are receiving widespread interest: 1) logistics/supply chain models, and 2) tour-based models. The logistics/supply chain models borrow techniques from industrial supply chain planning in an effort to track goods as they move along the supply chain from producer to consumer. The tour-based models focus on the trip chain characteristics of intrametropolitan trucks. Examples of these model types are presented below.

Logistics/Supply Chain Models

GoodTrip Model[7]. The GoodTrip model combines features of logistics chain models and tour-based models to analyze urban goods movement flows. The model defines a set of activity types, which when linked together, may describe either a logistical chain or a set of stops on a vehicle tour (or in some cases, a combination of both). Activity types include the following:

- Consumers,
- Supermarkets,
- Teleshop,
- Hypermarkets,
- Urban distribution centers, and
- Factories.

The model starts its calculations at the consumption end of the chain and estimates the demand for goods by goods type (analogous to commodity) for each zone in the model. The share of this demand, allocated to each of the activity types in each zone, is also estimated based on models developed from survey data. The model then uses information about the spatial and functional relationships of each of the activity types and probabilities to estimate flows by activity type and zone. The goods flows are then assigned to vehicle tours for each origin-destination pair. The origin's activity type determines the transport mode, vehicle capacity, vehicle loading factor, and number of stops per tour. This conversion of goods flows to vehicle tours establishes the trip table for assignment to a network.

This modeling approach is of particular interest because of its urban focus, and its ability to analyze how changes in logistics organization affect vehicle traffic.

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[7] Boerkamps and van Binsbergen, *GoodTrip – A New Approach for Modelling and Evaluation of Urban Goods Distribution*, Delft University of Technology, and The Netherlands Research School for Transport, Infrastructure and Logistics.

Strategic Model for Integrated Logistics Evaluation (SMILE)[8]. Researchers at the Transport Research Centre of the Netherlands Ministry of Transport, Netherlands Economic Institute, and TNO Inro have developed a logistics chain model called SMILE, which can be used as a decision support system for freight transportation policy evaluations. This model begins with an economic input-output modeling approach that calculates supply and demand for each economic sector based on industry production functions. This establishes the economic trade flows for the region of interest. The logistics module assigns each goods flow to a logistics family with common characteristics. The assignment of goods to logistics families is based on the spatial patterns of supply and demand options for the good. The common characteristics for each logistics family are those that define the type of inventory control and logistics system that will be used to distribute the product. A series of logistics models are developed that define the distribution systems that are used by each logistics family and the spatial organization of warehousing and distribution systems for product delivery and supply chain management. The information about logistics chains is then fed into a transport model that determines the modes of transport used and the optimum modal network paths from origins to destinations.

Tour-Based Models

University of Calgary[9]. Researchers at the University of Calgary have developed an approach that applies tour-based microsimulation modeling concepts to urban goods movement modeling that was originally developed for passenger modeling. However, in their approach, they define the tours for vehicles rather than for passengers. The model recognizes that many commercial vehicles conduct activities in tours – that is, a series of linked trips that do not necessarily involve a return to home base on every trip. In the model, a synthetic population of business establishments is developed from aggregate data, and these are used to estimate the number of tours generated for a particular commercial activity. The business establishments are the operators of the vehicles that conduct the tours, and the approach can be applied to retail establishments, service businesses, or any other type of commercial vehicle operation.

Stops on the tours are generated based on traditional variables used in trip generation (population, households, employment by business sector). For each vehicle tour, a series of choice models are employed in order to determine the type of vehicle that will be used to conduct the business of the tour; the purpose of each stop (goods pickup or delivery, service, return to home); and the location

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[8] Tavasszy, Smeenk, and Ruijgrok, *A DSS for Modelling Logistics Chains in Freight Transport Policy Analysis*, Seventh International Conference of IFORS, 1997.

[9] Hunt, Stefan, and Abraham, *Modeling Retail and Service Delivery Commercial Movement Choice Behaviour in Calgary*, 10th International Conference on Travel Behaviour Research, 2003.

of the next stop. The choice models are logit choice models that use variables related to what has happened previously on the tour, the attractiveness of zones that could include the next stop on the tour (measured in terms of the number of trip attractions estimated for the zone), and the location of the stops relative to home base (taking into account travel times from zone to zone). The choice models are estimated from travel diary data, and have been applied successfully to simulate retail and service trips.

2.3 Summary of Pros and Cons of Modeling Approaches

Each of the modeling techniques described in the previous sections has strengths and weaknesses. The state-of-the-practice commodity flow models have the advantage of being based on extensive and readily available multimodal freight flow and economic activity data. On the other hand, many local truck moves, including trips from warehouses and distribution centers, fleet repositioning, empty return trips, and truck drayage moves, as well as service, utility, and construction trucks, are not accounted for in these models. Many of these missed truck trips are short trips within urban areas. Therefore, truck models based exclusively on commodity flow data tend to underestimate truck trips in the urban area. In addition, the commodity flow data are generally not available at the TAZ level, and techniques of questionable accuracy must be used to disaggregate county-level data.

Models built exclusively from truck trip generation and attraction rates based on local economic activity have the advantage of being tailored to the economic activity data of the study area. Truck trip generation rates can be estimated from local data that include all truck moves, and not simply moves based on commodity flows. These models can be made more responsive to changes in local economic activity and population relative to truck models based on commodity flow data. However, truck models based on locally generated truck trips do not incorporate goods movement factors for external regions. Therefore, external and through truck trips are not well modeled. In addition, changes in external regions over time cannot easily be incorporated into truck model forecasts. The behavioral basis of these models is crude; they cannot reflect changes in the structure of truck operations over time, and they do not accurately account for the trip chain characteristics of many urban truck trips. Finally, the data required to estimate accurate trip generation and distribution models, given the variety of truck trip types, are very extensive. Collecting sufficient data of this type from private businesses has proven to be very difficult in past studies.

Hybrid models, which take advantage of the benefits of the commodity flow and local truck models, including freight and other nonfreight truck purposes, have proven to be the most effective modeling framework to date. Long-haul truck trips are modeled using the commodity flow database, which can be adjusted over time based on economic factors. Short-distance truck trips can be estimated as a function of local employment characteristics. The hybrid models are used in several metropolitan areas, and therefore have a theoretical framework that has proven applicable to metropolitan and regional models.

Despite their proven benefits and usefulness, hybrid models lack the ability to fully track logistics chains that have mixed long-haul and local components. The commodity flow data accurately estimate primary movements – that is, the flow from producers to consumers. The extensive information available on the amount of goods produced and consumed in the economy and the location of production and consumption sites helps ensure the accuracy of primary commodity flow data. However, not all of the secondary moves – the intermediate handling of goods at warehouses, distribution centers, and truck terminals – are effectively captured in commodity flow data. Sources such as the Bureau of Transportation Statistics/Bureau of Census Commodity Flow Survey, which surveys warehouses about commodity moves, do not distinguish primary and secondary flows. It is therefore impossible to associate these secondary flows with warehouse locations or warehouse activities. The hybrid models attempt to fill this gap by estimating all local truck trips through three-step trip generation and distribution models. However, these models lack explicit links between the primary flows generated by the commodity flow data and the local truck trips. It is impossible to track flows of goods throughout the entire logistics chain to ensure consistency of the two approaches. The hybrid models do not allow for analysis of how changes in logistics patterns affect transportation demand.

Another disadvantage of the hybrid model is that it does not account for the trip-chaining characteristics associated with several different types of local truck moves. Both the commodity flow truck trips and the local truck trips are generated based on a trip being a single origin with a single destination. However, several types of trips (particularly those made within the metropolitan area) are by trucks that utilize a "sequentially unloading, return empty" truck-trip pattern. Trucks leave their origins with a full load, make several stops to deliver partial loads, and return empty to their point of origin. Some trucks follow the reverse pattern, leaving their origin empty and returning with a full load after making pickups at multiple locations. These truck-trip types are not well captured by the hybrid model. Service trucks also exhibit this trip chaining characteristic.

2.4 Recommendations for the MAG Truck Model

The primary objectives of this Urban Truck Travel Model project are to conduct a travel survey of commercial vehicles operating within MAG's region, and to use the data collected in this survey to develop a commercial vehicle travel model. The commercial vehicle truck model needs to be incorporated into the MAG regional travel model system that includes passenger vehicular trips. The model is focused on internal truck trips, which are usually short-haul trips, and generated predominantly by certain types of industry sectors. Based on the review of all the state-of-the-practice and the state-of-the-art models, the three-step truck modeling approach is the best suited for this study.

The socioeconomic data that is used to estimate internal trip generation in the truck model is consistent with those data being used in the passenger model, except that the employment data is stratified into more employment categories. This process provides more accuracy for truck travel and allows for a direct relationship between the industrial sectors being represented in the internal trip model and the allocation of trucks generated from these industries to TAZs within the region. The different land use/employment categories that are used in the internal truck model are households (residential, group quarter, and total); retail; industrial; public; office; and other employment.

The approach to targeting truck owner segments in the survey task is to identify truck owners and/or operators who represent the prevalence of trips to specific land use/business types based on the profile of customers served by the truck owners. The trip diaries and operator surveys collected information on the type of business at each stop. When all of the trips to each industry category represented in the model are aggregated and the sample is expanded, data on the total number of trip ends at businesses in each industry category is achieved. Dividing by the number of employees in each industry category provided trip generation rates by truck size class that are applied to socioeconomic data to estimate trip ends by TAZ. This approach is a little different than traditional trip generation modeling since the trip end represents both an origin and a destination, and this needs to be input properly to travel demand modeling software.

In the new truck model, attempts are made to add more categories to increase precision of truck trip generation. This includes modeling of truck trip generation from warehouses, distribution facilities, and truck terminals, which are known to generate multiple-stop tours in a single day. This is based on the operator survey-based data collection approaches. However, wherever the characteristics of truck trip behavior are very similar among certain sectors, they are grouped back into fewer categories.

The QRFM and the NCHRP Truck Trip Generation Synthesis Report is used as a means to validate and/or adjust the trip rates computed from the trip diaries during model calibration. Other sources of validation data for trip generation are investigated and included in a trip generation/distribution model validation plan that is presented to MAG prior to completion of the trip generation and distribution models.

As mentioned earlier, a separate analysis of existing data is also conducted to model trucks in the service industry sector. The data, collected as part of the FHWA research project that identified the magnitude and distribution of service vehicles, was based on the California DMV obtained for Los Angeles. This data was also used to identify fleet sizes for these vehicles. The Vehicle Inventory and Use Survey (VIUS) also can be summarized by state or metropolitan areas within a state, but this may be too small a sample size. A similar approach is used in this study where the size and weight of the vehicles in this category are determined from available data for the MAG region.

The truck trips are distributed from origins to destinations using the gravity model technique. The external trips from the existing truck model are added to the internal trips before trip distribution; that is, the same set of gravity models are used for both internal and external trips. The friction factor curves from the existing truck model are used as a starting point to distribute truck trips by type. These friction factors that are a function of travel time impedances are recalibrated based on the new truck trip diaries that are collected through truck travel surveys. The calibration process involved comparing the trip length distributions of trucks by weight class from the gravity model to the observed trip length frequencies from the truck trip diaries. Gravity model parameters are calibrated separately for short- and long-haul truck movements using average trip length data from trucks surveys. After distributing trucks based on truck impedances generated from free-flow travel time skims, the trip tables are balanced after assigning trucks along with autos; congested travel time skims are derived and fed back into the trip distribution process to recompute impedances based on congested conditions.

The truck trip assignment methodology is refined and improved based on new data and techniques that is part of the surveys and model development effort. These include the following:

- **Time-of-day factors.** The existing factors are examined through recent traffic count data, and the time periods are consistent with MAG's existing travel demand modeling process. As we have reliable counts only for the arterials, but not the freeways, it is recommended to use the existing time-of-day factors.
- **Roadway capacity and congested speeds.** The volume-delay functions (VDF) used to estimate average speeds as a function of volume and capacity will be evaluated to determine if new VDFs are necessary. This will be an iterative process that involves modifying the parameters of the speed-flow curve during model calibration and validation. However, since this study involves updating just the internal trucks and not the autos and external trucks, the existing VDFs will be used as is for assignment validation.
- **PCE factors.** The existing model does not use any PCE factors. In order to incorporate new PCE factors, the existing capacities that are expressed as vehicle per hour per lane on all the highway links need to be updated to reflect passenger car per hour per lane. So it is recommended that this task not be done as it will affect the validation of the auto passenger model.

The existing multi-class assignment procedures in the MAG travel demand model is examined and necessary changes made to incorporate the improved methodology.

2.5 RECOMMENDATIONS FOR MODEL DATA

Socioeconomic and Demographic Data

There are five employment categories currently being used in the truck model. These categories are very aggregate and they are retail, industrial, public, office and other employment. More disaggregate employment data is required to adequately capture the relationships between truck trip generating entities and various employment types. This is very essential in developing robust truck-trip generation models. The employment data should either be at the 3-digit NAICS level or 2-digit Standard Industrial Classification (SIC) level.

Another data source that is becoming increasing popular and reliable is the Longitudinal Employment and Household Dynamics (LEHD) data that is produced by the U.S. Census Bureau. LEHD is potentially an alternate/additional source of place of work and flow data. LEHD links State Quarterly Census of Employment and Wages (QCEW) with Federal administrative records. It is recommended that MAG staff evaluate these data and compare it with the existing SED data to identify any problem areas and approaches to improve data quality.

Model Skims, Networks, and Scripts

The existing skimming process and skim data were reviewed to identify any drawbacks, and subsequent improvements will be suggested. The underlying highway networks were reviewed for connectivity, and truck routes coded based on available information. The model files in TransCAD GISDK scripts were also reviewed, and appropriate recommendations made to improve its efficiency.

Traffic Count Data

Truck counts from various sources were compiled to obtain a set of truck counts by truck class. Other parallel studies, such as the 2006 MAG Regional Traffic Volume Survey, were also considered to derive truck data for validation purposes. These truck counts were used to validate average daily truck volumes from the model by screenline and facility type. The count locations were examined to evaluate its adequacy to perform a thorough model validation. In cooperation with MAG staff, reasonable validation criteria were identified that determines the reliability and accuracy of results.

2.6 TRUCK STRATIFICATION: GVW OR FHWA CLASSES?

This section provides a brief discussion about the type of stratification scheme to be adopted for this truck model update. The following two schemes are presented here:

1. **Gross Vehicle Weight (GVW).** This is the scheme of stratification of trucks in the existing MAG truck model that produces truck volumes into the following weight categories: less than 8,000 lbs; 8,001 to 28,000 lbs, and more than 28,001 lbs. GVW is a unique characteristic of a vehicle that is the sum of the empty vehicle weight and its payload. GVW classification ratings are primarily used for air quality modeling purposes; however, the recent MOBILE6 new air quality emissions model, while still based on engine power and GVW, includes 14 truck classes that are in excess of the three classifications in the existing model. GVW ratings of vehicles cannot be observed or measured, but can only be determined while administering intercept surveys. Hence, it is hard to associate a vehicle of certain GVW to a particular vehicle configuration, as it only gives an indication about probable body type, and it therefore becomes extremely difficult to validate these classes to observed truck counts. The FHWA provides guidance on how to estimate the MOBILE6 vehicle classifications consistent with its own VMT reporting.[10]
2. **FHWA vehicle configuration.** This is primarily based on the physical appearance of a vehicle, especially the body type (e.g., automobile, single unit, combination tractor trailer, and multiple trailers); and number of axles and/or tires. The classification scheme adopted by the FHWA separates vehicles into 13 categories, including passenger vehicles (i.e., motorcycles, automobiles, and buses) and trucks. Trucks are further subdivided by number of axles and number of units, both power and trailer units. Vehicle configuration can be determined by machine counters that provide number and spacing of axles, or even length-based counters that provide length of vehicles. The truck classification is customarily grouped into pickup trucks (FHWA Class 3), single-unit trucks (FHWA Classes 5 to 7), and combination trucks (FHWA Classes 8 to 13). The U.S. Environmental Protection Agency (EPA) provides guidance on the mapping of the FHWA vehicle classes to MOBILE6 vehicle classes for air quality modeling.[11]

Implications

The available trucks counts and those that are being collected by MAG classify trucks by the FHWA classification scheme or by number of axles, because it is just not possible to collect GVW ratings of trucks in a traffic count program.

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[10] http://www.fhwa.dot.gov/resourcecenter/teams/airquality/disaggregating.cfm.

[11] The High Performance Monitoring System (HPMS) vehicle types can be mapped to MOBILE5b vehicle types using Table 2-1 from the Emission Inventory Improvement Program (EIIP) document, *Use of Locality-Specific Transportation Data for the Development of Mobile Source Emission Inventories*, available at www.epa.gov/ttn/chief/eiip/techreport/volume04/ (see PDF of Chapter 2). The resulting MOBILE5 VMT mixes can be converted to MOBILE6 fractions using a methodology in Chapter 5 (Section 5.3.2) of the MOBILE6 User Guide.

Hence, one of the main issues before the validation of the truck model is that the truck volumes from the model have to be converted from GVW ratings to the FHWA classes, and then compared against the counts. This process, while feasible, introduces the errors of the conversion process into the validation. This is a problem especially in the lighter categories where the GVW is less than 10,000 lbs. There is not a one-on-one correlation between the GVW ratings and the number of axles in this weight range.

Analyses from previous truck modeling studies[12,13] confirm that the ability to accurately predict truck volumes in the lighter-weight categories is one of the most serious shortcomings in an urban truck model. The analyses also show that this is a problem that is unlikely to be successfully resolved within the existing GVW framework of the existing MAG truck model, given the variety of uses of trucks in this weight class and the characteristics of their behavior relative to other trucks included in the model. The gray area or the problem area is of trucks less than 10,000 lbs, which are mostly standard pickups and vans. Many of these types of trucks are used as personal vehicles, and thus are already captured in the MAG passenger travel model. It is extremely difficult, if not impossible, when conducting vehicle classification counts to distinguish those pickups and vans that should be included in the truck model from those that should not. This leads to poor results when validating the truck model for light trucks.

Recommendations

As the main application of the MAG truck model will be for planning purposes and policy analyses, the model should be reconfigured to estimate trucks by the FHWA classes and not GVW ratings. Also, since the truck counts will be based on the FHWA classes that distinguish trucks by axles and body type, a direct correlation can be achieved between those that are modeled versus observed. The most typical way of stratifying trucks is:

- **Light.** 2-axle, 4-tire commercial vehicles;
- **Medium.** 2+ axle, 6+tire, single unit commercial vehicles; and
- **Heavy.** 3+ axle, 6+tire, combination unit commercial vehicles.

The only pitfall is that the modeled truck volumes need to be converted to GVW ratings before applying the model to perform air quality analyses; however, guidance on this process is available from the FHWA and the EPA.

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[12] Meyer Mohaddes Associates, *SCAG Heavy Duty Truck (HDT) Model*, prepared for Southern California Association of Governments, 1999.

[13] Cambridge Systematics, Inc., *SCAG Truck Count Study: Truck Classification System*, prepared for Southern California Association of Governments, August 2001.

3.0 Survey Methodology and Sampling Framework

This chapter provides detailed description of the various survey methodologies used in this study, along with the sampling framework used to conduct these surveys. It provides a description of the various methods adopted to accomplish data collection for this project. These are the following:

- **Trip Diary Surveys.** NuStats worked on this;
- **Operator Surveys.** Northwest Research Group worked on this; and
- **Service Truck Activity.** Cambridge Systematics worked on this.

These three methods are described here with the focus on the following two main topics:

- **Survey Methodology.** Description of the survey methodology adopted for truck travel surveys and other data collection procedures. This includes the various steps involved in conducting the surveys, and also provides a list of various sectors targeted in these surveys.
- **Sampling Framework.** Findings from analyses of the sampling framework and recommendations on any changes. This involves reviewing the sample database to assess its reliability to perform surveys for the various sectors. It also includes any suggestions on supplementing the database with more information.

3.1 TRIP DIARY SURVEYS

NuStats worked on these surveys. The sectors that are focused in these surveys are agriculture, mining, construction, retail trade, local pickup and delivery, mail/parcel, and for-hire categories.

Sampling Framework

MAG's 2005 Employment Database was used to select the sample of truck fleet operators to conduct the truck travel diary portion of MAG's internal truck survey. The truck diary survey focuses on businesses located in Maricopa and Pinal Counties and portions of Yavapai County, which own trucks that are two-axle, six-tire and larger vehicles that are used to transport products within the region.

The Employment Database is a list of all known businesses employing 5 or more persons in the MAG modeling region (The majority of businesses are in Maricopa County, but there are also a small number of locations that fall within Pinal and Yavapai Counties.). The dataset was compiled in 2005, and was created using

Dunn and Bradstreet's base data, with MAG enhancements. The database includes information for over 37,000 employers and includes the following variables:

- **MAGID.** Unique identification/reference number;
- **NAME1.** Name of employer;
- **NAME2.** Name of employer (continued) or secondary company name;
- **ADDRESS.** Address of employer;
- **CITY.** City of address;
- **STATE.** State of address;
- **ZIP.** Five-digit zip code of address;
- **EMPLOYEES.** Number of employees;
- **NAICS.** North American Industry Classification System code;
- **NAICS_TEXT.** Text describing NAICS code;
- **IND_CLUSTER**. Industry cluster; and
- **ECONSECT.** Economic sector.

The survey population represents all businesses located in the MAG modeling area, which own and operate trucks that are two-axle, six-tire vehicles and larger, and that are used for the purposes of delivering goods to other businesses and residential sites within the Phoenix region. Excluded from this definition are businesses that own and operate vehicles used for transporting goods to or from central warehouses, distribution sites, etc.; and businesses that own and operate vehicles for the purpose of delivering services to other businesses and residents within the same region.

The North American Industry Classification System (NAICS) codes were used to identify the businesses targeted for this effort. A thorough review of the NAICS codes was needed to fine-tune the sampling frame to include only businesses which we anticipated owning and operating vehicles for the local transport of goods. The actual ownership details were not known until the businesses were contacted, thus businesses with different NAICS codes were included as the survey effort unfolded.

The biggest deficiency in the database is the fact that fleet characteristics, primarily fleet size and type, are not contained. So the number of employees per company was used as a proxy for the fleet size. Unfortunately, the correlation between these two variables, fleet size and number of employees, is unknown.

In order to aggregate the sample frame into common elements, variables had to be established for aggregation. The two most appropriate variables to aggregate were the two-digit NAICS code and the Industrial Cluster, as provided by MAG.

If using number of employees as a measure of size, it is important to determine if any significant bias is introduced by this variable.

Table 3.1 analyzes the two-digit NAICS code by comparing the unweighted distribution of number of firms with the number of firms weighted by the number of employees. Generally speaking, the number of employees varies proportionally with the number of firms. NAICS Code 49, Wholesale Trade, is the one category where this does not hold true. The sample size is very low (99) for this type of firm, so it is more prone to large variability. These types of firms contribute more employees per firm than all other NAICS codes.

Table 3.1 Two-Digit NAICS Codes

NAICS Code	Number of Firms	Percent of Firms	Number of Employees	Percent of Employees
11	214	1.8	5,200	1.6
21	50	0.4	1,737	0.5
23	3,596	30.7	101,151	31.2
32	323	2.8	6,180	1.9
44	1,999	17.1	59,716	18.4
45	792	6.8	22,293	6.9
48	166	1.4	3,378	1
49	99	0.8	13,000	4
51	233	2	6,815	2.1
53	191	1.6	4,584	1.4
54	408	3.5	6,517	2
56	686	5.9	18,101	5.6
72	2,754	23.5	71,626	22.1
81	186	1.6	3,601	1.1
Total	11,697	100	323,899	100

The second variable that was used to aggregate is the industry cluster variable. Table 3.2 addresses the potential biases the number of employees brings upon this variable. As was the case with the two-digit NAICS codes, number of employees does very little to affect the distributions, with the possible exception of the Federal government, which also has a relatively small sample size of 54.

Table 3.2 Industry Cluster Codes

Industry Cluster	Number of Firms	Percent of Firms	Number of Employees	Percent of Employees
Advanced Business Services	66	0.6	630	0.2
Aerospace & Aviation	2	0	30	0
Agriculture & Food Processing	214	1.8	5,200	1.6
Consumer Industries	3,526	30.1	100,252	31
Development Industries	5,009	42.8	135,829	41.9
Federal Government	54	0.5	7,247	2.2
Mining & Primary Metals	50	0.4	1,737	0.5
Other Basic Industries	64	0.5	1,258	0.4
Software	77	0.7	1,877	0.6
Supplier Industries	499	4.3	10,858	3.4
Tourism/Travel	1,924	16.4	49,725	15.4
Transportation & Distribution	212	1.8	9,256	2.9
Total	11,697	100	323,899	100

When these two variables are concatenated, the distribution shown in Table 3.3 is produced. This segmentation is consistent with the results from the previous two tables looking at these variables separately.

The final recommendation for aggregating the employment locations is outlined in Table 3.4. The aggregation is based on a review of the six-digit NAICS codes present in the subset of the MAG Employer Database used to develop the sampling frame of 11,697 locations. Similar two-digit NAICS categories were grouped using the NAICS descriptive text. The aggregation shown in Table 3.4 provides for a fairly intuitive grouping of the data and yields a good distribution of the sample.

Table 3.3 Two Digit NAICS and Industrial Cluster Codes

Two-Digit NAICS and Industry Cluster Codes	Number of Firms	Percent of Firms	Number of Employees	Percent of Employees
11 Agriculture & Food Processing	214	1.8	5,200	1.6
21 Mining & Primary Metals	50	0.4	1,737	0.5
23 Development Industries	3,596	30.7	101,151	31.2
32 Development Industries	14	0.1	182	0.1
32 Other Basic Industries	5	0	339	0.1
32 Supplier Industries	304	2.6	5,659	1.7
44 Consumer Industries	1,733	14.8	51,824	16
44 Development Industries	266	2.3	7,892	2.4
45 Consumer Industries	565	4.8	18,512	5.7
45 Tourism/Travel	227	1.9	3,781	1.2
48 Transportation & Distribution	166	1.4	3,378	1
49 Federal Government	54	0.5	7,247	2.2
49 Transportation & Distribution	45	0.4	5,753	1.8
51 Consumer Industries	97	0.8	4,019	1.2
51 Other Basic Industries	59	0.5	919	0.3
51 Software	77	0.7	1,877	0.6
53 Aerospace & Aviation	2	0	30	0
53 Development Industries	111	0.9	2,676	0.8
53 Supplier Industries	78	0.7	1,878	0.6
54 Advanced Business Services	66	0.6	630	0.2
54 Development Industries	342	2.9	5,887	1.8
56 Development Industries	680	5.8	18,041	5.6
56 Supplier Industries	6	0.1	60	0
72 Consumer Industries	996	8.5	23,935	7.4
72 Supplier Industries	111	0.9	3,261	1
72 Tourism/Travel	1,647	14.1	44,430	13.7
81 Consumer Industries	135	1.2	1,962	0.6
81 Tourism/Travel	50	0.4	1,514	0.5
81 Transportation & Distribution	1	0	125	0
Total	11,697	100	323,899	100

Table 3.4 Aggregate Business Sectors Based on Targeted NAICS Categories

Aggregate Business Sector	NAICS Codes in Sector	Number of Firms	Percent of Firms	Number of Employees	Percent of Employees
Construction/Agriculture/ Mining	11	3,860	33.00%	108,088	33.40%
	21				
	23				
Retail Trade	44	2,791	23.90%	82,009	25.30%
	45				
Accommodation & Food Services	72	2,754	23.50%	71,626	22.10%
Delivery/Publishing	48	689	5.90%	27,777	8.60%
Equipment/Rental/Leasing	49				
	51				
	53				
Other Services with Product Delivery	32	1,603	13.70%	34,399	10.60%
	54				
	56				
	81				
Total		11,697	100.00%	323,899	100.00%

MAG's employment database was also analyzed by reviewing the geographic dispersion of employment locations across the MAG region. The following figures indicate that the employment locations provided by MAG are well distributed throughout the region. Figure 3.1 shows the subset of employment locations selected from the complete database. Figures 3.2 and 3.3 show employment locations and employees summarized by TAZ. As expected, the concentration of businesses is centered around Phoenix and along major connectors (Figure 3.2). Figure 3.3 shows that some of the larger businesses (i.e., those with more employees) are more spread throughout the region. The final map in this series, Figure 3.4, compares the employment locations from MAG's Employment Database (all 37,000+ locations) to total employment projections data from the year 2000. Ideally, the database would be compared to 2005 employment data, but estimates for this year are not yet available from MAG. Figure 3.4 indicates that there are some areas populated with MAG total employment projections data where there are no employment locations (points) from the Employment Database. Since the projections data shows total employees across all employment types and the database only shows employers with 5 or more employees, this mismatch could be a result of businesses with fewer than 5 employees on the perimeter of the region.

Figure 3.1 Geographic Distribution of MAG Employment Database Sampling Frame

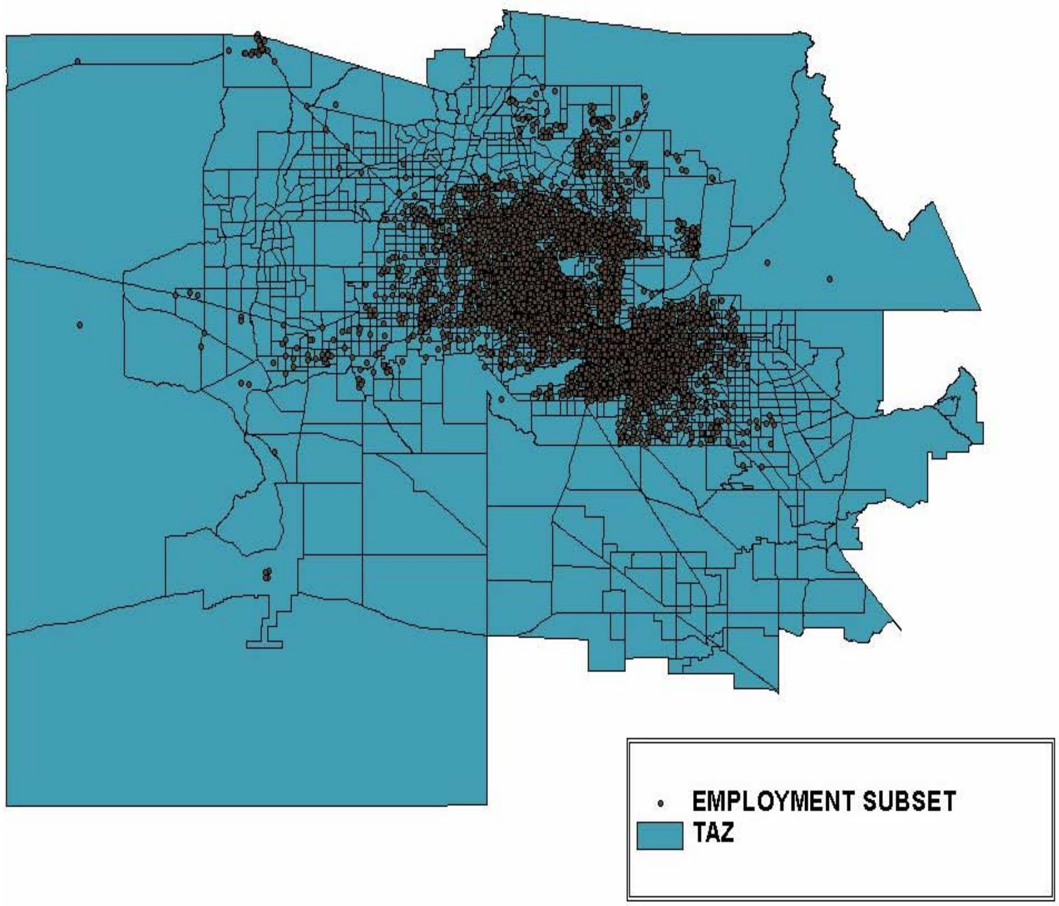


Figure 3.2 Distribution of Employment Locations by TAZ

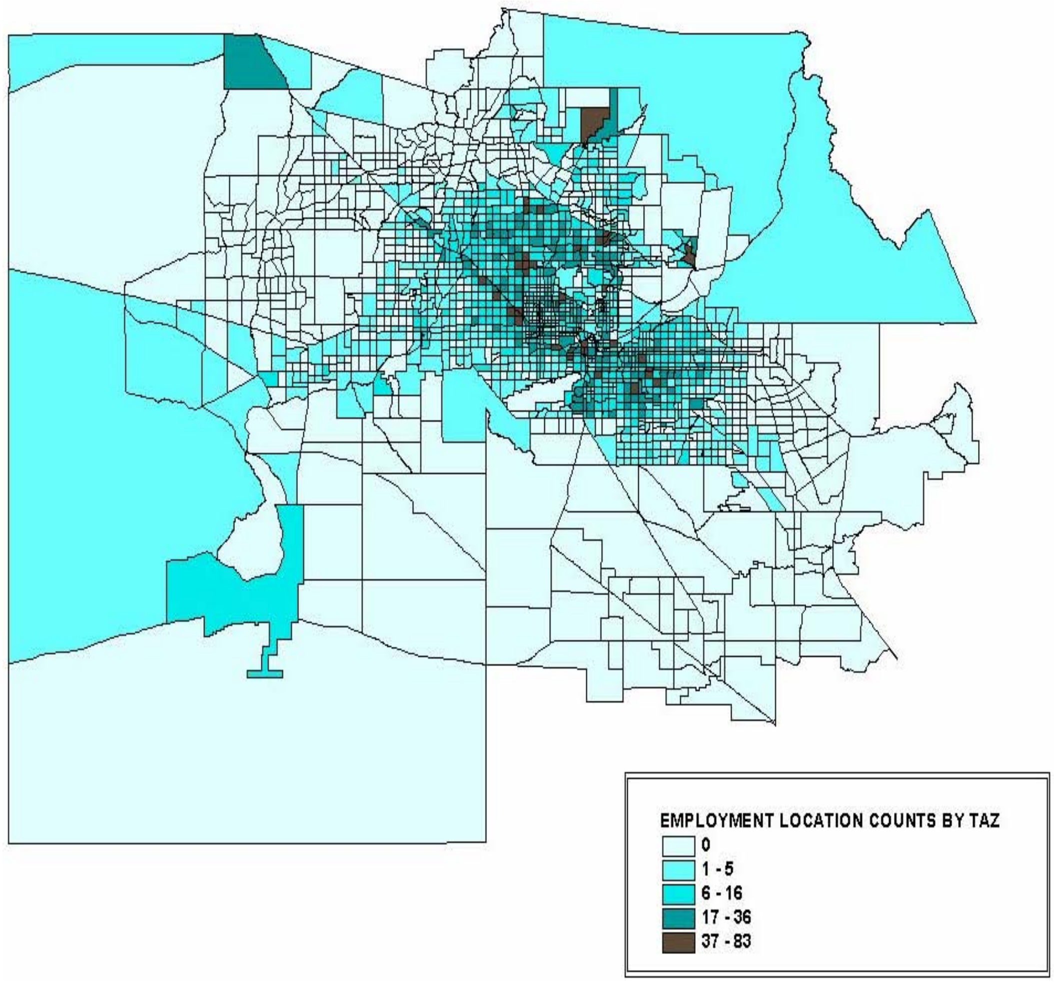


Figure 3.3 Distribution of Total Employees by TAZ

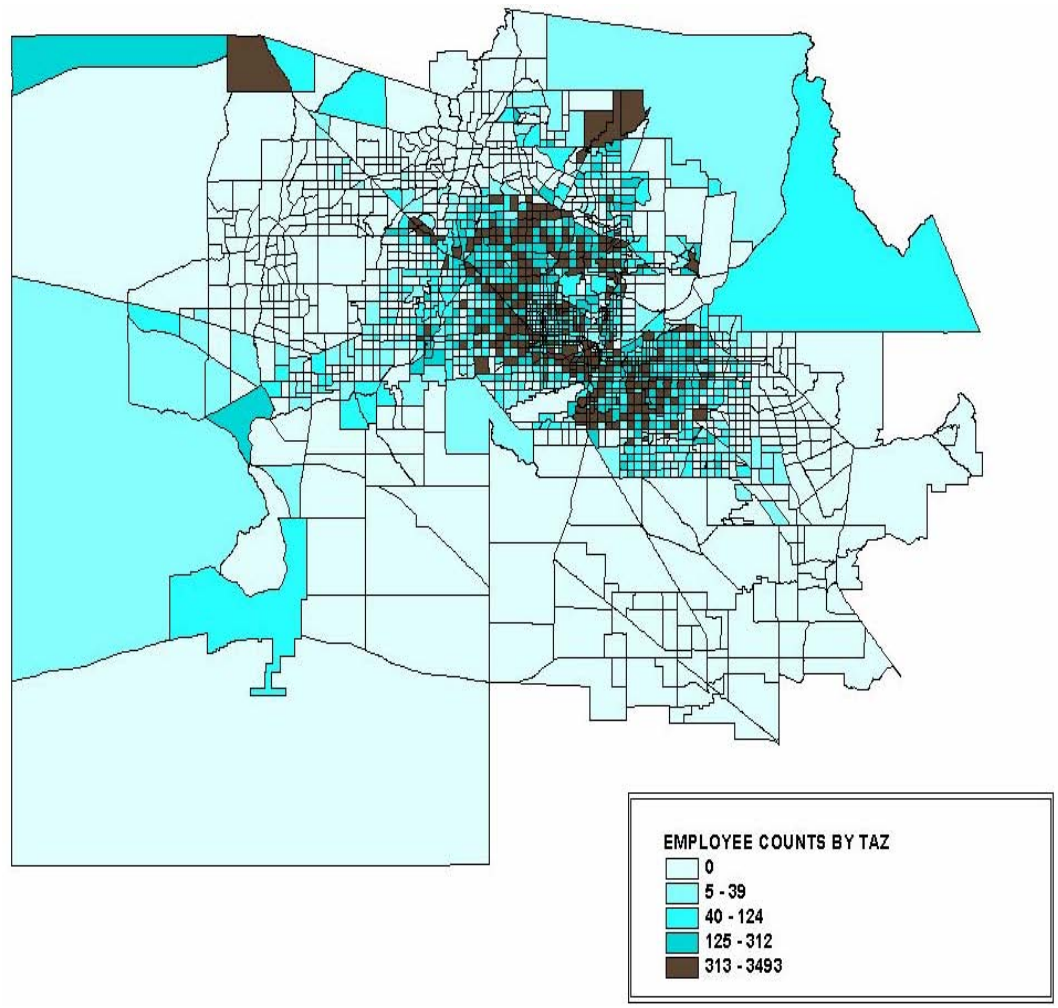
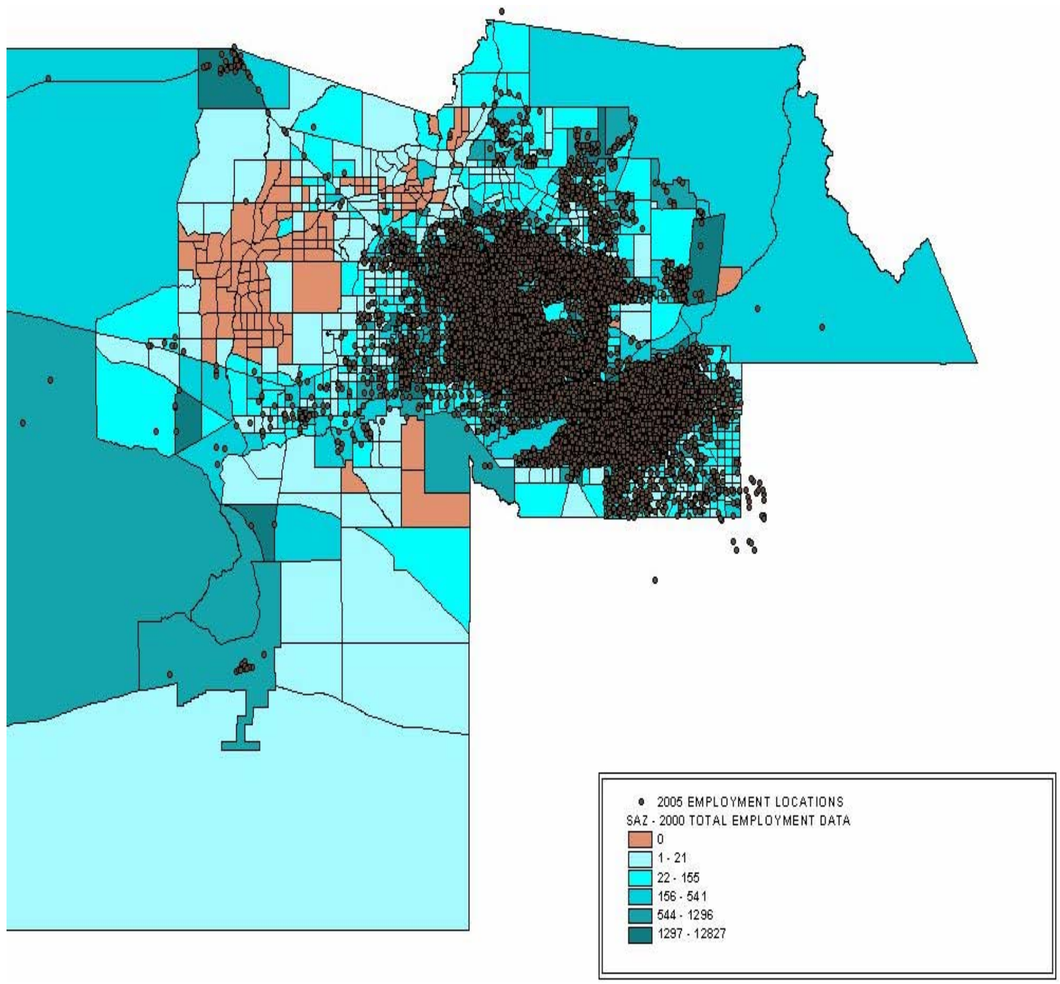


Figure 3.4 Distribution of MAG Employment Locations* by Year 2000 Total Employment Data (at the SAZ level)



Survey Methodology

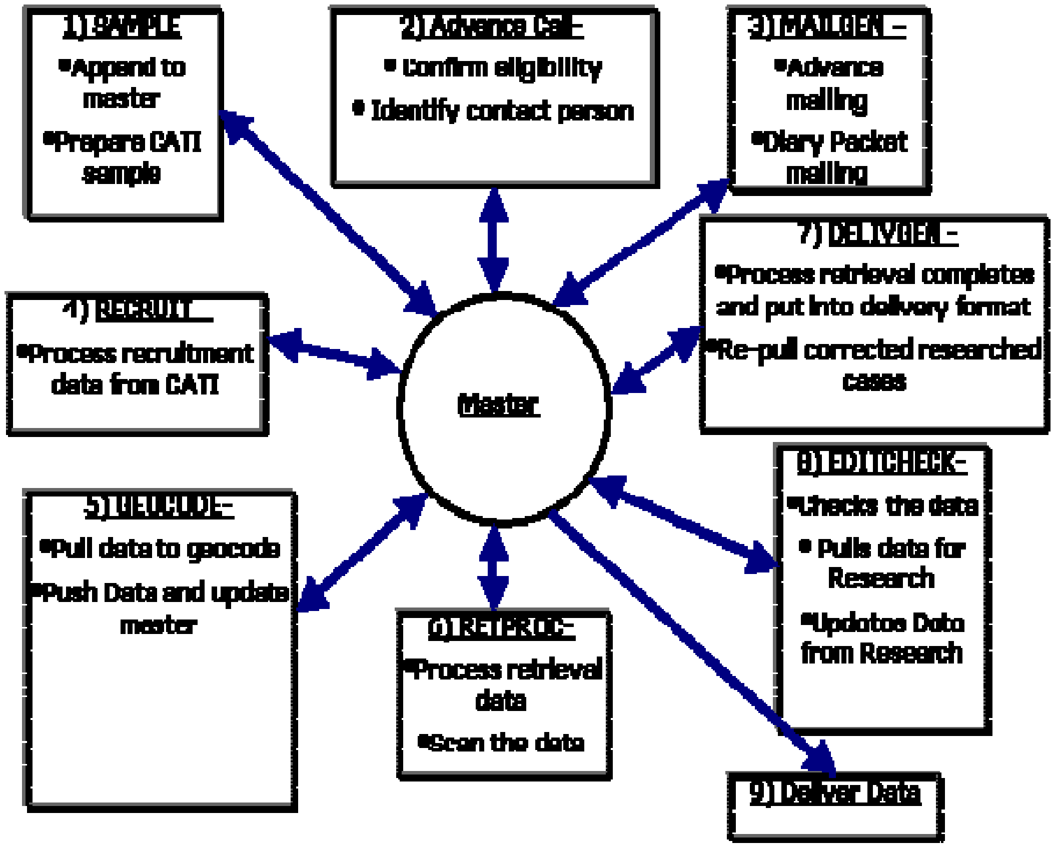
The approach for this type of survey resembles a household travel survey: the truck is the equivalent of the household traveler, and the fleet garage locations (i.e., sampled business sites) are the equivalent of the household locations. Just as households are stratified by household size, income, and other variables for forecasting household travel patterns, the businesses were stratified by employment size, type of industry, and area type. Finally, just as household members are asked to complete travel diaries, truck drivers at the sample sites were asked to complete travel diaries. Paper diaries that cover a 24-hour period were delivered to the sampled sites for all drivers. Drivers will be asked to fill in the diaries and turn them in at the site at the end of their "travel day." The diary data items to be collected include number of truck trips carried out by each driver, the origin and destination of the trips, the time of day they are made, the type of trucks making the trips, information on the types of commodities being hauled, odometer readings, and other factors mutually determined by MAG and Cambridge Systematics. Questionnaire design has a major impact on data quality, respondent behavior, and respondent relations. Questionnaires were designed to permit data to be collected efficiently and with few errors, while also minimizing the amount of post-processing editing and/or imputation that might be required. Most importantly, the questionnaires were designed to impose low-response burden while remaining respondent-friendly. The trip diary questionnaire is shown in Appendix C.

Collecting the Data

Introduction to CDF. The backbone of the entire data collection effort is the continuous data flow (CDF) management system. This system played a central role in the performance of all work activities on this project. For the NuStats survey team, the CDF management system provided the reporting and data access necessary to track the status of the survey effort as a whole and each piece of sample individually. It also provided the checks and balances for staff to know that all businesses are receiving the appropriate attention, as well as a mechanism to quickly identify businesses that are not proceeding according to plan. For the participating businesses and their drivers, this translated into timely contact and reduced burden, which increased response rates. This system provided attention to details that was necessary to ensure that the final data set is complete and an accurate reflection of regional commercial travel patterns.

Figure 3.5 shows the CDF management system and its components. Each component addresses a specific aspect of the data collection process, and also is used in the management of that aspect. As indicated in the figure, there are nine components comprising the CDF management system, with the MASTER database at its core. This system also includes daily programs and reports used to update the status of each business; notification to staff that the data are ready for the next stage of the process; identification of businesses that may not be proceeding according to the scheduled plan; and summarizing the status of survey businesses based on sample targets, geographic units, travel day periods, and other views necessary to equip the project team with the diagnostic tools necessary to keep the survey on-time and on-budget.

Figure 3.5 CDF Management System



Pre-Tests

The sample for the pre-test study was comprised of 407 businesses. The sample size was calculated using an eligibility rate of 6 percent and a response rate of 30 percent, with an assumption that on average there would be 10 trucks per business. The final response rate was 20 percent, the eligibility rate (i.e., ratio of eligible to ineligible sample) was 5 percent, and the final refusal rate was 62 percent.

In total, six companies agreed to participate in the pre-test; two of which offered to provide electronic-generated forms of their delivery trips rather than have their drivers complete the diary, while one company provided a diary to six of their drivers. In total, 30 diaries were returned and roughly 80 electronic records were provided to NuStats. Of the 6 companies that participated in the pre-test, 2 companies were warehouse distributors, and thus their data was not included in the pre-test database. In sum, the pre-test resulted in 24 completed diaries from 4 eligible companies, which translates into an average of 6 diaries per company and about 132 trips.

Findings from the Pre-Tests

The pilot study shed light on two issues tied to truck incidence:

1. There was a lower incidence of the types and number of trucks in the study area, comprising the sample population definition (2-axle and 6-tire vehicles and larger) than expected. The pilot test demonstrated that our initial assumptions regarding incidence and truck ownership (meeting study definition) within companies were erroneous. The pilot study showed that companies were averaging fewer than 7 trucks. Many of the companies contacted were ineligible because their truck fleet consisted of 2-axle, 4-tire vehicles only.
2. Based on the NAICS codes that were targeted in the trip diary study, the sample frame did not contain sufficient number of businesses with the desired types of trucks. Many of the businesses contacted were ineligible to participate in the study, because they performed product distribution-related delivery services.

Taking these factors into consideration, several study modifications were made to address these issues, including the following:

- Assess and eliminate businesses from the sample frame that are within the NAICS codes, but are likely to produce an ineligible company based on service type or truck fleet; and
- Stratify the sample on business size with emphasis on large businesses (that may have larger fleets).

In addition to these two, it was also recommended to consider alternate databases to supplement the employment database during the full surveys, and to inform the potential respondents about the truck travel surveys in the form of a recruitment letter, as shown in Appendix B.

Some of the other lessons learned from the pre-test include the following:

- **Contacts forget they had agreed to participate in the study.** When reminder calls were made, some contacts had forgotten they made the commitment to participate in the pre-test; however, all were willing to participate in the study.
- **Number of drivers/trucks is highly variable and depends upon staffing levels at the company, the need for truck deliveries on that day, and the type of business the company is involved in.** Two of the six companies had more drivers than reported during the recruitment interview. One company's use of trucks was dependent upon the number of construction jobs it was involved in at the time of the survey.
- **Driver details or full address information were the most common missing data point on the survey**. During retrieval of the diaries, a quick edit check for completeness was conducted at the place of the business. Missing or

incomplete data was generally related to driver details or trip address information, and the contact person was able to assist with completing the diary.

- **Offering an incentive did not increase participation.** One-half of the sample called was offered a cash incentive to help increase the participation rate. However, none of the companies that were offered the incentive agreed to participate in the study.
- **Drivers were not available for training when the diaries were dropped off.** Training was provided to the contact person, who then relayed the information to their drivers.
- **Flexibility has to be offered in the travel date.** All of the companies were assigned a travel date during the recruitment interview. However, two of the six companies needed to switch their travel dates due to extra time needed to get the surveys distributed and returned to their drivers.
- **A Spanish version of the diary was needed.** One of the companies asked for a Spanish language diary. A Spanish version was provided for the full study.

As a result of the pre-test, the expected number of companies needed to complete the surveys was increased due to the lower incidence in type and number of trucks than originally anticipated. In addition, a few of the NAICS codes were removed from the sample frame in order to avoid recruiting businesses that engage in distribution type activities. The recruitment script was also modified to screen firms to determine if they performed distribution type activities.

Alternate Sampling Frameworks

The pilot study modifications to trip diary surveys primarily sought to address the issue of incidence. However, after only three days of closely monitoring the recruitment for the full study, it became apparent that the study design parameters were not being met, and the study goals would not be met within existing resources.

Two options were suggested. The first option was to supplement the current sampling methodology with multiplicity sampling, which is a sampling technique that would enable the data collection specialists in the field to recruit neighboring businesses with observed fleet characteristics as they visit those firms already participating in the study. The second option was to consider additional sample databases from which to draw sample.

The first option proved to be ineffective, so three supplemental sampling frameworks were purchased and assessed for inclusion in the full study sample frame. These were the following:

1. **FleetSeek.** This database is maintained by Transportation Technical Services that offers information on the corporate locations of U.S. for-hire trucking companies and fleets operated by various corporations. Details include name and title of principal officer, toll-free and fax numbers, revenue, commodities

hauled, number of straight trucks, tractors and trailers, fleet size and type, GVW class, SIC code, and more. A total of 647 samples were obtained from FleetSeek. Once purged of duplicate sample (already existing in the MAG database) and missing data elements or otherwise ineligible companies, the FleetSeek database resulted in a total of 386 pieces of new sample to include in the full study frame.

2. **ATA Fleet Directory.** This database, which is maintained by the American Trucking Association (ATA), consists of all the trucking companies in the U.S. that own or operate 11 or more trucks. The database includes name of the company, address, phone and fax numbers, commodities carried, fleet size, fleet type, trailer type, SIC codes, and many more. This database consists of 330 samples for the 3-county region. About 140 of these already existed in the MAG sample and the FleetSeek database, and 113 of the database items fall under the study sector targets.

3. **U.S. Data Corporation (DataCorp).** DataCorp provided a list of owner-operators of trucking companies in the Phoenix area requiring screening for the company name and the industry type during the interview to ensure eligibility. It resulted in a total of 357 pieces of new sample to include in the full study frame.

Full Surveys and Findings

The sample for the full surveys was comprised of 3,276 companies (combining the four databases). The overall response rate for the study was 21 percent, while the eligibility rate was 13 percent and refusal rate 66 percent. Using multiple databases for the sample frame contributed to these final rates. For example, MAG employment sample delivered a lower response rate (18 percent) than the overall rate, while the FleetSeek and DataCorp databases generated higher response rates (22 percent and 21 percent, respectively). As a result, a total of 236 completed trip diaries were retrieved from 46 companies (5 trucks per company).

Over one-half of drivers that were surveyed (57 percent) reported driving trucks in the heavy-heavy-vehicle weight category (33,001 lbs and above). Three-quarters of the 236 truck reported were either classified as semi's or single unit, 2-axle vehicles (as shown in Table 3.5).

Table 3.5 Frequency of Truck Type

Axle	Frequency	Percentage
Semi	91	39%
Single unit 2-Axle	84	36%
Single unit 4-Axle	43	18%
Other	10	4%
DK/RF	1	<1%
Total	236	100%

In all, there were a total of 1,304 stops reported from the 236 completed truck travel diaries. This translates to an average of 5.5 stop per day among trucks surveyed traveling within the Phoenix metropolitan area. Table 3.6 below shows the type of stops made by those surveyed. The most common stop type was construction site, indicative of the recent high levels of commercial and residential growth in the Phoenix metropolitan area. The second most common stop type was my company or employer. These stops represent return trips to the company office or yard for one of two following reasons:

- To pick-up goods or equipment to drop-off at a job site, or
- To park the truck at the office or yard at the end of the shift or day.

The third and fourth most common stop types were warehouse/wholesale store and house/other residential. These 12 stop types served as a key variable to stratify the trip generation model into 12 different land use sectors, as explained in Chapter 4.

Table 3.6 Frequency of Truck Stop Type

Stop Type	Frequency	Percentage
My company/employer	299	23%
Construction site	308	24%
Warehouse/wholesale Store	214	17%
House/other residential	144	11%
Retail/store/restaurant/mail	99	8%
Industrial	89	7%
Other	35	3%
Office/bank/medical/repair	32	3%
Transportation hub	23	2%
Government building/school/institution	16	1%
Mine	15	1%
Farm	6	<1%
Total	1,280	100%

Lessons Learned

The following are some of the lessons learned from the full trip diary surveys:

1. **Diary retrieval complications was a challenge.** Despite employing diary distribution and retrieval methods designed to reduce burden on the company contact (e.g., a NuStats representative arranged an appointment to deliver diaries and review the process for filling out the diary with the company representative and set a second appointment for retrieving the diary), a number of companies that originally agreed to participate in the study did not fulfill their commitment and provided fewer diaries than anticipated, and some provided none at all. As such, NuStats spent a considerable amount of time and effort in diary retrieval, including repeated callbacks to check the status of diary completion. This is due to two factors:
   a. Retraction of agreement to participate by company contact following recruitment. When contacted to schedule the diary delivery date or on the day of diary delivery, the company contact would not agree to participate despite previous commitment. Lack of interest in the study was often provided as the reason for this.
   b. Low participation by truck drivers in completing the diary. Diary completion ultimately rested in the hands of the drivers, and many failed to complete the diary, resulting in fewer diaries retrieved per company than anticipated.
2. **Ineffective sample slowed recruitment.** One of the techniques to boost recruitment was in-person recruitment of FleetSeek and MAG employment sample that had already been called and had not refused the survey. This included answering machines, no answers, and partial or "soft" refusals. Over a 3-day period, nearly 100 businesses were visited. Nearly one-quarter of those businesses were private residences in which nobody was home. The home addresses in the sample suggest that a number of truck drivers in the sample frames are owner-operators that report their home phone number and address as their place of business, making them hard to reach. NuStats also discovered that many of the businesses visited on these days had either moved, or the address information obtained for the sample was wrong.
3. **Failing to meet the eligibility criteria.** Companies in our sample frame failed to meet two important eligibility criteria: a) their truck fleet did not contain one or more large trucks that are being targeted in this study, and b) they provided warehousing services that were not targeted in these surveys.
4. **Using multiple sample sources increased response rates and eligibility rates for the full study.** The quality and performance of the sample were improved by the use of more than one sample frame.

3.2 Operator Surveys

NWRG worked on these surveys. The sectors that were focused in these surveys were primarily manufacturing facilities and warehouse/distribution centers.

Sampling Framework

The 2005 MAG employment database has a total of 6,143 records that belong to Manufacturing- and Warehousing-related industry sectors. Table 3.7 illustrates the number of sample elements in each category.

Table 3.7 Frequency Distribution of Businesses by Industry Sector for Operator Surveys

Sector	Frequency	Percent
Manufacturing	3,030	49%
Wholesale Trade	2,730	44%
Transportation and Warehousing	383	6%
Total	6,143	100%

Based on an initial review of the database, it was found that the sample was sufficient to complete the required 550 surveys. NWRG recommended stratifying the sample and completing a specified number of surveys within each major category. This included 250 with Manufacturing firms, 250 with Wholesale Trade companies, and 50 in the Transportation and Warehousing sector. A further review of the sample revealed that the sample for the manufacturing firms covered a wide range of different industries as shown in Table 3.8.

Table 3.8 Frequency Distribution of Sectors by Industry Type

Industry Type	Manufacturing	Wholesale Trade	Transportation & Warehousing	Total
Aerospace & Aviation	86	0	0	86
Agriculture & Food Processing	173	0	6	179
Bio-Industry	142	0	0	142
Development Industries	557	0	0	557
High-Tech	385	0	0	385
Mining & Primary Metals	55	0	0	55
Other Basic Industries	898	0	0	898
Plastics & Advanced Composites	139	0	0	139
Supplier Industries	595	0	0	595
Transportation & Distribution	0	2,730	377	3,107
Total	3,030	2,730	383	6,143

About 70 percent of the sample comprised of relatively small employers that employed between five and 20 employees. The median number of employees was found to be 12. This suggested that these companies would own/operate relatively small fleets of trucks. Table 3.9 illustrates the breakdown of the number of employees by industry sector.

Table 3.9 Distribution of Sectors by Number of Employees

Number of Employees	Manufacturing	Wholesale Trade	Transportation & Warehousing	Total
5 to 10	355	413	61	829
6 to 15	1,322	1,424	168	2,914
16 to 20	266	244	32	542
21 to 30	286	237	29	552
31 to 50	302	201	36	539
51 to 100	259	127	25	411
More than 100	240	84	32	356
Total	3,030	2,730	383	6,143

It was estimated that about 10 sample elements would be needed to generate a completed survey. Therefore, a minimum of 5,500 usable sample elements with telephone numbers was required. The sample fully covered the region, indicating no geographic bias in the employment database. There are about 3,100 in the Phoenix metropolitan area, which is about 50 percent of the sample, while the remainder of the sample covers the rest of the region. The following Figures 3.6, 3.7, and 3.8 show the geographic dispersion of employment related to Manufacturing and Wholesale Trade sectors in the MAG region.

Figure 3.6 Geographic Distribution of Manufacturing and Wholesale Trade Employment from the Sampling Frame

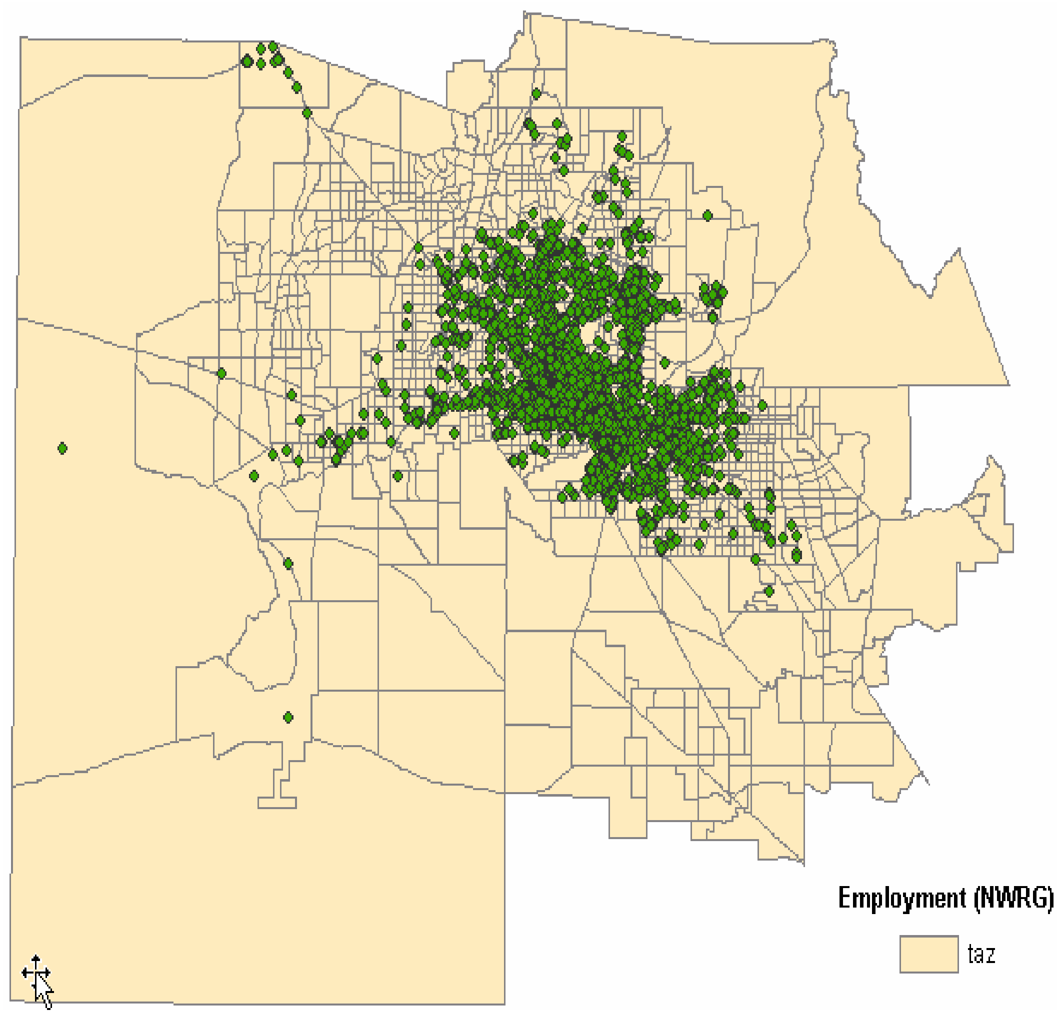


Figure 3.7 Distribution of Manufacturing and Wholesale Trade Employment Locations by TAZ

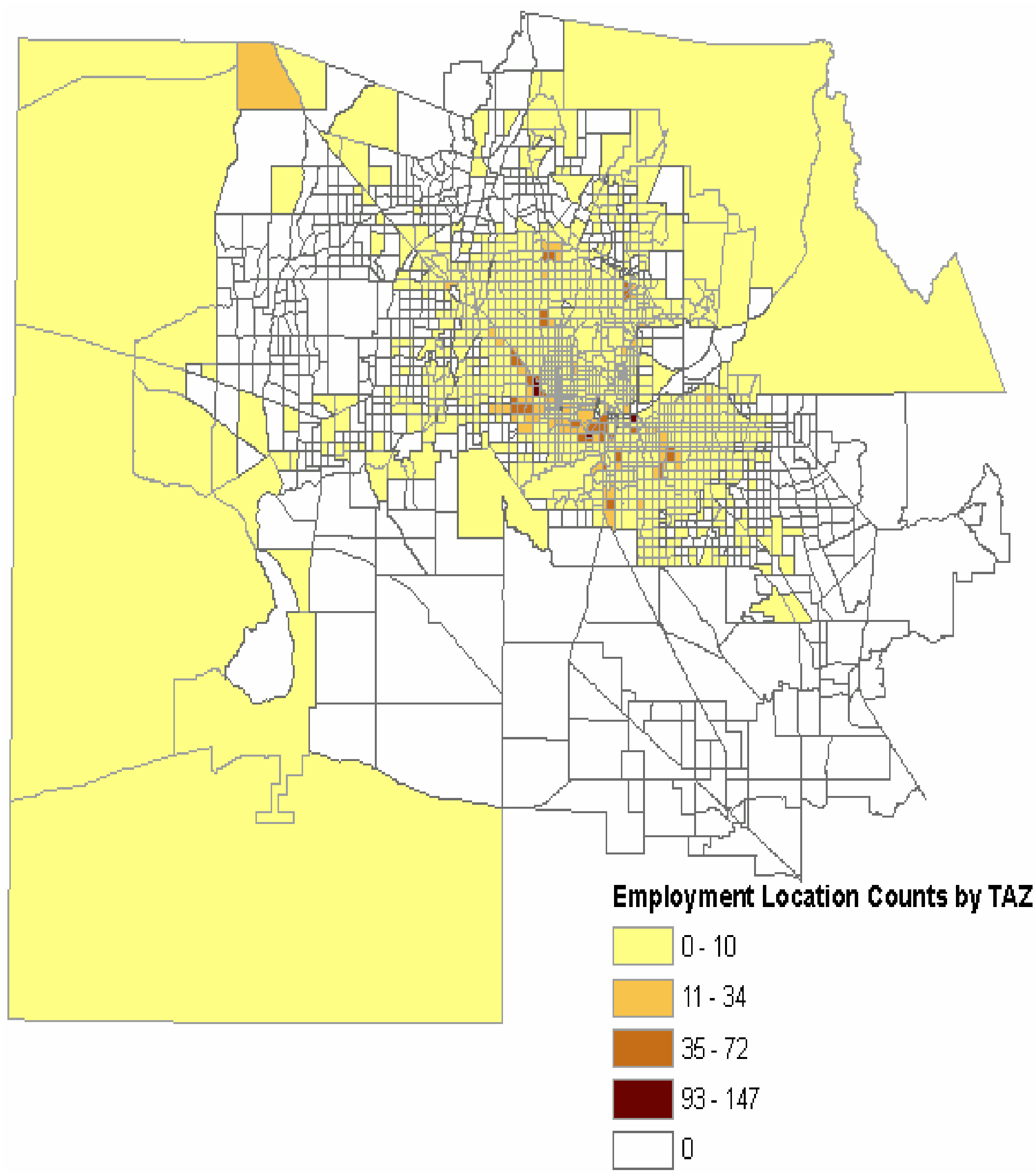
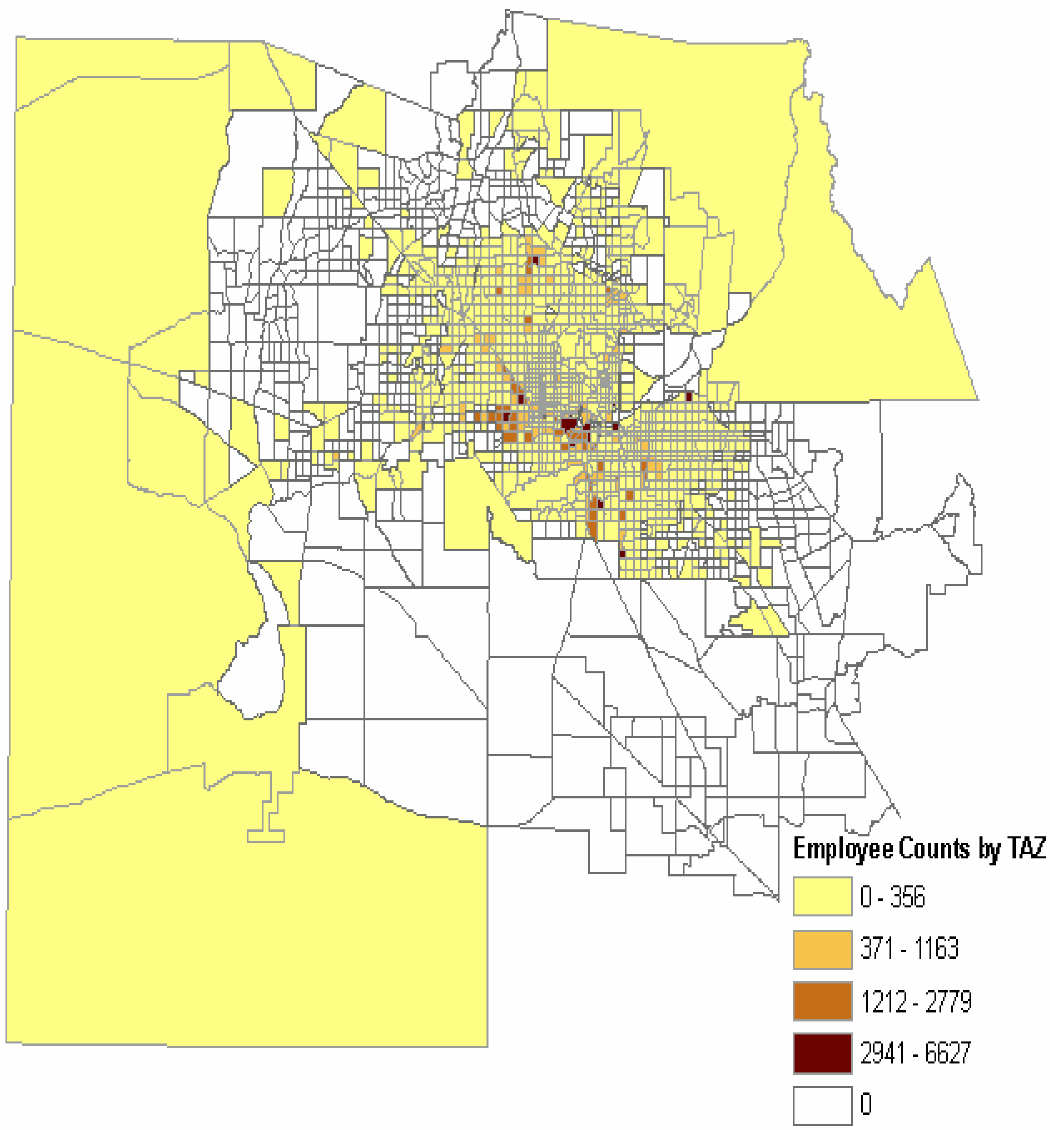


Figure 3.8 Distribution of Total Manufacturing and Wholesale Trade Employees by TAZ



Survey Methodology

Sampling

The target number of completions for NWRG was set at 550 surveys drawn from a random sample of manufacturing (NAICS 31 to 33), wholesale trade (NAICS 42), and a subsample of transportation/warehousing (NAICS 48 to 49) companies located in the Maricopa region. The MAG employment database provided samples of employers in these target segments. The number of sample elements that were targeted in each sector is described in the previous section and presented in Table 3.7.

Several strategies were used to increase the response rates. Each sample element was attempted up to 10 times in an effort to reach the correct person in the company, and messages were left on answering machines. Once contact had been made and the correct person to survey identified, additional attempts were made to complete an interview with the person contacted. Many persons who refused to complete a survey did so simply because the call was made at inconvenient times. In many instances, this refusal happened to be before the correct person to be interviewed was identified. In the face of an immediate and potentially final refusal where the person on the phone stated they were busy and/or that the person selected for the interview was unavailable or busy, NWRG interviewers attempted to schedule an appointment time that was convenient for the respondent. They also attempted to get the name of the specific person to be interviewed. To make this process more effective, a record of the selected respondent, the name of the person with whom the interviewer initially spoke, the date, day of week, time for the appointment, the reason for the callback, and any additional useful notes were recorded.

NWRG maintained a toll-free number that was provided to all respondents. This toll-free number was provided when messages were left on answering machines, and when requested by respondents that enabled them to call back to complete the surveys. In addition to the toll-free number, NWRG maintains information on their web site (www.nwrg.com) for study participants. This web site included a general overview of NWRG's privacy policy and provided answers to frequently asked questions about surveys. In addition, a study-specific page was posted that provided respondents answers to information on the study (for example, its purpose, how the data will be used, etc.). This page also included the toll-free number to contact for further information, if needed.

Various attempts were made to minimize the refusal rates, which by function lead to poor response rates. NWRG had a comprehensive system to prevent refusals. During screening, all companies that immediately refused to complete the survey (e.g., immediate hang-up, failure to listen to the initial introduction, simple statements such as "I'm busy right now" or "I don't do surveys") were dispositioned as a "soft refusal" and were re-contacted on a different day at a different time, typically three to five days after the initial refusal. The interviewer had the ability to record notes as to the reason for the initial refusal. Efforts were also made to reach a different member of the company to start the respondent selection screening. The other type of refusals was more hostile. The first step in the refusal-conversion process is the identification of reasons for refusals and retraining the interviewers to minimize these impacts. The second and integral component of this effort involved the use of a select team of refusal conversion specialists. This team was comprised of NWRG's highly trained interviewing staff members who have demonstrated exceptional skills in achieving high cooperation rates. A refusal conversion interviewer then attempted to convert the remaining cases. If the company refused to complete the interview at any point, refusal conversion interviewers handle all subsequent contacts of the company.

Recruiting

NWRG developed a Screening and Recruitment Instrument to determine whether a company qualifies for the operator and to obtain their agreement to participate in the survey. A major focus of this instrument will be to identify the person or persons within the company who is most responsible for handling or managing the truck trips in and out of the facility.

Recruiting was done by telephone using the script prepared in the Screening and Recruitment Instrument. The key questions/information that were included are as follows.

- Information on the primary purpose of the research;
- Verification of industry sector;
- Type of facility;
- Number of trucks business owns or subcontracts in specified size classifications;
- Average number of trips each truck makes per day; and
- Invitation to participate, including description of purpose of the study, tasks required, etc.

It was anticipated that the transportation or fleet manager was the person that is most knowledgeable and was the one to complete the actual survey. However, permission to participate and provide the necessary materials was sometimes obtained from a senior manager at the company.

An incentive was also recommended that was a drawing. An award of $100 was provided to 10 of the participating companies. In past studies, it was found that a larger drawing is often more of an incentive than smaller incentives paid to everyone.

Survey Questionnaire

The telephone survey was designed to gather the following information:

- Location of facility;
- Type of facility;

- Industry type;
- Number of trucks by size;
- Type(s) of trucks;
- Truck ownership;
- Number of employees at facility;
- Number of drivers;
- Type of materials shipped from facility;
- Number of outbound truck trips facility generates in an average week;
- Percent of trips that deliver to multiple locations;
- Percent of trips deliver to single location;
- Destinations for one-day's worth of trips for a specified number (maximum of three) trucks can be provided as dispatch or GPS records; and
- Nature/land use of destinations.

Each of these telephone surveys averaged no more than 15 minutes in length.

CATI Survey

Data collection was completed by telephone using a script as shown in Appendix D. For telephone surveys, NWRG used one of the most advanced computer-assisted telephone interviewing (CATI) systems, WinCATI Ci3, from Sawtooth Technologies. NWRG has used Ci3 and the subsequent WinCATI programs since its initial launch in 1989. For web surveys, NWRG uses SensusWeb, which is also from Sawtooth Technologies. These two systems are virtually interchangeable, allowing to the conductance of the same survey using multiple modes of administration.

Both systems manage the logic of the questionnaire – determining which question the interviewer will ask – thereby minimizing the introduction of interviewer error. The interviewers or respondents entered the answers via the computer's keyboard. The programs accept both alpha and numeric responses and limit the range and type of responses that can be entered, thereby, minimizing data entry errors.

These systems allows the development of virtually any type of questionnaire, while at the same time programming edits, consistency checks, and other quality control measures to ensure the most valid data. Some of the other features of these systems included are the following:

- Complete control of what the interviewer or respondent sees;
- Automatic skip or branch patterns based on previous answers, combinations of answers, or even mathematical computations performed on answers;

- Randomization of response categories or question order;
- Customized questionnaires using respondents' previous responses; and
- Incorporation of data from the sample directly into the sample database for use in the survey instrument.

NWRG also has a comprehensive process that ensured all aspects of the programming meeting the requirements for the study. This includes the following:

- Programming of the questionnaire logic (skip and branching patterns);
- Inclusion of interviewer instructions and help screens, as required;
- Programming for sample management, including scheduling of callbacks, dispositions, etc.; and
- Development of daily reporting requirements (e.g., response rate calculations).

The testing of the programming goes through the following three steps:

1. Development of a testing document that identifies critical paths that the survey should follow. Trained survey testers carefully follow the scenarios outlined in this document to ensure that the skip and branching logic is correct. In addition, these testers carefully review all text for accuracy.
2. Generation of dummy data to test the questionnaire logic. This step also enables the development of the base programming that was used to convert the data to the final required data formats, which expedited the back-end data processing. This dummy data is carefully reviewed to ensure that responses are within the specified ranges, questions are asked of the correct respondents, etc.
3. Final review and certification of the CATI programming by the assigned Project Director.

Pre-Tests

NWRG conducted a pre-test with a sample of 10 study participants. Four primary subtasks were used to test the questionnaire and procedures as described below.

1. **Program testing.** Once the telephone questionnaire was programmed into WinCATI, NWRG ran several tests with "dummy" data to ensure that the skip patterns and branching logic were performing correctly.
2. **Call monitoring.** This involved continuous monitoring of interviews as a key measurement of the pre-test. MAG project staff were invited to join the NWRG project management team in this monitoring. This task provided assurance that questions were worded clearly and unambiguous, and that the instrument was efficiently collecting the appropriate information.
3. **Pre-test plants.** In addition to the randomly selected participants, NWRG asked the MAG Project Team to provide contact information for pre-test

plants, which include MAG project staff. The use of pre-test plants was an excellent way to probe for greater feedback on questionnaire length and flow, and to identify potential problem points in the questionnaire.

4. **Sample productivity analysis.** While the pre-test may not always provide an accurate indication of final participation rates, it certainly gave some indication as to the quality of the sample list and the final contact rates. NWRG carefully analyzed the call disposition reports following the pre-test to identify weaknesses in the sample list and call pattern algorithms.

The purpose of the pre-test was two-fold. First, the pre-test allowed the project team to evaluate the efficacy of the survey instrument. Specifically, the following were considered:

- Did the respondents understand the questions, and were they able to provide meaningful/reliable data?
- What questions had the highest rate of refusals?
- What points of the questionnaire had the highest rate of interview termination?
- What questions tended to elicit confused responses or result in a respondent asking for clarification?
- Was the survey of a reasonable length so as to minimize respondent burden and increase response rates? It was determined prior to the pre-test that a survey instrument longer than 10 minutes would be considered unreasonable by most respondents and would increase refusal rates significantly.
- Did the questionnaire programming contain skipping or branching errors?

Findings from the Pre-Test

It was clear from the pre-test that, while the original version of the questionnaire was a reasonable length, it required a level of detailed information that respondents were unable or unwilling to provide. For example, respondents were asked to provide detailed data about the nature of shipments and deliveries for each type of commodity they received or shipped from their facility. For those shipping or receiving more than a single commodity, this greatly increased the survey length. Moreover, respondents were generally unable to provide detailed information at the commodity level. As a result of this finding, the questionnaire was changed so that respondents were asked to provide data about shipments/deliveries by truck size rather than commodity type.

In addition, the questionnaire was further simplified by eliminating redundant or unnecessary questions, and providing categories for responses for some questions where respondents might not know an exact number (e.g., square footage of facility).

The pre-test also allowed the evaluation of the efficacy of the sampling plan. Some of the questions asked included the following:

- How many telephone numbers were dialed per completed interview?
- What percentage of telephone numbers was disconnected?
- What percentages of businesses contacted qualified to complete the survey?
- What time of day yielded the highest contact rate?

Full Surveys and Findings

During the full survey, as it is consistent with any business sample, it was found that some of the numbers were nonworking numbers. Given that the sample database was only a few years old (2005), the percentage of nonworking numbers (22 percent) was relatively low. As expected, a significant percentage of the businesses did not qualify to complete the survey. Over one-half of those contacted was disqualified because they did not operate any trucks of qualifying sizes. Another reason for disqualification was that they did not make any shipments out of or receive deliveries into that facility. Finally, some were disqualified because all shipments into or deliveries out of were carried by a mail or parcel service (which are targeted through the trip diary survey).

Though the rate of disqualification was somewhat larger than anticipated, it was found that the sample was adequate enough to achieve the desired sample size with strict calling protocols that were used. Some of the other strategies implemented to encourage response rates are stated below.

- Making multiple attempts (up to 15) to each number;
- Leaving messages on answering machines about the purpose of the study, and asking the respondent to contact NWRG (toll-free number provided);
- Sending follow-up materials via fax or e-mail providing additional information about the study to those who initially refused or indicated they needed permission from their manager or parent company to participate; and
- Providing respondents with an option to complete the survey on-line at their convenience.

After implementing these procedures, there was a significant impact on the overall response rate. While overall incidence of qualified firms remained at pre-test levels (less than 50 percent), only 4,748 of the 6,143 sample elements were actually required to complete the survey. NWRG was unable to reach only 29 percent of the sample elements loaded and/or the appropriate contact within the business. Finally, only 22 percent of those contacted refused to complete the survey.

The target number of completes was achieved as part of this survey for the desired sectors. No major issues were discovered while conducting these CATI-based surveys. These types of surveys have demonstrated to be very effective for sectors like Manufacturing, Wholesale, and Warehousing sectors, where the trip-making characteristics seem to involve a finite set of destinations or land use types, and also where the starting and ending point of trips seem to be at these facilities.

Table 3.10 provides a summary of the key statistics from the survey data. These include the sample sizes and the number of inbound and outbound shipments by sector and truck type that are essential to estimate truck trip generation estimates. Also included are truck trip length distributions that will provide a validation measure while developing the trip distribution model. These findings are found to be consistent with other published sources, and can be used effectively for developing inputs for modeling trucks in these sectors.

Table 3.10 Summary of Key Statistics from Operator Surveys

	Total	Manufacturing	Wholesale Trade	Warehousing/ Transportation
Sample Sizes				
Number of businesses in sample frame	6,143	3,030	2,730	383
% Businesses in sample frame		49%	44%	6%
Number of completed surveys	562	275	198	89
% Completed surveys		49%	35%	16%
Precision	+/– 4.1%	+/– 5.9%	+/– 7.0%	+/– 10.4%*
Trip Generation				
Inbound shipments	8.54	6.23	5.36	23.12
% Starting within study area	46.30%	34.10%	50.30%	55.30%
Inbound shipments within study area	3.95	1.16	2.2	10.1
Outbound shipments	15.23	9.15	15.04	34.45
% Ending within study area	62.60%	52.90%	75.00%	64.40%
Outbound shipments within study area	9.54	4.83	11.28	22.18
% Inbound shipments – light trucks	9.60%	9.80%	9.60%	8.60%
% Inbound shipments – medium trucks	18.00%	18.70%	21.20%	8.10%
% Inbound shipments – heavy trucks	65.40%	64.50%	64.20%	71.90%
% Outbound shipments – light trucks	11.30%	11.30%	12.00%	9.50%
% Outbound shipments – medium trucks	26.40%	24.50%	32.30%	18.70%
% Outbound shipments – heavy trucks	52.50%	54.60%	44.60%	64.00%

	Total	Manufacturing	Wholesale Trade	Warehousing/ Transportation
Trip Distribution				
0 to 5 miles trip length	13.30%	10.30%	17.80%	11.50%
6 to 10 miles trip length	13.10%	13.90%	13.20%	11.00%
11 to 15 miles trip length	13.60%	14.20%	12.70%	14.10%
16 to 20 miles trip length	14.30%	15.00%	13.30%	14.80%
21 to 30 miles trip length	9.60%	9.40%	8.10%	12.80%
31 to 50 miles trip length	10.00%	10.70%	8.80%	10.40%
51 plus miles trip length	26.10%	26.40%	26.10%	25.40%
Median trip length (miles)	19.5	19.87	18.37	20.53

* The transportation/warehousing industry may represent a finite population. As more than 10 percent of the total population were sampled, the finite correction factor is applied to the error.

3.3 SERVICE TRUCK ACTIVITY

This segment includes utility uses and other services related to commercial and residential land uses (i.e., business and personal services). The Service sector trucking activity is very hard to collect through conventional survey methods. This is due to the overlapping nature of these types of truck trips with other industry types. For this study, available data from other studies is used that Cambridge Systematics has contributed to within the last few years. A detailed explanation of this methodology is provided in the following sections.

Sampling Framework

Tables 3.11 and 3.12 provide some summary statistics of service industries by type in the MAG's employment database, while Figures 3.9, 3.10, and 3.11 show the distribution of service employment from the sampling frame, service employment locations by TAZ, and number of service employees by TAZ.

Table 3.11 Distribution of Businesses by Type of Service from the Sampling Frame

Type of Service	Number of Businesses	Percent
Advanced Business Services	4,142	20%
Aerospace & Aviation	2	0%
Bioindustry	153	1%
Consumer Industries	2,501	12%
Development Industries	2,641	13%
Educational Services and Other Government	1,651	8%
Federal Government	75	0%
Health Services	3,012	15%
High-Tech	142	1%
Other Basic Industries	109	1%
Software	563	3%
Supplier Industries	2,352	12%
Tourism/Travel	2,938	14%
Transportation & Distribution	1	0%
Total	20,282	100%

Table 3.12 Number of Employees by Type of Service

Type of Service	Number of Employees	Percent
Advanced Business Services	137,948	19%
Aerospace & Aviation	30	0%
Bioindustry	9,461	1%
Consumer Industries	47,929	7%
Development Industries	66,596	9%
Educational Services and Other Government	155,032	22%
Federal Government	10,159	1%
Health Services	97,302	14%
High-Tech	10,042	1%
Other Basic Industries	2,941	0%
Software	13,431	2%
Supplier Industries	63,955	9%
Tourism/Travel	100,280	14%
Transportation & Distribution	125	0%
Total	715,231	100%

Figure 3.9 Geographic Distribution of Service Employment from the Sampling Frame

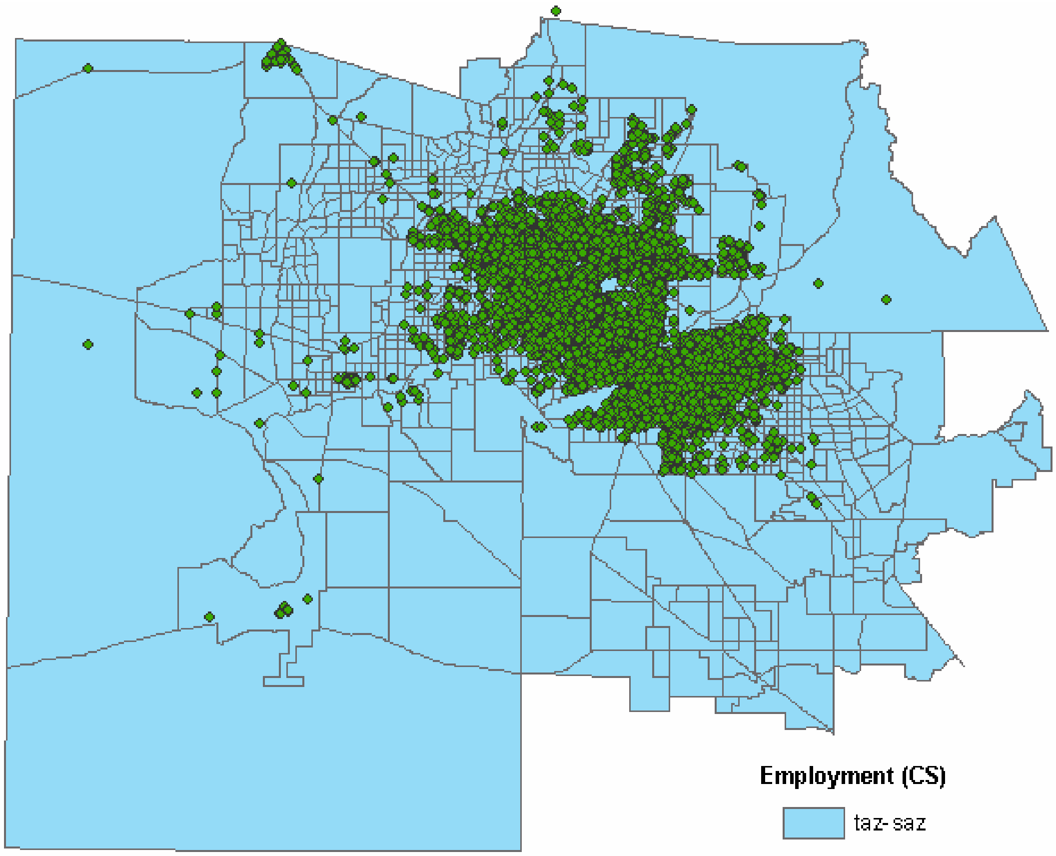


Figure 3.10 Distribution of Service Employment Locations by TAZ

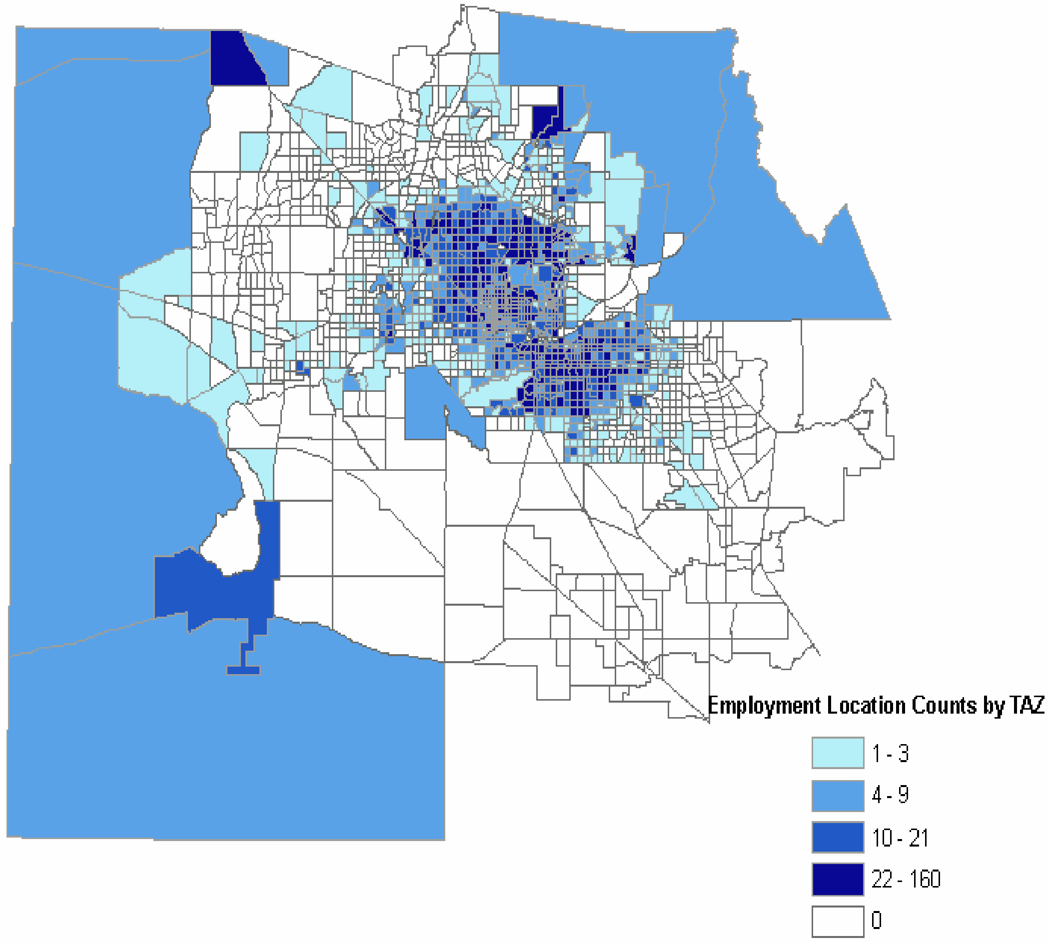
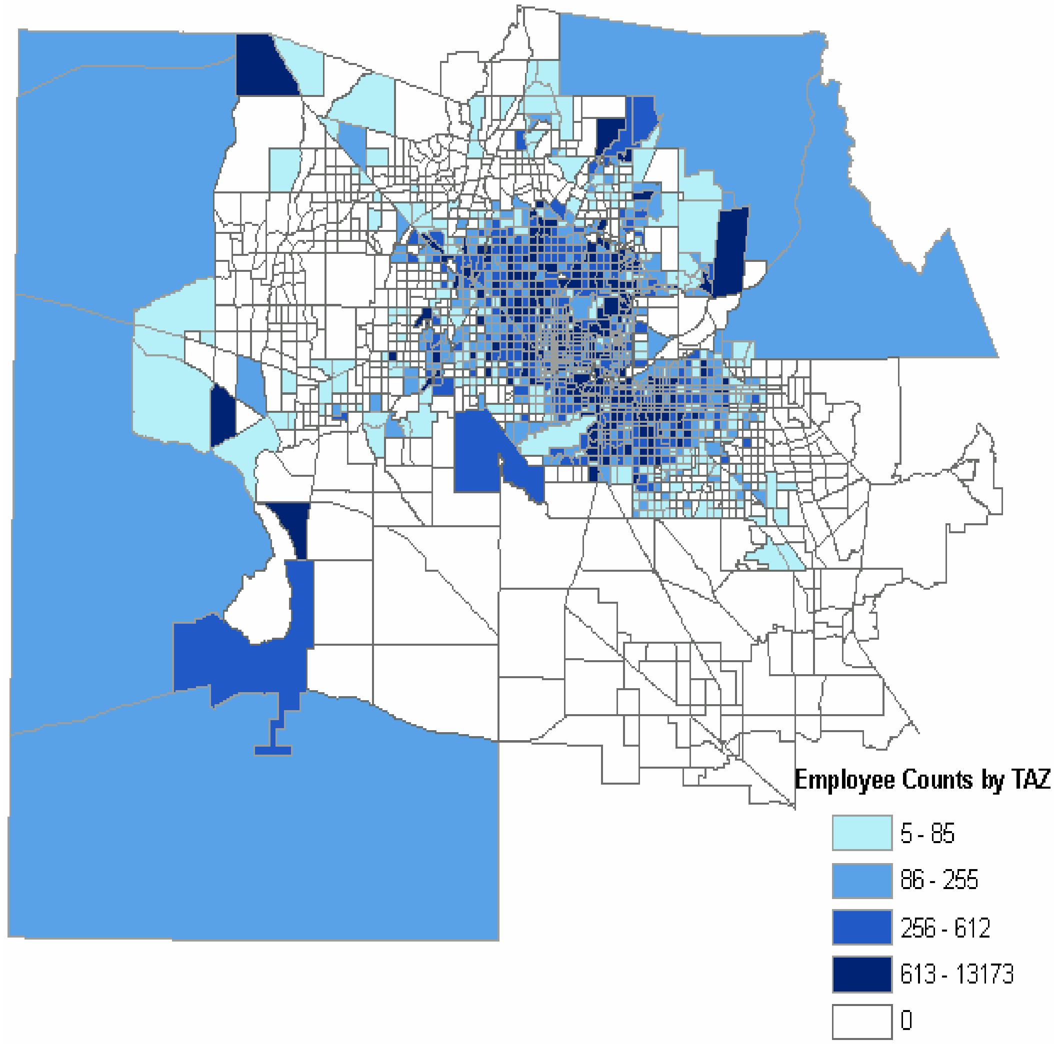


Figure 3.11 Distribution of Total Service Employees by TAZ



Model Methodology

A separate model for trucks in the Service sector was developed to estimate all other truck traffic not represented by truck models based on truck surveys. This model is kept separate because of the extreme difficulty in collecting good data from surveys that makes it very hard to update or calibrate the trip generation, distribution and assignment of commercial service vehicles. Data was collected as part of an FHWA research project on accounting for commercial vehicles in urban transportation models[14] that identified the magnitude and distribution of service vehicles in four categories: 1) safety, 2) utility, 3) public service, and 4) business and personal service vehicles.

Table 3.13 shows the travel behavior characteristics of all commercial service vehicles that were estimated using data from the DMV registration data; Census Bureau's VIUS data, and commercial vehicle surveys in Atlanta, Detroit, Denver, and the Triad cities.

Table 3.13 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 date from the DMV.	0.05 per population (data from 4 cities)
Trip/tour length	Average mileages are consistent across different cities and categories, ranging form 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 8 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 4 cities)
VMT	Service vehicles range from 5 percent to 13 percent of total VMT for 4 cities (San Diego, Sacramento, San Francisco, and Los Angeles), based on DMV and VIUS data, and represent 50 percent of total commercial vehicle VMT.	5.9 percent of total VMT (data from 4 cities)

Source: Cambridge Systematics, Inc., November 2003.

[14] Cambridge Systematics, Inc., *Accounting for Commercial Vehicles in Urban Transportation Models*, prepared for the Federal Highway Administration, February 2004.

In order to derive the estimates, as presented in Table 3.13, for the MAG region, the total number of commercial service vehicles need to be estimated to determine the Service sector VMT, which needs to be distributed to the highway network. The derivation of the commercial service vehicle fleet is described below.

Fleet Size

The number of commercial service vehicles in the MAG region is estimated using a combination of the County Vehicle Fleet Mix data, 2002 VIUS, and the FleetSeek Carrier Directory. The County Vehicle Fleet Mix data was obtained from MAG's Air Quality Modeling Group, and this data is classified by County and MOBILE5 vehicle classes. In order to correlate these with business sectors and classes being used in the new MAG truck model, additional data sources, such as the truck fleet statistics provided by the VIUS and the FleetSeek, are also used.

The truck population data is developed for different business sectors, which include Agriculture, Construction, Mining, Manufacturing, Retail Trade, Services, Transportation and Warehousing, Utilities, and Wholesale Trade. The 2002 VIUS data are used to get the distributions of truck fleet across these business sectors for the State of Arizona, which were then applied to the truck population at the county level available from the County truck fleet data. VIUS includes all these business sectors, but also includes an additional sector: Vehicle Leasing and Rental. Since each business sector uses owned as well as leased trucks, it was decided to allocate trucks in the 'Vehicle Leasing and Rental' sector to each of the other business sectors. This is done using the FleetSeek database, which provided the shares of total leased vehicles in the three counties (Maricopa, Pinal, and Yavapai) that are used by companies in the different business sectors identified above. These shares are then applied to the total trucks under the 'Vehicle Leasing and Rental' category to allocate them to each of the other business sectors.

To maintain consistency with the new MAG truck model, the truck population data is developed for three truck classes: light (FHWA Class 3), medium (FHWA Classes 5 to 7), and heavy (FHWA Classes 8 to 13). Since VIUS has its own detailed vehicle classification system, a correspondence is first developed to link the VIUS classification to the FHWA vehicle classes. This correspondence is then used to determine the number of trucks in each truck class belonging to each of the business sectors. VIUS also provided distributions of truck population by truck class and business sectors, which are then applied to the truck population data available at the county level to get the corresponding distributions for the MAG region. The County truck fleet statistics provides total truck population in each county belonging to light-duty and heavy-duty trucks. All the light-duty trucks belong to the FHWA Class 3 category, while all the heavy-duty trucks belong to FHWA Classes 5 to 13 category. Since the distributions to business sectors are available from VIUS for the FHWA Class 3 category, these are directly applied to the total light-duty trucks in each county from the County truck fleet statistics data to get the corresponding light-duty trucks by business sector in each county (Maricopa, Pinal, and Yavapai).

In order to get the splits between FHWA Classes 5 to 7 and FHWA Classes 8 to 13 trucks at the county level, the distributions of these truck classes of total heavy-duty trucks are derived from VIUS (by taking the total across all business sectors), and applying this distribution to the heavy-duty trucks from the County fleet statistics data. Once the total trucks by FHWA Classes 5 to 7 and FHWA Classes 8 to 13 are obtained at the county level, then the distributions of trucks in each of these truck classes across business sectors from VIUS are applied to get the corresponding distributions at the county level. The end result of this process is a cross-tabulation showing the number of trucks in each truck class belonging to each business sector for the MAG region as shown in Table 3.14.

Table 3.14 Truck Population by Sector and Truck Type

Business Sector	FHWA Class 3	FHWA Classes 5-7	FHWA Classes 8-13	Total Trucks
Agriculture	1,204	1,602	988	3,794
Construction	184,935	15,363	8,883	209,181
Manufacturing	58,229	4,325	728	63,283
Mining	429	673	225	1,326
Retail Trade	57,438	4,599	10,997	73,034
Services*	193,118	10,320	1,970	205,408
Transportation and Warehousing	85,966	79,632	16,824	182,422
Utilities*	59,088	7,041	600	66,730
Wholesale Trade	21,170	5,711	2,030	28,911
Total	661,576	129,266	43,246	834,088

* Total service vehicles are a combination of 'Services' and 'Utilities'.

The total vehicles that belong to the Service sector in the MAG region is a combination of 'Services' and 'Utilities' sectors, or 272,138 commercial vehicles. The service vehicles account for about one-third of the total truck population in the region, where a majority of these vehicles (93 percent) fall under the FHWA Class 3, about 6 percent under Classes 5 to 7, and 1 percent in Classes 8 to 13.

Trip/Tour Length

The estimated trip length characteristics from other studies indicate that on an average the commercial service vehicles travel about 41 miles per day and have an average trip length of 14 miles. This data, however, is not broken down by truck type, but can be assumed the same for all types of vehicles as the majority of these vehicles fall under the 'light' category or Class 3. This statistic could be used for validating service truck trip lengths.

Trips

The data from four cities, namely, Atlanta, Detroit, Denver, and the Triad, indicate the average number of trips generated by commercial service vehicles is 3 daily trips per vehicle. It should be noted that 3 trips per vehicle at 14 miles per trip is approximately equal to 41 miles per vehicle. This statistic could be used directly if there is more confidence in that data.

Vehicle Miles Traveled

Using the fleet size, trip length, and number of trips estimates, the VMT generated by commercial service vehicles in the MAG region can be computed as a product of these three variables. Table 3.15 shows the VMT of these vehicles by truck type using data from other studies.

Table 3.15 Potential VMT Generated by Commercial Service Vehicles

	FHWA Class 3	FHWA Class 5-7	FHWA Class 8-13	Total
Commercial service vehicles registered in the MAG region	252,206	17,361	2,570	272,138
Percent by vehicle type	93%	6%	1%	100%
Percent of total vehicles	38%	13%	6%	33%
Trip length from other studies (miles)	14	14	14	14
Trips per vehicle from other studies	3	3	3	3
Potential Service sector VMT*	10,592,652	729,162	107,940	11,429,796

* This VMT is just an estimate if statistics from other studies are used. This will, however, change if data from local surveys are used to generate and distribute these truck trips. The actual VMT generated in this sector is shown in Chapter 4.

Options Considered

The following are a few viable options that were considered to distribute or assign the commercial service VMT to the MAG highway network:

- Commercial service vehicles have very different trip distribution patterns that are not typical; that is, their distribution behavior changes everyday, depending on their customer needs and locations. Therefore, it is best to treat them very similar to nonhome based (NHB) trips in a passenger model, where the trips do not have a home-base. If the current MAG passenger model assigns NHB trips separately, then the approach would be to:

  - Determine the total NHB VMT from the model for each time period;
  - Allocate the total daily commercial service VMT by time period, either from the factors derived from the trip diaries or from the share of the model NHB VMT in each time period; and
  - Allocate the commercial service vehicle regional VMT by time period to each model link based on the share that a link's NHB VMT is of the regional total NHB VMT by time period.
- If the current MAG passenger model will not separately assign NHB trips, then we will have to aggregate the NHB VMT by district (or some level of geography) and set control totals or control percentage distributions, so that while distributing the commercial service VMT, the amount distributed does not exceed the NHB control percentages by district (or some level of geography).
- The third option considered was based on the assumption that the service trucks serve every other sector in the region on a need-basis that constantly varies by the day. So in order to distribute them among various sectors, the total truck trip ends for the Service sector need to be determined first through the traditional trip generation process. These trip ends will yield the percentage of the Service sector medium and heavy trucks, which will be used to increase the rest of the sectors before assignment. In other words, in aggregate, the total number of medium and heavy trucks assigned to the network will include the service trucks, as well as that would follow the distribution patterns of every other sector.

As the current MAG travel model does not assign the NHB trips separately, and since it is rather difficult to change the model structure to capture the NHB VMT, it was decided to use the third option to determine the Service sector truck trip generation and the corresponding VMT. The results of this analysis are provided under Chapter 4.

4.0 Internal Truck Travel Model

4.1 INTRODUCTION

The base year for this internal truck travel model development effort is 2006 and is a typical three-step freight truck model, which estimates trip generation, distribution, and traffic assignment for all trucks in the three-county MAG region. A three-step freight truck model produces highway freight truck flows by assigning an O-D table of freight truck flows to a highway network. This is the class of truck model currently included in the existing MAG travel demand model. The O-D truck table is produced by applying truck trip generation and distribution steps to existing employment and/or other variables of economic activity for analysis zones. The O-D table is estimated using trip generation rates/equations and trip distribution models at the TAZ level. The mode choice step is unnecessary since truck trips are estimated directly, and there is no need for the consideration of other possible modes for moving freight. The components required for this modeling technique include zonal employment data, methods to generate zonal freight productions and attractions by using freight truck trip generation rates, methods to generate truck O-D flows by applying trip distribution procedures to truck productions and attractions, and methods to assign the O-D freight truck flows to a highway network.

As noted above, freight truck models follow a three-step process of trip generation, trip distribution, and traffic assignment. Trip generation estimates the number of trips either produced in each zone or attracted to each zone, and is a function of socioeconomic characteristics of the zone (employment by industry, population, or number of households). Trip generation is accomplished using truck production and attraction equations, which coefficients are estimated based on the truck travel surveys. Trip distribution determines the connection between trip origins and trip destinations, and is accomplished using a gravity model similar to that used in the passenger model. In the gravity model, the number of trips that travel between one zone and another is a function of the number of trip attractions in the destination zone, and is inversely proportional to a factor measuring the impedance between the two zones. The gravity model used here is related to the travel time between two zones (i.e., the longer it takes to get from one zone to another, the less attractive trips to that destination zone become). The parameters in the gravity model are developed from the truck trip diaries. The route that trucks use to get from origin to destination is a function of network characteristics, taking into account traffic conditions on each route. Network assignment of the truck trips is based on a multi-class equilibrium highway assignment that includes passenger cars; in other words, the model looks for the shortest time path for all trips simultaneously. Freight truck models can take into account the different classes of trucks and their impact on congestion compared to automobiles (large trucks cause more congestion, because they occupy more space than autos). The assignment procedures and results are also discussed in more detail in this section.

4.2 Description of the Internal Truck Model

The internal truck model is designed to develop forecasts of trucks that are internal to the MAG region; that is, these truck trips have both the origins and destinations inside the MAG regional boundary. As described in Section 2.0, the FHWA stratification scheme is used here to classify the trucks into different categories. This classification scheme is separated into categories depending on whether the vehicle carries passengers or commodities. Nonpassenger vehicles are further subdivided by number of axles and number of units, including both power and trailer units. These stratifications are presented in Appendix A.

The internal truck travel model uses the following three groups of trucks:

1. **Light trucks (2-axle, 4-tire).** The FHWA Class 3 (or less than 8,000 lbs GVW);
2. **Medium trucks (single units).** The FHWA Classes 5, 6, and 7; and
3. **Heavy trucks (combination units).** The FHWA Classes 8, 9, 10, 11, 12, and 13.

The model is specifically designed to predict truck movements in the region for planning purposes. The model employs socioeconomic data by TAZ, with employment data broken down into further detail by the NAICS code to better estimate commodity flow demand that correspond to truck travel demand.

External truck trips and trips with a trip end outside of the MAG region were developed in previous study and are not updated in this study. These truck trips are added to the new internal truck trips after internal truck trip distribution. This chapter describes the truck trips that are "internal" to the region.

4.3 Trip Generation

Socioeconomic Data

The socioeconomic data that is used to estimate internal trip generation in the truck model is more detailed than those data being used in the auto passenger model; that is, the employment data is stratified into more employment categories. This process provides more accuracy for truck travel and allows for a direct relationship between the industrial sectors being represented in the internal trip model and the allocation of trucks generated from these industries to TAZs within the region. The different land use/employment categories that are used in the internal model are: Agriculture, Mining, Utilities, Construction, Manufacturing, Wholesale Trade, Retail Trade, Transportation/Warehousing, FIRES, Education, Government, and Households, which include all 22 two-digit NAICS categories. As most of the service industries are very similar to one another in terms of truck-trip generation characteristics, these 22 two-digit

NAICS categories are aggregated to eight distinct categories for modeling purposes. The aggregation is shown in Table 4.1. In addition to these, total households, total population, and total employment were also used as explanatory variables in the trip generation models.

Table 4.1 Aggregated 2-Digit NAICS Categories

2-Digit	2-Digit Description	Aggregate Categories for Trip Generation Models
11	Agriculture, Forestry, Fishing, and Hunting	Farming Employment
21	Mining	Mining Employment
22	Utilities	Service Employment
23	Construction	Construction Employment
31	Manufacturing	Manufacturing Employment
42	Wholesale Trade	Wholesale Employment
44	Retail Trade	Retail Employment
45	Retail Trade	Retail Employment
48	Transportation and Warehousing	Wholesale Employment
49	Transportation and Warehousing	Wholesale Employment
51	Information Services	Service Employment
52	Finance and Insurance	Service Employment
53	Real Estates, and Rental and Leasing	Service Employment
54	Professional, Scientific, and Technical Services	Service Employment
55	Management of Companies and Enterprises	Service Employment
56	Administrative and Support, and Waste Management and Remediation Services	Service Employment
61	Educational Services	Service Employment
62	Health Care, and Social Assistance	Service Employment
71	Arts, Entertainment, and Recreation	Service Employment
72	Accommodation, and Food Services	Service Employment
81	Other Services (Except Public Administration)	Service Employment
92	Public Administration	Service Employment

Issues With 2-Digit NAICS Employment Data

The existing MAG travel demand model uses employment for five categories, namely, retail, office, industrial, public, and other at the TAZ level to forecast both auto passenger and truck volumes in the region. In the new truck model, disaggregate 2-digit NAICS employment data is used as truck trip generation is land use based and not occupation based.

MAG was able to derive the 2-digit NAICS data for the base year 2006 at the TAZ level, but does not have a readily available procedure in place to derive the same for the forecast years. Since having similar data is important for producing forecasts, it was decided to have an interim solution to derive employment data forecasts. This interim procedure involves producing 2-digit NAICS at an aggregate level by looking at the distribution of employment and location of freight centers and economic activity for trucks, and MAG can achieve this in a short period of time at the RAZ level for the forecast years. The procedure recommended to apply the RAZ-level data to produce TAZ-level truck trip generation estimates is described in the following section.

Procedure to Develop 2-digit NAICS Employment Forecasts

The following are the series of steps that need to be undertaken by MAG to generate forecast year truck trip generation estimates:

1. The base year truck model uses the detailed 2-digit NAICS employment data at the TAZ level to produce truck trip generation estimates for all the 2,400 TAZs. However, as the 2-digit NAICS employment data for the forecast years will be available only at the RAZ level, the truck trip generation estimates will first be derived for the 145 RAZs.
2. The percentage distributions of truck trip generation estimates will be derived from the 2006 base year truck model at the TAZ level. These percentages will be by land use type and truck type.
3. These TAZ-level percentages by land use and truck type will then be applied to each of the 145 RAZs to disaggregate the RAZ-level truck trip generation estimates to individual TAZs. The assumption here is that the relative distributions of land use and employment is the same in the forecast years. The validity of this assumption can be quickly checked by comparing the distribution of MAG's current five employment categories across the base year and the forecast years at the RAZ level.
4. After deriving the TAZ-level truck trip generation estimates for the forecast years, the rest of the modeling procedure will be very similar to that of the base year model; that is, there will not be any change in the trip distribution and assignment models.

The pros and cons of using such an approach are listed below.

Pros

- Using disaggregate 2-digit NAICS employment data for the truck model will increase the accuracy of the truck model forecasts as it will be land use based;
- Developing the base year model using a disaggregate land use-based truck trip generation procedure will prevent MAG from updating the model again when the 2-digit NAICS employment data is available for the forecast years; and

- The interim procedure will help MAG produce truck forecasts without having to wait for the detailed TAZ level 2-digit NAICS employment data.

Cons

- There could be minor differences in the truck forecasts when MAG starts to use the TAZ level 2-digit NAICS employment data when it is available;
- Any pitfalls of assuming a constant distribution of land use and employment across base and forecast years need to be kept in mind; and
- Extending the region's boundary in the forecast years before the TAZ-level, 2-digit NAICS employment data is available will warrant MAG to either use regional average distributions of employment from the base year, or determine the economic activity for trucks in the extended or new RAZs.

Internal Truck Trip Generation Rates

The trip generation models use economic variables to forecast freight flows/ vehicle flows to and from a geographic area using equations. These trip generation equations are developed using the truck travel information obtained through the trip diary surveys and operator surveys. The outcome of trip generation is the number of vehicles that comes into or goes from a TAZ in a specified unit of time.

The truck trip generation rates or equations are used to determine the daily truck flows originating or terminating in TAZs as a function of zonal population and/ or industry sector employment data. In other words, employment and/or population data are the essential input data required for computing freight trip generation. These independent variables, such as employment and population, dictate the level of detail the truck flows can be generated using the trip generation model.

The trip diaries and the operator surveys that collected information on the type of business at each stop, when expanded, resulted in data on the total number of trip ends at businesses in each industry category. Dividing by the number of employees in each industry category provided trip generation rates by truck type that was then applied to socioeconomic data to estimate trip ends by TAZ. With the available survey data, one set of trip rates for the productions and one set of rates for consumption are estimated. These rates are developed for each industry sector or land use and truck type. These industry sectors or land uses are analogous to "trip purposes" in the passenger model. The intercept is always forced to zero, because there should be no truck activity in or out of a zone with any related economic activity.

The following land use categories are considered for the truck trip productions and attractions:

- My Employer (start and end point of any truck trip);
- Retail;
- Construction
- Farming;
- Mining;
- Households;
- Governments;
- Warehousing;
- Transportation;
- Office; and
- Industrial/Manufacturing.

The four tables presented below show the truck trip generation rates for productions and attractions by land use and truck type. The production and attraction trip rates are computed using a combination of linear regression equations and the ratio of the productions/attractions and the corresponding employment. The employment data is at the TAZ level by 2-digit NAICS codes. Tables 4.2, 4.3, 4.4, and 4.5 show medium- and heavy-truck production and attraction trip rates by land use, where the categories along the columns are land uses and those along the rows are the variables that go into the production and attraction equations. The rates can also be called as the coefficients in these equations.

These estimated trip rates are derived after several iterations of the trip generation model. The results of the trip generation model are productions and attractions by land use and truck types, which are compared against the expanded survey database. The comparison of these results helped determine the final trip rates that need to be used for the truck-trip generation model.

Table 4.2 Medium-Truck Production Trip Rates by Land Use

Variable	My Employer	Retail	Construction	Farm	Mining	Household	Government	Warehouse	Transportation	Office	Other	Industrial
Total Employment	0.04638	–	0.01135	–	–	–	–	–	–	–	–	–
Retail Employment	–	0.12415	–	–	–	–	–	–	–	–	–	–
Retail Square	–	0.00012	–	–	–	–	–	–	–	–	–	–
Total Population	–	–	0.00603	–	–	–	–	–	–	–	–	–
Log (Total Households)	–	–	–	–	–	1.95453	–	–	–	–	–	–
Wholesale Employment	–	–	–	–	–	–	–	0.50886	0.01223	–	–	–
Mining Employment	–	–	–	–	–	–	–	–	–	–	–	–
Farming Employment	–	–	–	0.32511	–	–	–	–	–	–	–	–
Manufacturing Employment	–	–	–	–	–	–	–	–	–	–	–	0.1674

Table 4.3 Heavy-Truck Production Trip Rates by Land Use

Variable	My Employer	Retail	Construction	Farm	Mining	Household	Government	Warehouse	Transportation	Office	Other	Industrial
Total Employment	0.09548	–	0.02488	–	–	–	–	–	–	–	–	–
Retail Employment	–	0.105	–	–	–	–	–	–	–	–	–	–
Retail Square	–	–	–	–	–	–	–	–	–	–	–	–
Total Population	–	–	0.02189	–	–	–	–	–	–	–	–	–
Log (Total Households)	–	–	–	–	–	3.29133	–	–	–	–	–	–
Wholesale Employment	–	–	–	–	–	–	–	0.72675	0.09575	–	–	–
Mining Employment	–	–	–	–	–	–	–	–	–	–	–	–
Farming Employment	–	–	–	0.13632	–	–	–	–	–	–	–	–
Manufacturing Employment	–	–	–	–	–	–	–	–	–	–	–	0.13390

Table 4.4 Medium-Truck Attraction Trip Rates by Land Use

Variable	My Employer	Retail	Construction	Farm	Mining	Household	Government	Warehouse	Transportation	Office	Other	Industrial
Total Employment	0.0340	–	0.01774	–	–	–	–	–	–	–	–	–
Retail Employment	–	0.15486	–	–	–	–	–	–	–	–	–	–
Retail Square	–	0.0001	–	–	–	–	–	–	–	–	–	–
Total Population	–	–	0.00471	–	–	–	–	–	–	–	–	–
Log (Total Households)	–	–	–	–	–	2.05792	–	–	–	–	–	–
Wholesale Employment	–	–	–	–	–	–	–	0.52718	0.02273	–	–	–
Mining Employment	–	–	–	–	–	–	–	–	–	–	–	–
Farming Employment	–	–	–	0.32551	–	–	–	–	–	–	–	–
Manufacturing Employment	–	–	–	–	–	–	–	–	–	–	–	0.20577

Table 4.5 Heavy-Truck Attraction Trip Rates by Land Use

Variable	My Employer	Retail	Construction	Farm	Mining	Household	Government	Warehouse	Transportation	Office	Other	Industrial
Total Employment	0.08367	–	0.02189	–	–	–	–	–	–	–	–	–
Retail Employment	–	0.10965	–	–	–	–	–	–	–	–	–	–
Retail Square	–	–	–	–	–	–	–	–	–	–	–	–
Total Population	–	–	0.0241	–	–	–	–	–	–	–	–	–
Log (Total Households)	–	–	–	–	–	3.13073	–	–	–	–	–	–
Wholesale Employment	–	–	–	–	–	–	–	0.75971	0.1155	–	–	–
Mining Employment	–	–	–	–	–	–	–	–	–	–	–	–
Farming Employment	–	–	–	0.13632	–	–	–	–	–	–	–	–
Manufacturing Employment	–	–	–	–	–	–	–	–	–	–	–	0.13915

Table 4.6 shows the total internal truck-trip productions and attractions by truck type and by land use category for the MAG region. These are derived from the internal truck model after the application of the final set of production and attraction trip rates.

Table 4.6 Internal Truck-Trip Ends by Land Use and Truck Type

	Medium Trucks		Heavy Trucks	
Land Use	Productions	Attractions	Productions	Attractions
My Employer	56,740	53,669	129,991	121,714
Retail	36,834	35,196	18,942	17,081
Construction	43,830	43,175	133,749	119,921
Farming	1,965	19,65	–	823
Mining	–	–	655	13,574
Household	21,874	17,991	35,771	30,793
Warehousing	64,652	62,689	92,761	91,119
Transportation	1,581	2,128	13,182	11,950
Industrial	29,424	25,828	20,590	20,589
Service*	31,067	29,105	29,318	28,129
Total	287,967	269,781	474,959	455,693

*Service includes ‘Government’, ‘Office’, and ‘Other’ land uses.

4.4 Trip Distribution

In trip distribution, the truck flow linkages are captured between origin and destination for those land uses that are developed in trip generation. A gravity model is typically used for trip distribution, and this is a statistical process that has been found useful to explain the relationship between transportation zones. The considerations are the total trips that begin in the first zone, the number ending in the second zone, and the impedance or difficulty to travel (such as cost or time) between them. These gravity models or trip distribution equations are developed using the trip diary surveys by truck type. The average trip lengths needed to obtain trip length frequency distributions, and friction factors are obtained from the surveys as well. The degree of difficulty of travel, which is represented as a function of congested travel time used in the distribution model, is matched with the survey data, and the calculation of the degree of difficulty is called the friction factor.

Friction Factors

The friction factors are calculated as a negative exponential function of the average trip time from origin TAZ to destination TAZ. The parameters in the exponential function are calculated from the trip length frequency distribution, which is summarized by the average trip length. These parameters are adjusted to provide the best fit with the average trip lengths from the survey of trucks. In the previous truck model, the light, medium, and heavy trucks are distributed from origins to destinations using this gravity model technique with different parameters, as shown below.

For all light trucks:

$F_{ij} = e^{-0.08 * t_{ij}}$

For all medium trucks:

$F_{ij} = e^{-0.10 * t_{ij}}$

For all heavy trucks:

$F_{ij} = e^{-0.03 * t_{ij}}$

Where:

F_{ij} = friction factor for O-D pair ij, and

t_{ij} = congested travel time for O-D pair ij.

For this revised truck model, no adjustment was made to the light-truck trip distribution equations. For the medium and heavy trucks, the method of distributing productions and attractions and the coefficient in the distribution equation have been updated.

Aggregating truck trip ends by purpose and attraction and then distributing those aggregated productions and attractions would link types of land use categories for which no activity was identified in the survey, and for which none is expected. For example, as shown in Table 4.7, the survey found no medium-truck trips originating at mines and terminating at government buildings. If the productions and attractions were aggregated prior to distribution, as was the practice in the previous model, there is no way to ensure that the distribution of trips between incompatible land uses would not occur.

The process that was developed was based on the recognition that trip distribution is a connection between a land use category serving as a production and a land use category serving as an attraction. For example, in passenger modeling, Home-Based Work (HBW) passenger trips are those that occur between the Home land use production and the Work land use attraction. The HBW productions are the percentage of total home productions that will be distributed to work attractions, and the HBW attractions are the percentage of total work attractions that will be distributed to home productions. This same principle was applied in the revised truck model.

Table 4.7 Medium-Truck Trips
Expanded Survey

Origin/Destination	My Employer	Retail	Construction	Farm	Mining	Household	Government	Warehouse	Transportation	Office	Other	Industrial/ Manufacturing	Total Productions
My Employer	23,957	13,540	42,044	–	–	16,030	5,119	40,931	2,254	6,777	5,363	15,284	171,299
Retail	13,617	52,229	5,363	1,694	–	7,960	–	6,777	–	1,694	1,694	–	91,028
Construction	32,148	5,363	43,656	1,694	–	7,057	–	5,643	–	280	–	14,125	109,966
Farm	3,389	–	–	–	1,694	–	–	–	–	–	–	–	5,083
Mining	–	–	–	–	–	–	–	–	–	–	–	–	–
Household	16,402	4,494	5,643	–	–	14,351	560	3,389	1,694	3,949	–	2,559	53,040
Government	865	-	1,694	–	–	1,974	–	–	–	865	–	5,083	10,482
Warehouse	19,310	17,097	6,777	–	–	3,389	–	101,561	–	3,389	1,694	11,031	164,248
Transportation	1,974	–	280	1,694	–	–	–	–	–	–	–	–	3,949
Office	2,559	1,694	280	–	–	5,083	280	3,389	1,694	9,616	1,694	–	26,290
Other	1,974	3,389	1,694	–	–	–	1,694	1,694	–	–	5,083	5,083	20,611
Industrial/ Manufacturing	9,372		11,286	–	–	–	3,389	6,777	1,694	–	3,389	30,300	67,901
Total Attractions	125,568	99,500	118,717	5,083	1,694	55,844	11,041	170,160	7,337	26,570	18,917	83,465	723,897

Table 4.8 Heavy-Truck Trips
Expanded Survey

Origin/Destination	My Employer	Ret ail	Construction	Farm	Mining	Household	Government	Warehouse	Transportation	Office	Other	Industrial/ Manufacturing	My Employer
My Employer	4,413	827	15,032	276	1,379	2,917	421	16,445	827	–	5,363	15,284	45,716
Retail	827	2,482	972	–	-	276	276	552	827	–	1,694	–	6,212
Construction	15,453	276	19,328	–	2,482	972	–	1,669	696	552	–	14,125	43,939
Farm	–	–	–	–	–	–	–	–	–	–	–	–	–
Mining	–	–	3,861	–	–	–	–	–	–	–	–	–	3,861
Household	2,089	276	1,538	–	–	4,889	–	1,117	–	1,669	–	2,559	11,578
Government	421	972	–	–	–	–	–	–	–	–	–	5,083	1,393
Warehouse	13,804	1,103	1,538	–	–	1,683	–	10,625	552	–	1,694	11,031	30,408
Transportation	276	552	972	–	–	–	–	552	552	–	–	–	4,006
Office	276	–	276	–	–	–	1,393	–	–	276	1,694	–	2,220
Other	421	–	841	–	–	276	–	552	276	–	5,083	5,083	5,951
Industrial/ Manufacturing	2,075	–	1,379	–	–	–	–	276	1,103	–	3,389	30,300	7,040
Total Attractions	40,055	6,488	45,738	276	3,861	11,013	2,089	31,787	4,833	2,496	6,371	7,316	162,324

For medium and heavy trucks, a separate distribution was performed from each of the 12 land use categories as a production to each of the 12 land use categories as an attraction. The percentage of the total productions from that land use category using the trip ends, as shown in Table 4.6, to the land use attraction would be determined as the percentage of the total productions, as shown in Table 4.7, for medium trucks and Table 4.8 for heavy trucks, which are made to that land use category as an attraction. For example, for medium trucks distributed from the warehouse land use production to the retail land use attractions, the percentage of the warehouse productions to be distributed would be, from Table 4.7, the productions in this distribution connection, or 10.41 percent, (17,097 for warehouse production to retail attractions divided by the total warehouse productions of 164,248). The percentage of the retail attractions to be distributed would be the attractions in this distribution connection, or 11.76 percent, (17,097 for warehouse production to retail attractions divided by the total retail attractions of 99,500). This same process is repeated for medium and heavy trucks for each of the connections between land use productions to land use attractions.

Three land use categories, namely, government, office, and other, represent the Service sector and are distributed using the methodology described in Section 3.3. The rates and values are shown here, because these trips are included in order to properly determine the percentages to be applied for all of the other connections. The ratios of total truck trip ends and those that exclude the Service sector were found to be 1.1209 and 1.0658 for medium and heavy trucks, respectively. These are derived from the weighted survey results, where the trip diaries indicated a truck stop at government, office, or other locations. These factors are used to increase the truck-trip tables by sector and type, after trip distribution, to account for the service truck trips.

Trip Balancing

The trip rates after validation do not match the rates from the original expanded survey. These adjustments are described elsewhere in this report. While this affects the number of trip ends, it is assumed that it will not affect the percentage of the connections that can be calculated from the expanded survey, as shown in Tables 4.7 and 4.8. As there will be a difference between the survey and the validated trip ends, there is no longer an assurance that the productions for the distribution connection will match the attractions for that same distribution connection. A balanced number of productions and attractions is required for the gravity model distribution to function. In order to ensure that this distribution requirement is met, prior to distribution for each of the 144 potential connections, the attractions and productions are balanced to the average of the two numbers. Balancing to the average will not change the total number of trips to be distributed, but will ensure that the productions and attractions will balance within each connection. In some cases, the attractions for a land use category will be balanced downward to meet the attraction in a land use category, while in other connections, they will be balanced upwards to match the attraction in a different land use category. In aggregate, the number of trips will still be the same, and this is shown in the following formulation:

Balanced Pi = Pi *(sum Pi + sum Aj)/(2* sum Pi), and

Balanced Aj = Aj * (sum Pi + sum Aj)/(2* sum Aj).

Where:

Pi and Aj are productions and attractions for each of the 12 sectors.

Truck Trip Lengths

For each of the land use connections, average trip lengths were calculated from the surveys. The reciprocal of those average trip lengths for each connection was used as the original coefficient in the Friction Factor equation. In all, 288 coefficients were estimated for each of the 288 connections (12 land use productions by 12 land use attractions by two truck types), and used in the trip distribution process. On average, these coefficients were -0.0425 for medium and -0.039 for heavy trucks, as estimated by the average trip length coming from the model.

The average trip lengths are estimated from the survey data using information on the truck stops in each survey record, the TAZ location of each truck stop, and a TAZ to TAZ congested travel time matrix from the model. The TAZ to TAZ trip time matrix is linked to the survey database using the TAZ location of the truck stops as the common data field.

After performing the trip distribution as described above, the average trip lengths are calculated for medium and heavy trucks. Table 4.9 shows the average trip lengths by truck type from the expanded survey database compared against the updated truck model.

Table 4.9 Average Trip Length by Truck Type

Truck Type	Survey (In Minutes)	Model (In Minutes)	Difference (In Minutes)	Trips
Light	N/A	15.89	N/A	1,732,178
Medium	20.13	23.52	3.39	646,311
Heavy	23.11	25.53	2.42	145,855

Figures 4.1 and 4.2 show the trip length frequency distribution for medium and heavy trucks. The x-axis shows the trip lengths in minutes in five-minute increments, and the y-axis shows the cumulative frequency distributions. The curves show that the aggregate model results match the aggregate survey results very well. The difference is in the shape of the curve, not the averages. For both medium and heavy trucks, the model overestimates short trips compared to the survey, and underestimates long-distance trips. This suggests that the survey

may have been biased in favor of long-distance trips, or the friction factor for trucks may not follow the statistical basis of the gravity model. It is not possible to address either of these issues with the existing data, and given that the model otherwise produces acceptable results, it is recommended that this be addressed by future research.

Figure 4.1 Medium-Truck Trip Length Frequency Distribution

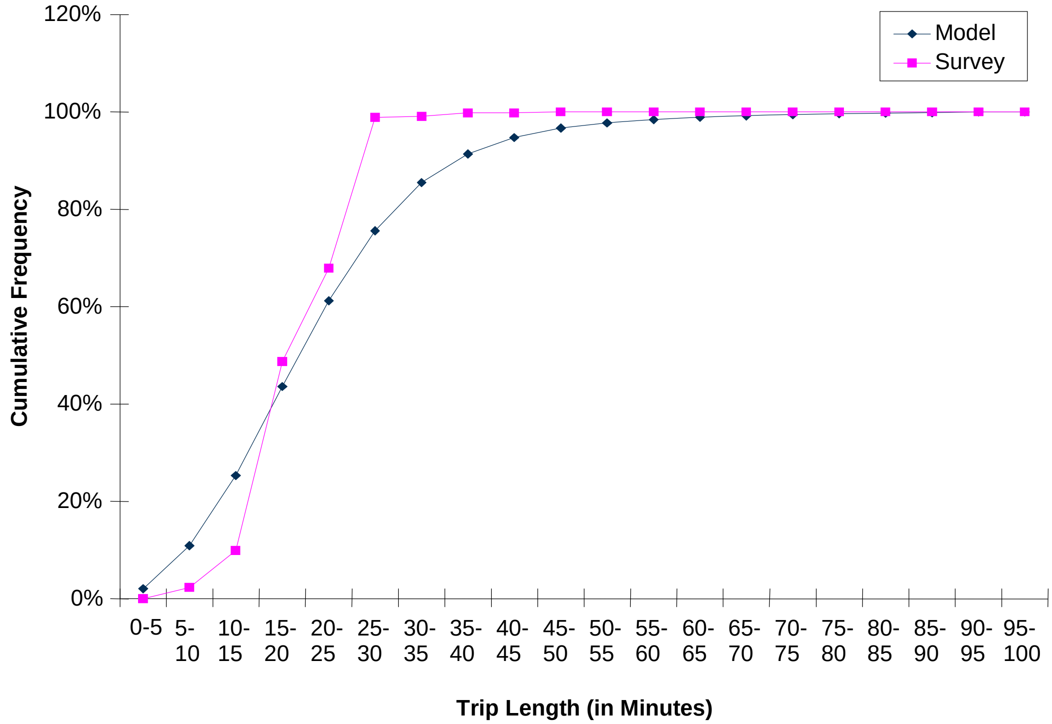
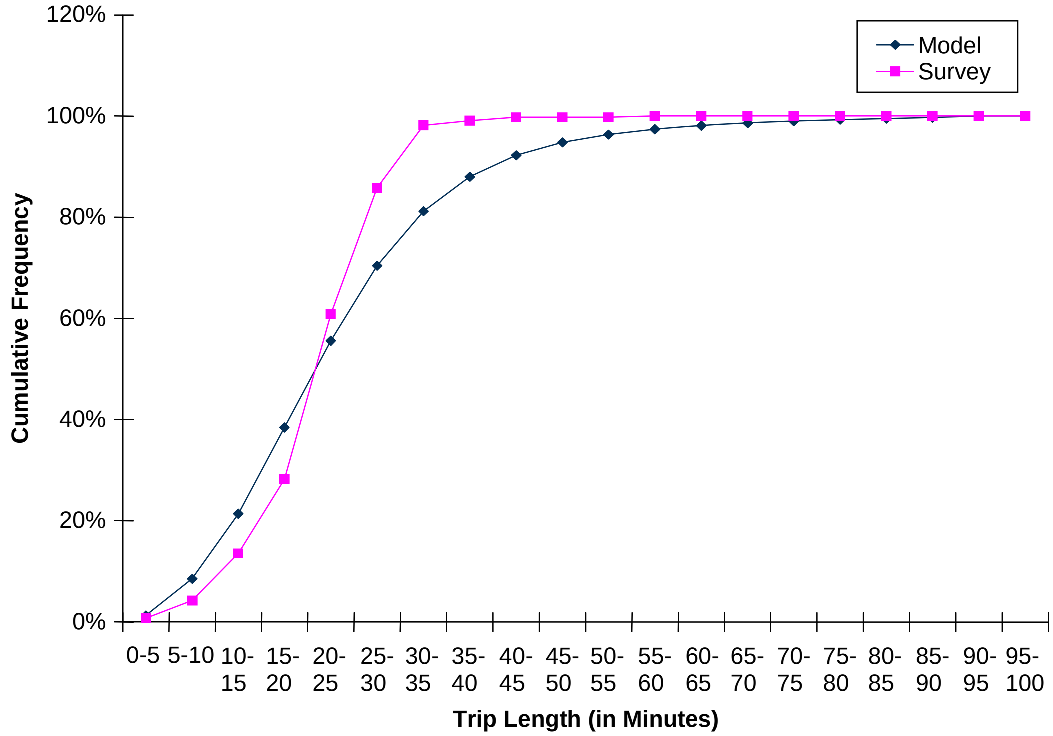


Figure 4.2 Heavy-Truck Trip Length Frequency Distribution



4.5 TRIP ASSIGNMENT

Multi-Class Assignments

Trip assignment of the truck trips was completed using an equilibrium highway assignment. Truck trips were assigned simultaneously with the passenger model, because congestion has a significant impact on travel times experienced by trucks. Truck trips are assigned separately by type using the multi-class assignment technique for five vehicle types:

1. Single-occupant passenger vehicles,
2. High-occupant passenger vehicles,
3. Light trucks,
4. Medium trucks, and
5. Heavy trucks.

Passenger Car Equivalents

The original truck model was developed using a conversion of truck volumes to passenger car equivalents (PCE) for assignment purposes. This factor provides a means to account for the fact that larger trucks take up more capacity on the roads than passenger cars. However, this process was subsequently changed and the existing model does not use any PCEs; that is, vehicles, and not PCEs, are assigned to the highway network. The use of PCEs is a fundamental change in the model that has larger implications on link capacity, and on the validation and route choice of autos and external trucks, as well as the internal trucks that were the focus of this study. If PCEs are to be included in the MAG model, and there are advantages to making this change, it should be undertaken in conjunction with a revalidation of the complete model.

Validation

As part of the 2006 Arterial Count Study, MAG collected vehicle classification counts on about 200 locations. The classification was based on the FHWA classification scheme, and the counts for Classes 5 to 7 were grouped together for medium trucks, and Classes 8 to 13 for heavy trucks. As the trip assignment model produces truck volumes in vehicles, these are directly compared against the counts on the arterials. Also, as this model update is focused on internal truck trips, it is more important to validate the truck volumes on the arterials. Table 4.10 provides the results from the truck assignments of the new truck model compared against the counts at the city level in the MAG region.

Table 4.10 indicates that there are five cities, namely, Buckeye, Carefree, Fountain Hills, Queen Creek, and Tonopah, which have differences between volumes and counts by over 40 percent. This is acceptable due to the low-volume facilities passing through these Cities that carry less than 1,000 trucks per day. All other cities are within the validation targets derived from the most recent guidelines from the FHWA[15]. However, there are two exceptions – Glendale and Surprise, where the new truck model underestimates total medium and heavy trucks by about -32 percent and -65 percent, respectively. Both these Cities, which fall under the volume group of 10,000 to 15,000, should be within a target of +/-25 percent according to the FHWA guidance. The reason for the underestimation could be attributed to the external trucks, as the City of Surprise is closer to the periphery of the MAG region and U.S. Highway 60, which has an external station on it, passes through the Cities of Surprise and Glendale. This should be further improved when the external truck model is calibrated and validated. The total number of medium and heavy trucks on all the arterial count locations is within 2 percent of the observed values.

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[15] U.S. Department of Transportation, Travel Model Improvement Program, *Model Validation and Reasonableness Checking Manual*, prepared by Barton Aschman Associates and Cambridge Systematics, Inc., for the Federal Highway Administration, February 1997, page 107.

Table 4.10 Comparison of Truck Volumes and Counts on Arterials

	2006 Arterial Counts			2006 New Truck Model			Difference		
City	Medium	Heavy	Medium & Heavy	Medium	Heavy	Medium & Heavy	Medium	Heavy	Medium & Heavy
Avondale	1,548	1,312	2,860	940	2,006	2,947	-39%	53%	3%
Buckeye	269	285	554	261	548	809	-3%	92%	46%
Carefree	607	187	794	190	372	562	-69%	99%	-29%
Chandler	2,045	5,883	7,928	2,344	4,736	7,080	15%	-20%	-11%
Fountain Hills	301	1,067	1,368	698	1,429	2,127	132%	34%	55%
Gilbert	2,097	2,164	4,261	1,010	2,007	3,017	-52%	-7%	-29%
Glendale	5,020	7,443	12,463	2,933	5,524	8,456	-42%	-26%	-32%
Mesa	4,725	10,268	14,993	3,751	7,426	11,177	-21%	-28%	-25%
Paradise Valley	533	1,208	1,741	555	1,057	1,612	4%	-12%	-7%
Peoria	1,615	1,629	3,244	1,095	1,965	3,060	-32%	21%	-6%
Phoenix	35,266	71,401	106,667	45,472	80,150	125,622	29%	12%	18%
Queen Creek	489	241	730	109	219	328	-78%	-9%	-55%
Scottsdale	4,672	13,899	18,571	6,068	10,498	16,566	30%	-24%	-11%
Surprise	7,864	2,970	10,834	1,213	2,543	3,755	-85%	-14%	-65%
Tempe	2,499	7,708	10,207	4,532	6,957	11,490	81%	-10%	13%
Tonopah	50	25	75	48	82	130	-5%	229%	73%
Total	69,600	127,690	197,290	71,219	127,519	198,738	2%	0%	1%

Figures 4.3 and 4.4 provide scatter plots of medium- and heavy-truck volumes against observed counts on the arterials. The x-axis shows the count location, while the y-axis represents the number of trucks per day.

Table 4.11 compares the new truck model volumes against the existing truck model volumes at those arterial locations where counts were collected. These are also aggregated to the city level and by light, medium, heavy, and medium plus heavy trucks. As the light trucks were not updated, the light-truck volumes are comparable across the two versions of the models. However, there is a significant difference between medium and heavy trucks combined. This can be attributed to the different truck model definitions between the two models, and it also shows that the existing truck model under-predicts medium and heavy trucks significantly. This is further corroborated when looking at the differences between the existing truck model volumes against the counts.

Figure 4.3 Scatter Plot of Medium-Truck Volumes and Counts on Arterials

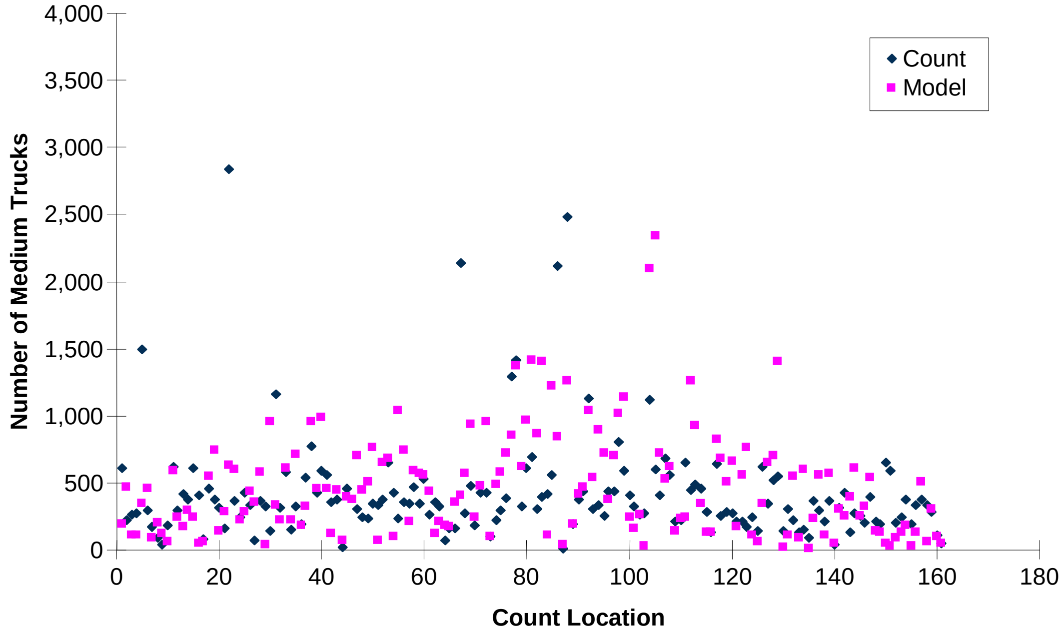


Figure 4.4 Scatter Plot of Heavy-Truck Volumes and Counts on Arterials

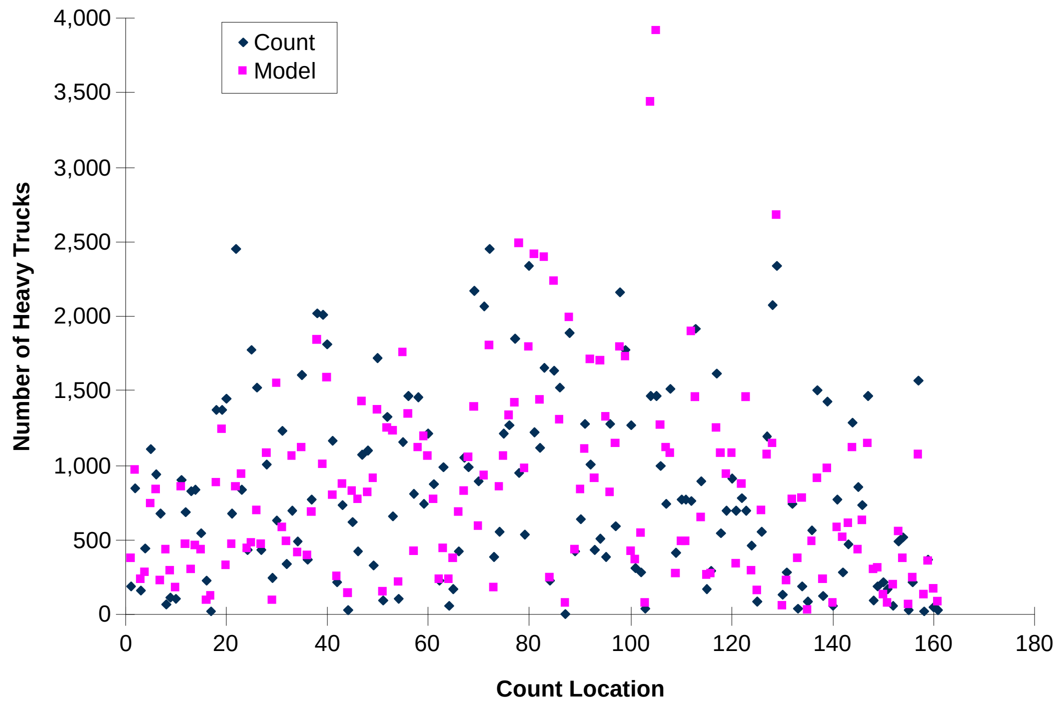


Table 4.11 Comparison of Truck Volumes on Arterials
Existing and New Truck Model

	2006 Existing Truck Model				2006 New Truck Model				Difference	
City	Light	Medium	Heavy	Medium & Heavy	Light	Medium	Heavy	Medium & Heavy	Light	Medium & Heavy
Avondale	3,795	607	624	1,230	3,878	940	2,006	2,947	2%	139%
Buckeye	640	57	90	147	530	261	548	809	-17%	451%
Carefree	1,698	461	182	643	1,666	190	372	562	-2%	-13%
Chandler	12,739	1,580	1,768	3,348	12,729	2,344	4,736	7,080	0%	111%
Fountain Hills	3,973	572	497	1,069	3,664	698	1,429	2,127	-8%	99%
Gilbert	5,138	698	652	1,350	5,173	1,010	2,007	3,017	1%	123%
Glendale	12,103	1,547	1,714	3,261	12,154	2,933	5,524	8,456	0%	159%
Mesa	18,138	2,855	2,315	5,170	18,832	3,751	7,426	11,177	4%	116%
Paradise Valley	2,394	536	311	847	2,457	555	1,057	1,612	3%	90%
Peoria	5,175	873	581	1,454	6,419	1,095	1,965	3,060	24%	110%
Phoenix	161,604	30,712	21,060	51,771	163,892	45,472	80,150	125,622	1%	143%
Queen Creek	684	68	99	167	617	109	219	328	-10%	96%
Scottsdale	27,908	6,159	3,273	9,433	28,008	6,068	10,498	16,566	0%	76%
Surprise	6,912	1,119	898	2,017	6,884	1,213	2,543	3,755	0%	86%
Tempe	17,869	6,462	2,091	8,553	17,749	4,532	6,957	11,490	-1%	34%
Tonopah	119	37	14	52	119	48	82	130	0%	152%
Total	280,888	54,344	36,169	90,513	284,771	71,219	127,519	198,738	1%	120%

The next set of figures show the daily truck flows for different truck types in the entire MAG region and the Phoenix metropolitan area. The truck flows are depicted in different ranges and colors. Figures 4.5 and 4.6 show the daily light-truck volumes where they are spread all over the region, indicating a uniform distribution of these vehicle trips. Figures 4.7 and 4.8 indicate that most of the roads carry very few medium-trucks, except for a few corridors in the Phoenix area. Figures 4.9 and 4.10 show the distribution of heavy trucks where a majority of the roads in the Phoenix area have greater than 1,000 heavy trucks per day, while the rest of region have very low heavy-truck volumes. It can also be seen that most of the major roadways through the MAG region carry more 1,000 heavy trucks per day.

Figure 4.5 Daily Light-Truck Volumes – MAG Region

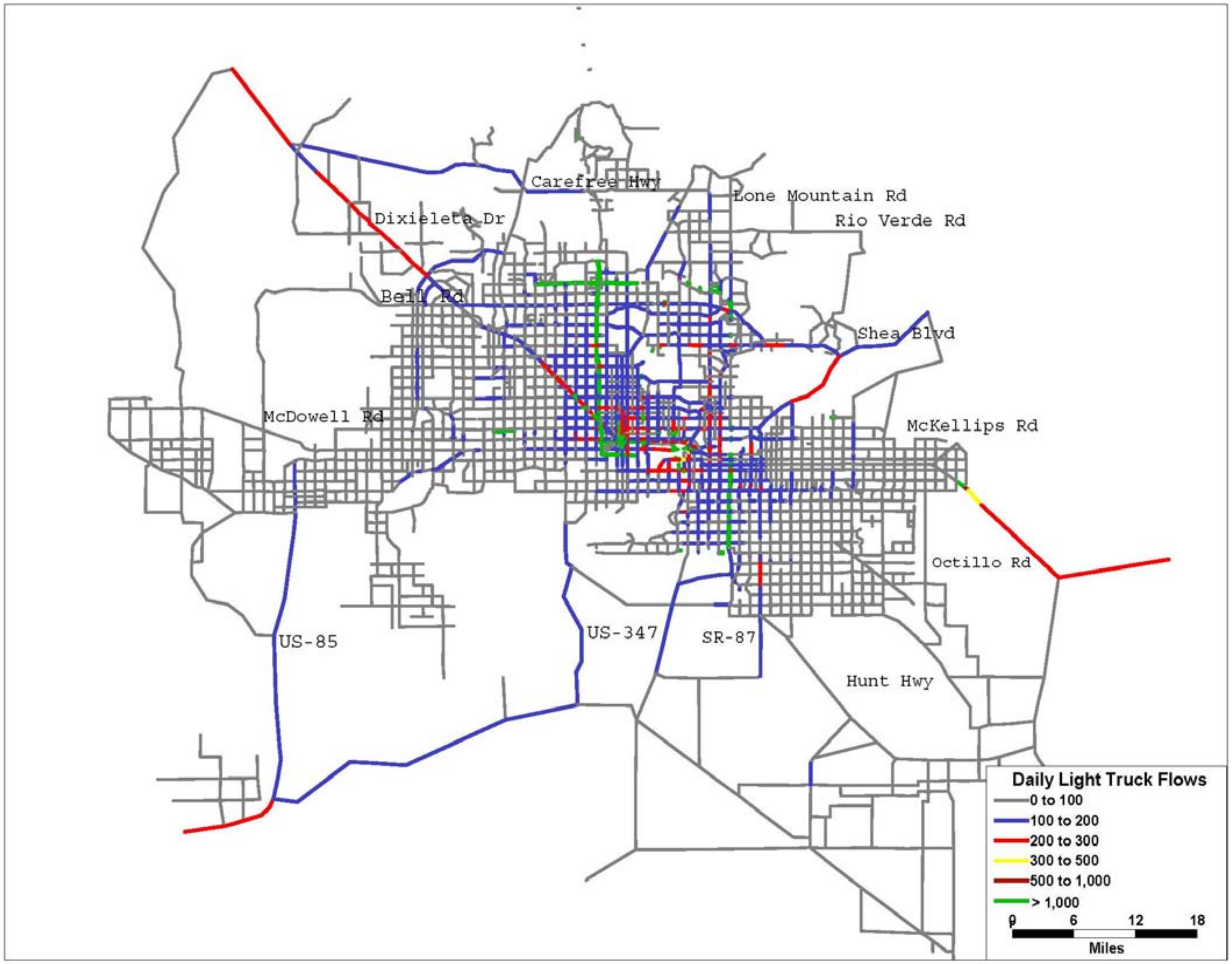


Figure 4.6 Daily Light-Truck Volumes – Phoenix Area

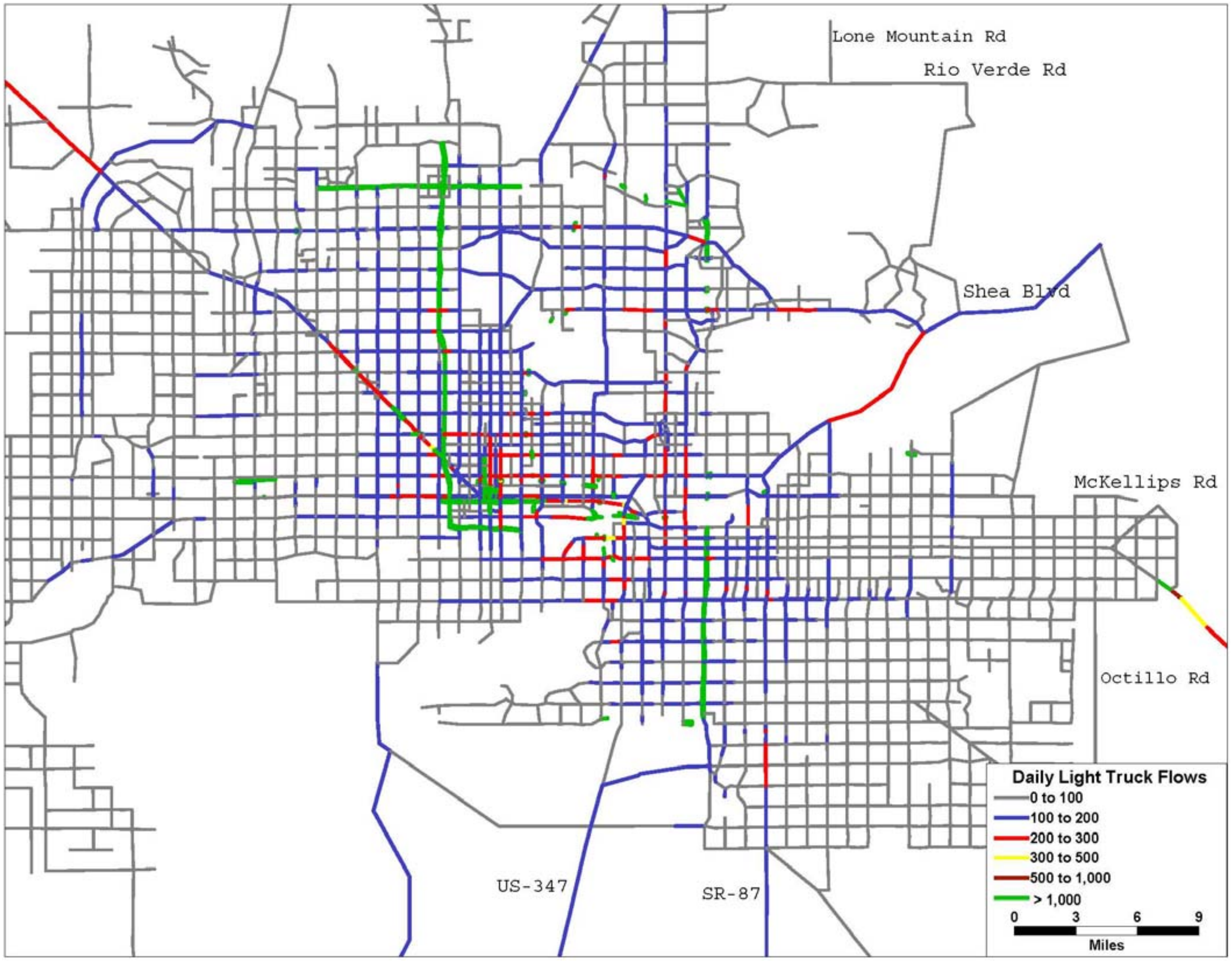


Figure 4.7 Daily Medium-Truck Volumes – MAG Region

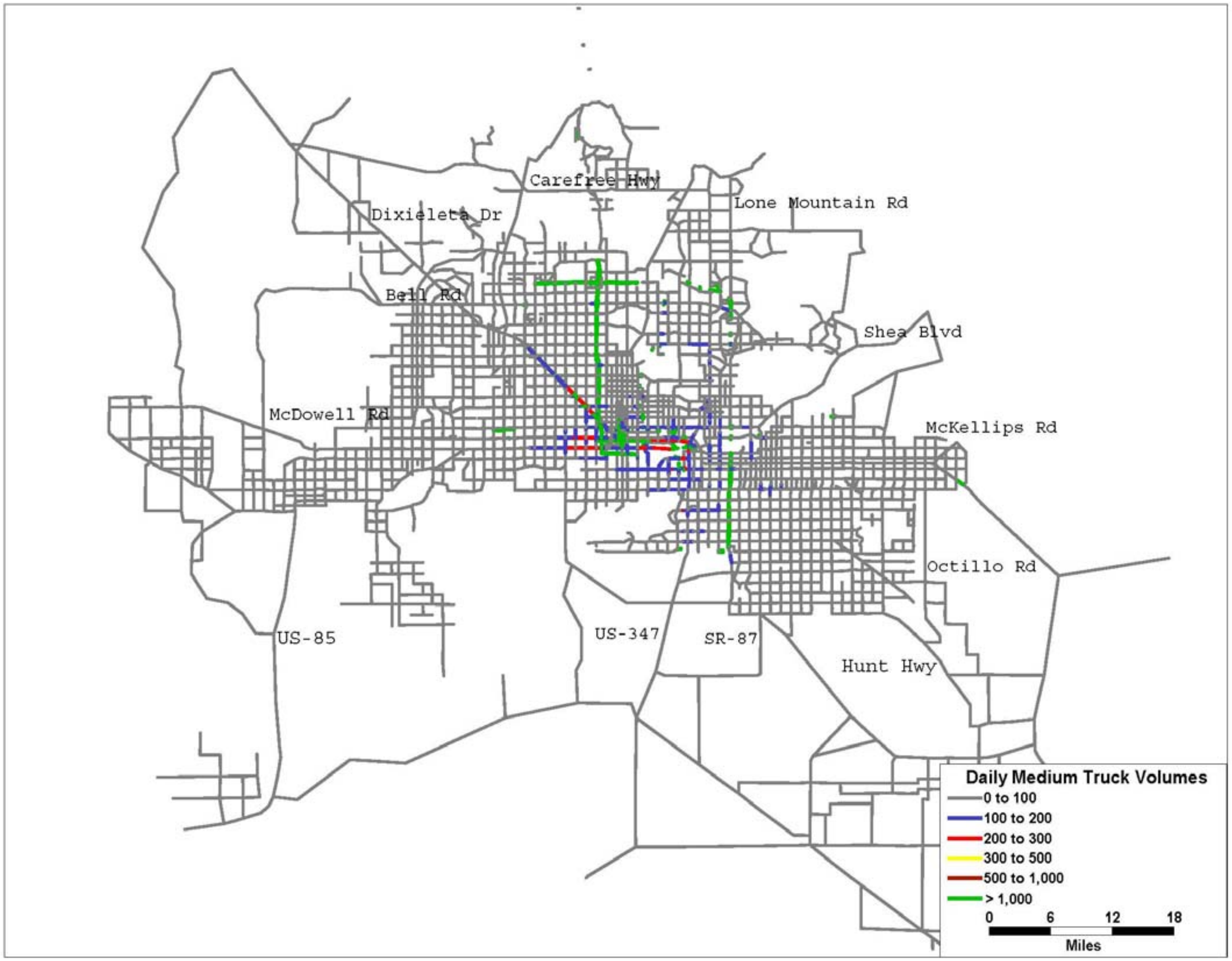


Figure 4.8 Daily Medium-Truck Volumes – Phoenix Area

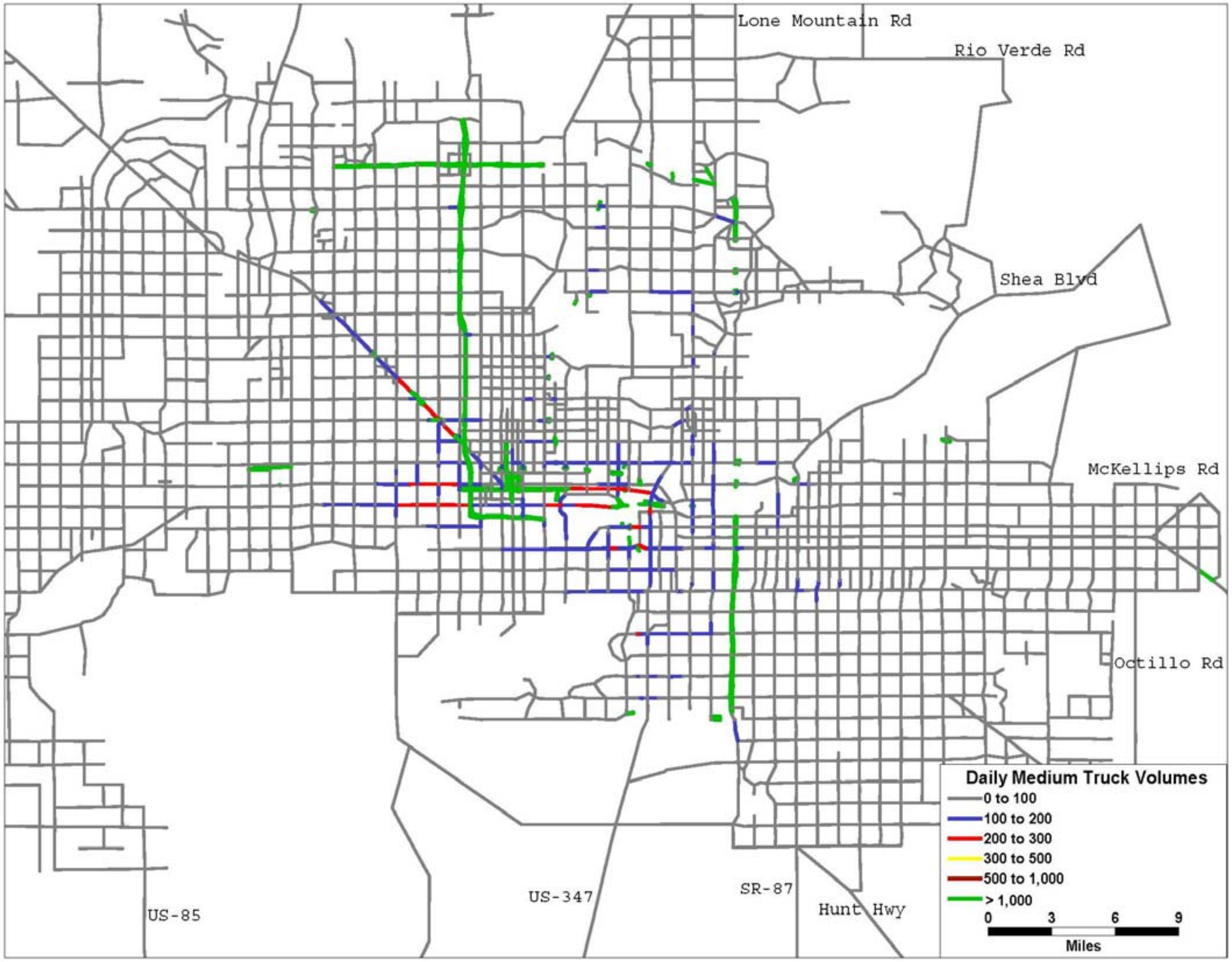


Figure 4.9 Daily Heavy-Truck Volumes – MAG Region

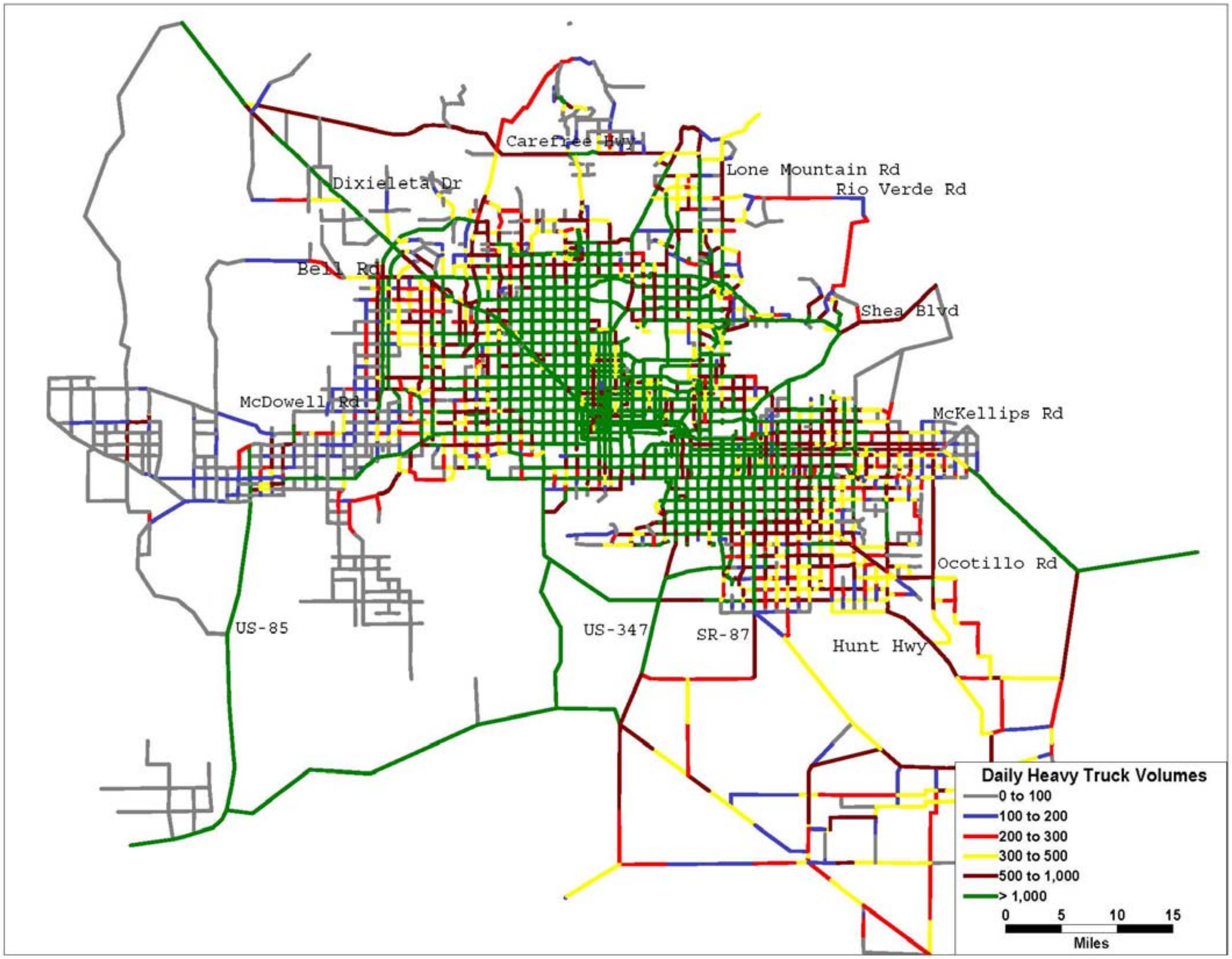


Figure 4.10 Daily Heavy-Truck Volumes – Phoenix Area

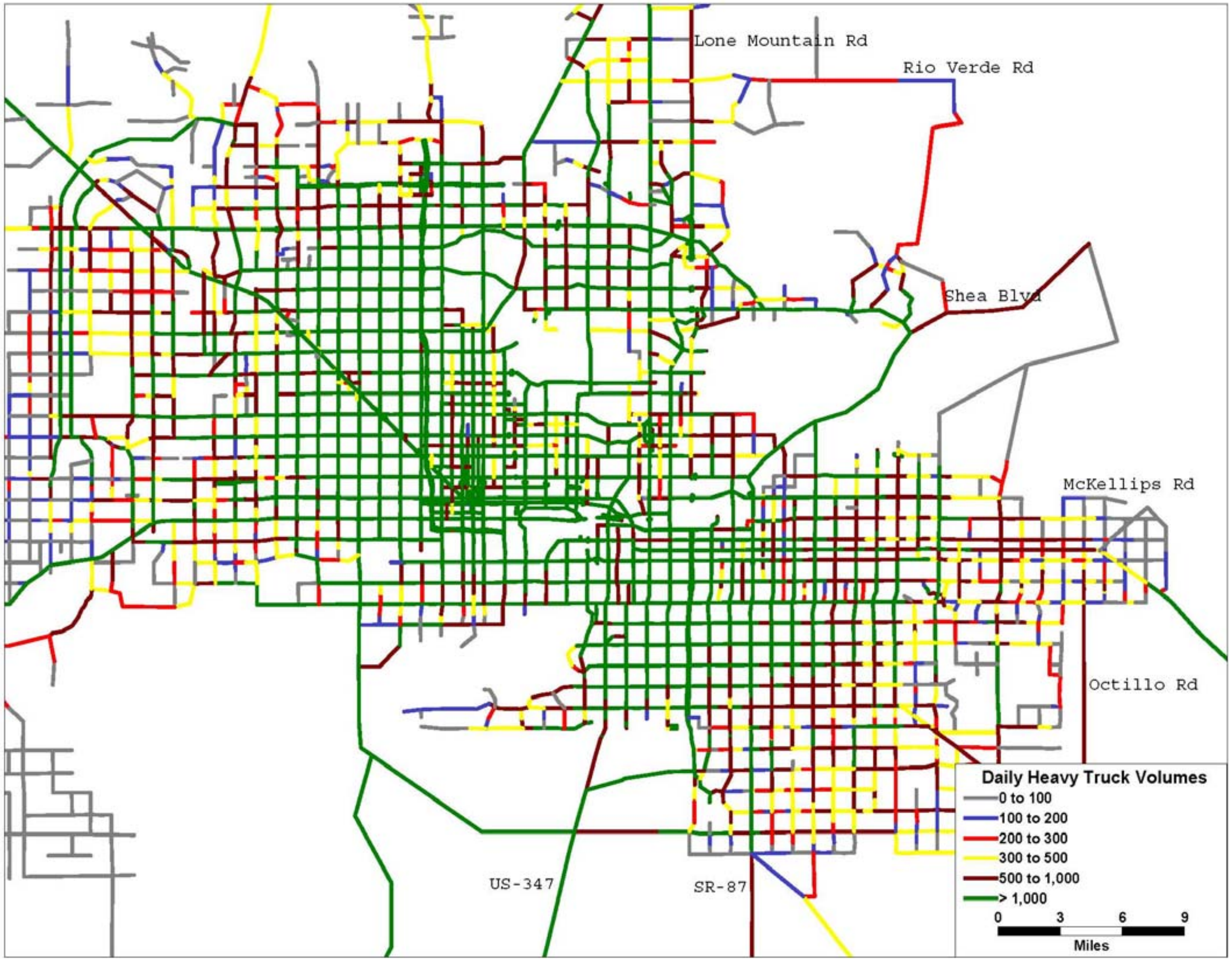


Table 4.12 compares the new truck model volumes against the existing truck model volumes on freeways where classification counts were collected by MAG as part of another study. These are aggregated to represent individual freeways and are shown by light, medium, heavy and medium plus heavy trucks. As the light trucks were not updated, the light-truck volumes are comparable across the two versions of the models. However, there is a significant difference between medium and heavy trucks combined. This can also be attributed to the different truck model definitions between the two models, and it also shows that the existing truck model under predicts medium and heavy trucks significantly. This further shows that the external truck model component needs to be updated and validated before the truck volumes from the new model are compared against the classification counts.

Table 4.12 Comparison of Truck Volumes on Freeways
Existing and New Truck Model

	2006 Existing Truck Model				2006 New Truck Model				Difference	
Freeway	Light	Medium	Heavy	Medium & Heavy	Light	Medium	Heavy	Medium & Heavy	Light	Medium & Heavy
I-10	657,252	97,575	119,201	216,776	577,689	168,027	344,130	512,156	-12%	136%
I-17	258,159	38,705	40,892	79,598	235,463	69,678	134,380	204,058	-9%	156%
Loop 101	88,131	14,650	12,995	27,644	80,551	24,835	44,335	69,170	-9%	150%
Loop 202	114,384	26,148	19,462	45,610	105,062	34,776	67,665	102,441	-8%	125%
SR-51	133,470	27,640	21,404	49,044	121,047	39,603	73,809	113,411	-9%	131%
US-60	203,249	37,606	31,409	69,015	185,835	52,504	98,908	151,412	-9%	119%
Total	1,454,645	242,325	245,363	487,688	1,305,648	389,422	763,226	1,152,648	-10%	136%

A thorough review of MAG's classification counts and ADOT's Freeway Management System (FMS) counts was also conducted, and it was decided that these were not appropriate for validating the new truck model. The main reasons are stated below.

- **FMS counts use length-based truck definitions, while the new truck model is based on body/axles (or FHWA classes).** The length and the body/axle definitions agree at the extreme, (e.g., Class 5 Two-Axle, Six-Tire, Single-Unit Trucks are generally short and Class 13 Seven or More Axle, Multi-Trailer Trucks are generally long). The problem is in the middle (e.g., it is possible that a Class 7 Four or More Axle, Single-Unit Trucks are longer than the medium length maximum threshold, and that a Class 8 Four or Fewer Axle, Single-Trailer Trucks are shorter than the heavy minimum). It is also possible that passenger cars may exceed the minimum medium-truck length and be classified as medium trucks. This results in misclassification errors.
- **MAG's classification counts cover 13 hours only.** In order to extrapolate MAG's manually collected truck counts from 13 to 24 hours, the distribution of trucks by time of day from the MAG counts and the FMS data was

compared to detect any trends. Similar trends were found, though the differences were huge in any given time period. So it was assumed that the same differences will exist in those hours where the manual counts were not collected, and the classification counts were extrapolated. However, this is an approximate procedure, where the approach used was based on an assumption that the misclassification errors observed during the hours in common (to the two sources) apply to the hours for which only FMS counts are available. The problem with this approach is that it assumes the percentage of misclassified trucks during MAG's manual count hours matches those during the FMS only hours. For that to be true, at least the percent misclassified should be consistent within the common time periods. This would mean that the difference between FMS Medium and MAG's Medium, and between FMS Heavy and MAG's Heavy should be the same for all hours during the common period. This is, however, not the case at most count stations.

- **Comparing counts against total assignment of E-E/I-E/E-I/I-I trucks, but the current validation includes improving the I-I trucks only.** So in order to improve the freeway volumes, the external truck trips (E-E/I-E/E-I) also need to be updated and validated before the total truck volumes are compared against freeway ground counts. Also, the likelihood of external trucks using the freeways that pass through the region is very high, compared to the internal trucks using the same freeways.

Service Truck VMT

As described in Chapter 3 under Section 3.3, the total truck trip ends for the Service sector were computed as part of the truck trip generation. The truck trip rates and trip ends by truck type are provided in Tables 4.2 through 4.6. Table 4.13 shows the various statistics of the Service sector truck trips. The factors that were used to account for the service truck VMT in the new truck model are computed as a ratio of total trucks trips and those trips that exclude service trucks. The distribution patterns of the service truck trips are similar to other sectors as these trips were distributed among other sectors. After making adjustments to the truck trip tables based on these factors, the trucks were then assigned to the highway network, as described in the previous section.

The Service sector truck VMT is about 12 percent for medium and 7 percent for heavy trucks, which are within the 5- to 13-percent range that was derived from other studies. The average trip length for all sectors for medium and heavy trucks is found to be 15.29 and 17.02 miles, respectively, which is very close to the average of 14 miles from other studies. Table 4.13 also provides the total number of service truck trips per day per truck, which is computed from the total truck VMT, the number of production trip ends, and the average trip length. The estimates from other studies indicate that about three truck trips are generated per day per truck that include light commercial service vehicles as well. However, this statistic is not available by truck type from other studies to directly compare the results presented in Table 4.13 below.

Table 4.13 Service Sector Truck-Trip Statistics

	New Model Total Truck VMT	Service Sector Factors*	New Model Service Sector VMT	New Model Service Sector VMT (%)	Average Trip Length for All Sectors (in Miles)	Number of Service Truck Trip Ends**	Number of Service Truck Trips Per Day Per Truck***
Medium trucks	9,331,478	1.1209	1,128,176	12.1%	15.29	31,067	2.38
Heavy trucks	4,491,365	1.0658	295,532	6.6%	17.02	29,318	0.59

*These factors are computed as [total truck trips / (total truck trips – service truck trips)].

**These are production trip ends after trip generation.

***These are computed as [total truck VMT / (number of trip ends * average trip length)].

A. FHWA Vehicle Classes With Definitions

Class 1 – Motorcycles (Optional). All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handlebars rather than steering wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.

Class 2 – Passenger Cars. All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.

Class 3 – Other Two-Axle, Four-Tire Single Unit Vehicles. All two-axle, four-tire vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, carryalls, and minibuses. Other two-axle, four-tire single-unit vehicles pulling recreational or other light trailers are included in this classification. Because automatic vehicle classifiers have difficulty distinguishing Class 3 from Class 2, these two classes may be combined into Class 2.

Class 4 – Buses. All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. Modified buses should be considered to be a truck and should be appropriately classified.

Class 5 – Two-Axle, Six-Tire, Single-Unit Trucks. All vehicles on a single frame, including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels.

Class 6 – Three-Axle Single-Unit Trucks. All vehicles on a single frame, including trucks, camping and recreational vehicles, motor homes, etc., with three axles.

Class 7 – Four or More Axle Single-Unit Trucks. All trucks on a single frame with four or more axles.

Class 8 – Four or Fewer Axle Single-Trailer Trucks. All vehicles with four or fewer axles consisting of two units, one of which is a tractor or straight truck power unit.

Class 9 – Five-Axle Single-Trailer Trucks. All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.

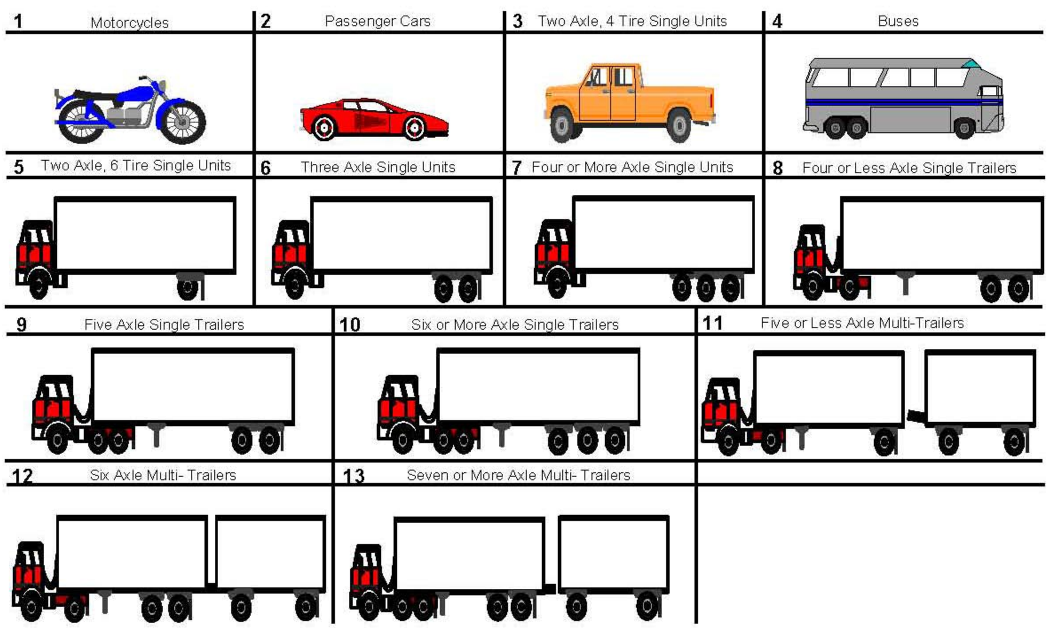
Class 10 – Six or More Axle Single-Trailer Trucks. All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.

Class 11 – Five or fewer Axle Multi-Trailer Trucks. All vehicles with five or fewer axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Class 12 – Six-Axle Multi-Trailer Trucks. All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.

Class 13 – Seven or More Axle Multi-trailer Trucks. All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.

Figure A.1 FHWA Vehicle Classifications



Source: 2006 NYSDOT Traffic Data Report.

B. Recruitment Letter

Maricopa
Truck Travel & Congestion Study
c/o of NuStats
3006 Bee Caves Rd, Suite A-300
Austin, Texas 78746

Sponsored by:
MARICOPA ASSOCIATION of GOVERNMENTS

<FNAME> <LNAME> DATE
<COMPANY>
<ADDRESS>
<CITY>, < ST> <ZIP>

Dear Owner/Operator OR <Mr/Mrs. LAST NAME>:

The Maricopa Association of Governments (MAG) requests your company participation in a travel survey to assess and analyze trucking behavior in the region. As a regional association of local governments and their governing officials in Maricopa County, MAG provides a focus for action on issues of regional concern including comprehensive transportation planning. MAG and transportation agencies throughout the region will use the data collected in this survey to plan transportation enhancements that will help improve traffic flow and minimize congestion.

MAG contracted with NuStats, an independent research organization, to administer this survey. The survey involves asking drivers from companies like yours – meaning, those that have a fleet of delivery or other trucking vehicles with at least two axles (six wheels) – to complete an easy to fill out one-day travel diary about the stops they make during that day. Your company was randomly selected to participate in the survey.

Your company's voluntary participation in the study is critical to the success of this project. It involves two easy steps.

1. First, if you are not the right person to make the decision on whether or not your company will participate, please forward this letter to the appropriate person then call or email Julie Wilke, NuStats Survey Manager, at 1-800-447-8287 x 2246 or jwilke@nustats.com with the name and phone number of the appropriate contact. An appropriate person may be the person who manages or works closely with your company truck drivers on a daily basis.
2. Second, await a call from a professional interviewer from NuStats with details about the study.

To best represent all companies who have trucks traveling in the region, your company's help in completing this survey is very important. We urge you to participate – the more accurate the information your company and your drivers provide, the better we can implement measures to reduce congestion.

Again, we appreciate your assistance in this important study. If you have any questions, please call Julie Wilke, NuStats Survey Manager, at 1-800-447-8287, ext. 2246 or email her at jwilke@nustats.com.

Sincerely,

Vladimir Livshits, Program Manager
Maricopa Association of Governments

C. Trip Diary Questionnaire

THANK YOU FOR YOUR PARTICIPATION!

Your help in completing this diary is very important. Results from this survey will be used by transportation agencies throughout the region to better plan for transportation improvements that will help improve traffic flow and minimize congestion. The more accurate the information you provide, the better we can implement measures to reduce congestion.
The responses you give are kept strictly confidential and are used only for research purposes.

If you have questions or need assistance, please call
Julie Wilke of NuStats toll-free at 800-447-8287, ext. 2246

Thank you!

Please return your completed diary to your Fleet Coordinator.

Maricopa
Truck Travel & Congestion Study

Sponsored by:

Truck Travel Diary for:

<<Company Name>>

Truck # <<truckno>> of <<total# in fleet>>

Record your Truck Travel on:
<<Travel Day>>, <<Travel date>>

<<sample number-truckno>>

Person completing this diary:
(If we have any questions about your travel we may contact you)

Name: ____________________

Phone: (___) ___ - ____

DIARY INSTRUCTIONS:

The purpose of this diary is to gather data for up to 10 stops you make in the TRUCK YOU ARE DRIVING TODAY for one work day. Please follow the instructions and example below.

Print letters/numbers clearly in upper case: A B C 1 2 3 Fill bubble with: ●

Step:

1. **Truck Information:** Begin your diary by telling us about the TRUCK YOU ARE DRIVING TODAY. Fill in the date, the license plate number, truck size, number of axles and the fuel type.
2. **Start Trip:** This is the location where you began your trip. Provide the name of the place, the complete address including the city and zip code, the type of stop, the beginning odometer reading, and the exact time you leave.
3. **Stops #1 - 10:** Provide the exact time you arrive, the complete address or the nearest major cross streets, the type of stop, the odometer reading, and the exact time you leave.

Type of stop: Choose the code that best describes the location from the list of STOP CODES on the flap below.

4. Please return your completed diary to your Fleet Coordinator. **Thank you!**

STOP #8

I got to this stop at: __ __ : __ __ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*:

Odometer reading when I arrived:

I left this stop at: __ __ : __ __ ○ am ○ pm

STOP #9

I got to this stop at: __ __ : __ __ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*:

Odometer reading when I arrived:

I left this stop at: __ __ : __ __ ○ am ○ pm

STOP #10

I got to this stop at: __ __ : __ __ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*:

Odometer reading when I arrived:

I left this stop at: __ __ : __ __ ○ am ○ pm

STOP CODES: Choose the code that best describes this location

Code:		Code:		Code:	
1	House/Other residential	5	Construction site	9	Farm
2	Office/Bank/Medical/Repair	6	Warehouse/Wholesale store	10	Mine
3	Government building/School/ Military base/Hospital	7	Industrial *(e.g. manufacturing factory)*	11	Other *(fill in the oval for code 11 and describe the location)*
4	Retail/Store/Restaurant/Mall	8	Transportation Hub *(e.g. port/rail/ truck terminal/airport)*		

STOP #5

I got to this stop at: ___ : ___ ◯ am ◯ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

◯ 1 ◯ 3 ◯ 5 ◯ 7 ◯ 9
◯ 2 ◯ 4 ◯ 6 ◯ 8 ◯ 10
◯ 11 Other *(describe the location)*:

Odometer reading when I arrived:

I left this stop at: ___ : ___ ◯ am ◯ pm

STOP #6

I got to this stop at: ___ : ___ ◯ am ◯ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

◯ 1 ◯ 3 ◯ 5 ◯ 7 ◯ 9
◯ 2 ◯ 4 ◯ 6 ◯ 8 ◯ 10
◯ 11 Other *(describe the location)*:

Odometer reading when I arrived:

I left this stop at: ___ : ___ ◯ am ◯ pm

STOP #7

I got to this stop at: ___ : ___ ◯ am ◯ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

◯ 1 ◯ 3 ◯ 5 ◯ 7 ◯ 9
◯ 2 ◯ 4 ◯ 6 ◯ 8 ◯ 10
◯ 11 Other *(describe the location)*:

Odometer reading when I arrived:

I left this stop at: ___ : ___ ◯ am ◯ pm

1 — TRUCK INFO

Date: 6 / 0 5 / 0 7

A. License plate number of the TRUCK YOU ARE DRIVING TODAY.

A Z 1 2 3 4 5

B. Truck size/gross vehicle weight *(mark one only)*

● Light-heavy (8,500-14,000 lbs.)
◯ Medium-heavy (14,001-33,000 lbs.)
◯ Heavy-heavy (33,001 lbs. and above)

C. Number of axles *(mark one only)*

● Single unit 2-Axle (6 wheels)
◯ Single unit 3-Axle (10 wheels)
◯ Single unit 4-Axle (14 wheels)
◯ Semi (all tractor-trailer combinations)
◯ Other *(specify)*:

D. Fuel type *(mark one only)*

● Diesel
◯ Unleaded gas
◯ Other *(specify)*:

2 — START TRIP

My trip began at:

THORN MEDICAL EQUIPMENT INC
Place name

17410 N COTTONWOOD DR
Address or Cross street #1

Cross street #2

SUN CITY
City

8 5 3 7 3
Zip code

Type of stop: *(use STOP CODES on flap below)*

◯ 1 ◯ 3 ◯ 5 ◯ 7 ◯ 9
◯ 2 ◯ 4 ● 6 ◯ 8 ◯ 10
◯ 11 Other *(describe the location)*:

Beginning odometer reading:

3 2 1 0 3

I left my starting location at:

9 : 0 7 ● am ◯ pm

3 — STOP #1

I got to this stop at: 9 : 4 4 ● am ◯ pm

The address is:

NORTH PHOENIX MEDICAL CENTER
Place name

5040 N 15TH AVE
Address or Cross street #1

Cross street #2

PHOENIX
City

8 5 0 1 5
Zip code

Type of stop: *(use STOP CODES on flap below)*

◯ 1 ◯ 3 ◯ 5 ◯ 7 ◯ 9
● 2 ◯ 4 ◯ 6 ◯ 8 ◯ 10
◯ 11 Other *(describe the location)*:

Odometer reading when I arrived:

3 2 1 2 6

I left this stop at:

1 0 : 1 8 ● am ◯ pm

If you need assistance, please call : Julie Wilke of NuStats toll-free at 800-447-8287, ext. 2246

Begin on next page →

TRUCK INFO

Date: ___ / ___ / ___

A. License plate number of the TRUCK YOU ARE DRIVING TODAY.

B. Truck size/gross vehicle weight *(mark one only)*

- ○ Light-heavy (8,500-14,000 lbs.)
- ○ Medium-heavy (14,001-33,000 lbs.)
- ○ Heavy-heavy (33,001 lbs. and above)

C. Number of axles *(mark one only)*

- ○ Single unit 2-Axle (6 wheels)
- ○ Single unit 3-Axle (10 wheels)
- ○ Single unit 4-Axle (14 wheels)
- ○ Semi (all tractor-trailer combinations)
- ○ Other *(specify)*: ____________

D. Fuel type *(mark one only)*

- ○ Diesel
- ○ Unleaded gas
- ○ Other *(specify)*: ____________

START TRIP

My trip began at:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*: ____________

Beginning odometer reading:

I left my starting location at: ___ : ___ ○ am ○ pm

STOP #1

I got to this stop at: ___ : ___ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*: ____________

Odometer reading when I arrived:

I left this stop at: ___ : ___ ○ am ○ pm

STOP #2

I got to this stop at: ___ : ___ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*: ____________

Odometer reading when I arrived:

I left this stop at: ___ : ___ ○ am ○ pm

STOP #3

I got to this stop at: ___ : ___ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*: ____________

Odometer reading when I arrived:

I left this stop at: ___ : ___ ○ am ○ pm

STOP #4

I got to this stop at: ___ : ___ ○ am ○ pm

The address is:

Place name

Address or Cross street #1

Cross street #2

City

Zip code

Type of stop: *(use STOP CODES on flap below)*

○ 1 ○ 3 ○ 5 ○ 7 ○ 9
○ 2 ○ 4 ○ 6 ○ 8 ○ 10
○ 11 Other *(describe the location)*: ____________

Odometer reading when I arrived:

I left this stop at: ___ : ___ ○ am ○ pm

D. CATI Survey Script

Maricopa Association of Governments
2007 Truck Survey
CSI-07-114 Screener
March 29, 2007

NOTE TO PROGRAMMER: NEED TO SAVE ALL DATA

INTRODUCTION

INTRO1 Hello, this is ____ with Northwest Research Group. We are working with the Maricopa Association of Governments to reduce traffic congestion and help improve efficient movement of goods in Maricopa County. Your company's input is critical to the success of the project. [AS NEEDED: For example, with input like yours, MAG conducted a Freeway Bottleneck Study where they ranked projects to improve freeway bottlenecks.]

May I please speak with the transportation manager or person responsible for providing assignments to drivers? [IF RESPONDENT SAYS COMPANY DOES NOT OWN TRUCKS: May I please speak to the person responsible for arranging truck shipments to or from this facility?]

1 YES **[SKIP TO INTRO2]**
2 NOT AVAILABLE AT THIS TIME **[SCHEDULE CALLBACK AND LEAVE MESSAGE]**
3 NO [SPECIFY REASON FOR REFUSAL:_________________] **[SKIPTO THANK5]**
9 DON'T KNOW/REFUSED [SPECIFY REASON FOR REFUSAL:_______] [SKIP TO THANK5]

Today/Tonight we are inviting companies located in Maricopa County to participate in this study. Results from this research will directly impact decisions for transportation improvements in the Phoenix area.

Please join the more than 500 other companies who are committed to helping the Maricopa Association of Governments with this important research effort.

Your input will remain strictly confidential. This call may be monitored and/or recorded for quality control purposes.

[AS NEEDED: Let me assure you that this is not a sales call. Northwest Research Group does not sell any type of consumer products or services. We are conducting this study only to provide data on travel in the region which will help plan for and improve the traffic conditions in the region. Everything you say will remain strictly anonymous. None of your company's or your personal information will be released and your name and telephone number will not end up on any list as a result of your participation.**]**

[PRESS ANY KEY TO CONTINUE]

INTRO2 Hello, this is ____ with Northwest Research Group. We are working with the Maricopa Association of Governments to improve the traffic congestion in Maricopa County. Your input is critical to the success of the project. Today/Tonight we are inviting companies that operate in Maricopa County to participate in this study. Results from this research will directly impact decisions for transportation improvements in the Phoenix area – that is, within Maricopa, Pinal, and Yavapai Counties. Your input will remain strictly confidential. This call may be monitored and/or recorded for quality control purposes.

[IF NEEDED: The survey should only take no more than 10 minutes of your time. I completely understand that you are extremely busy and because we value your input we have made this survey available to complete online. Would you rather complete this survey online? OK great I will just need to ask you a few questions to determine your eligibility and then I will get your email address.]

SCREENER

Q1 How many inbound truck deliveries does your facility receive on a peak day**?**

- ____ **[ENTER NUMBER] [IF Q1 = 0 SKIP TO Q2]**
- 888 DON'T KNOW [May I speak with someone who does know?(INTRO2)] **[SKIP TO Q2]**
- 999 REFUSED **[SKIP TO THANK8]**

INB2 About what percentage of inbound truck shipments that arrive at this facility…? [READ EACH CATEGORY AND RECORD PERCENT]

- __% come from destinations within the Maricopa region – that is from within Maricopa, Pinal, and Yavapai Counties?
- __% and how about shipments that come from outside the Maricopa region? **[IF INB2B EQ 100% SKIP TO Q2]**
- 888 DON'T KNOW
- 999 REFUSED

Q1A Of these inbound deliveries within Maricopa, Pinal, and Yavapai Counties, what **percentage** of these trucks are…?

[NOTE TO INTERVIEWER: RE-READ QUESTION EVERY TIME.]

- __% Heavy, that is 3+ axles and 6+ tires. [IF NECESSARY: COMBINATION UNIT COMCL. VEHICLE]
- __% Medium, that is 2+ axles and 6+ tires. [IF NECESSARY: SINGLE UNIT COMMERCIAL VEHICLE]
- __% Light, that is 2 axles and 6 tires. [IF NECESSARY- VEHICLE WITH DUAL TIRES]
- 777 NO TRUCKS IN ABOVE CATEGORIES
- 888 DON'T KNOW [May I speak with someone who does know?(INTRO2)]
- 999 REFUSED **[SKIP TO THANK8]**

[MUST ADD UP TO 100%]

Q1B [IF LIGHT TRUCKS EQ 100%] What percentage of these trucks are pick-up trucks?

- % PICKUP
- 888 DON'T KNOW [May I speak with someone who does know?(INTRO2)]
- 999 REFUSED **[SKIP TO THANK8]**

Q2 How many outbound truck deliveries does your facility send out on a peak day**?**

- ____ **[ENTER NUMBER] [IF Q2 = 0 SKIP TO Q3]**
- 888 DON'T KNOW [May I speak with someone who does know?(INTRO2)] **[IF Q1 = 888 AND Q2 = 888 THANK8]**
- 999 REFUSED **[SKIP TO THANK8]**

[IF Q1 = 0 AND Q2 = 0 THEN THANK30]

OUTNEW About what percentage of your outbound truck shipments …? [READ EACH CATEGORY AND RECORD PERCENT]

- __% travel to destinations within the Maricopa region – that is from within Maricopa, Pinal, and Yavapai Counties?

__% and how about shipments go outside the Maricopa region? **[IF INB2B EQ 100% AND OUTNEW EQ 100% -- THANK AND TERMINATE]**

888 DON'T KNOW

999 REFUSED

Q2A Of these outbound deliveries within Maricopa, Pinal, and Yavapai Counties, what **percentage** of these trucks are…?

[NOTE TO INTERVIEWER: RE-READ QUESTION EVERY TIME]

__% Heavy, that is 3+ axles and 6+ tires. [IF NECESSARY: COMBINATION UNIT COMCL. VEHICLE]

__% Medium, that is 2+ axles and 6+ tires. [IF NECESSARY: SINGLE UNIT COMMERCIAL VEHICLE]

__% Light, that is 2 axles and 6 tires. [IF NECESSARY- VEHICLE WITH DUAL TIRES]

777 NO TRUCKS IN ABOVE CATEGORIES

888 DON'T KNOW [May I speak with someone who does know?(INTRO2)]

999 REFUSED **[SKIP TO THANK8]**

[MUST ADD UP TO 100%]

[IF Q1A = 777 AND Q2A = 777 THEN THANK31]

[IF Q1 = 0 AND ALL OF Q2A = 777 THEN THANK31]

[IF ALL OF Q1A = 777 AND Q2 = 0 THEN THANK31]

Q2B [IF LIGHT TRUCKS EQ 100%] What percentage of these trucks are pick-up trucks?

% PICKUP

888 DON'T KNOW [May I speak with someone who does know?(INTRO2)]

999 REFUSED **[SKIP TO THANK8]**

[IF Q1B EQ 100% AND Q2B EQ 100% THANK AND TERMINATE – I.E., NO ONE SHOULD ONLY BE DRIVING PICK-UP]

Q3 Of these inbound and outbound trucks, about what percent does your company own?

____ **[ENTER PERCENT] [ALLOW 0, IF ALL / 100% SKIP TO OUTINT]**

888 DON'T KNOW

999 REFUSED

Q4 Of these inbound and outbound trucks, about what percentage does your company subcontract? **[IF NECESSARY: How many are owned/operated by another company?]**

____ **[ENTER PERCENT] [ALLOW 0, IF 0 SKIP TO OUTINT]**

888 DON'T KNOW **[SKIP TO OUTINT]**

999 REFUSED **[SKIP TO THANK8]**

[IF Q3 AND Q4 = 0 THANK32]

QUALIFIED RESPONDENTS CONTINUE FROM HERE:
TO QUALIFY RESPONDENTS MUST OWN OR OPERATE 1 OR MORE FHWA CLASS 5 PLUS VEHICLES THAT MAKE SHIPMENTS OUT OF OR COME INTO THEIR FACILITY FROM DESTINATIONS WITHIN MARICOPA, PINAL, AND YAVAPAI COUNTIES

Q5A To verify, is the address of your facility [IMPORT FROM SAMPLE AND READ

COMPLETELY]?

1 **YES**
2 **NO**

Q5b **[IF Q5A EQ 2]** What is the correct address of your facility

____________ **STREET**
____________ **CITY**
____________ **STATE**
____________ **ZIPCODE**

[IF QUALIFIED RESPONDENT INDICATES THAT THEY ARE UNABLE TO COMPLETE THE SURVEY AT THIS TIME OR ARE TOO BUSY TO COMPLETE THE SURVEY BY TELEPHONE, ASK QONL. GIVE AS OPTION ONLY IF THEY WILL NOT DO BY TELEPHONE AT THE TIME YOU HAVE THEM ON THE PHONE.]

QONL Do you wish to finish this survey online?

1 YES **[SKIP TO QONL1]**
2 CONTINUE ON THE PHONE **[SKIP TO Q3]**

QONL1 So that I can send you a link to the online version, what is your email?

__ ENTER EMAIL
888 DON'T KNOW **[SKIP TO Q3]**
999 REFUSED **[SKIP TO Q3]**

QONL2 I entered ____________ for your email is that correct?

1 YES **[SKIP TO THANK44]**
2 NO **[SKIP TO QONL1]**

OUTBOUND SHIPMENTS
[ALL OUT QUESTIONS IF Q2 GT 0]

OUTINT For the next couple questions I want you to think about your outbound truck trips from your facility to destinations in Maricopa, Pinal, and Yavapai Counties**?**

OUT1 Now thinking only about the commodities / goods that you ship from your facility to destinations in Maricopa, Pinal, and Yavapai Counties, which of the following best describes the **primary** commodity or good you ship?
[READ LIST AND ACCEPT ONE RESPONSE]

1 Raw agricultural & animal products (I.E. CROPS, LIVESTOCK, ANIMAL FEED)
2 Food products, alcohol, & tobacco
(I.E. MEAT, BAKERY PRODUCTS, DAIRY PRODUCTS)
3 Forestry, wood, and paper products (I.E. LOGS, LUMBER, PAPER, NOT FURNITURE)
4 Chemicals & chemical products (I.E. FERTILIZERS, PHARMACEUTICALS)
5 Petroleum products (I.E. PLASTICS & RUBBER GASOLINE, FUEL OIL)
6 Mining materials (I.E. COAL, SAND, GRAVEL, ORE CRUDE PETROLEUM)
7 Manufactured metal & mineral products
(I.E. METAL BARS, PIPES, CONCRETE, CEMENT, BRICKS)
8 Other manufactured products or equipment
(I.E. FURNITURE, TOOLS, ELECTRONICS, VEHICLES)
9 Waste, refuse, recycling

(I.E. HAZARDOUS WASTE, TRASH RECYCLABLE PRODUCTS)

10 Miscellaneous (I.E. MAIL & COURIER, MIXED FREIGHT)
666 NONE
777 OTHER SPECIFY
888 DON'T KNOW
999 REFUSED

OUT1A What other commodities / goods do you ship from your facility to destinations within Maricopa, Pinal, and Yavapai Counties?

[READ LIST AND CHECK ALL THAT APPLY]

1 Raw agricultural & animal products (I.E. CROPS, LIVESTOCK, ANIMAL FEED)
2 Food products, alcohol, & tobacco
(I.E. MEAT, BAKERY PRODUCTS, DAIRY PRODUCTS)
3 Forestry, wood, and paper products (I.E. LOGS, LUMBER, PAPER, NOT FURNITURE)
4 Chemicals & chemical products (I.E. FERTILIZERS, PHARMACEUTICALS)
5 Petroleum products (I.E. PLASTICS & RUBBER GASOLINE, FUEL OIL)
6 Mining materials (I.E. COAL, SAND, GRAVEL, ORE CRUDE PETROLEUM)
7 Manufactured metal & mineral products
(I.E. METAL BARS, PIPES, CONCRETE, CEMENT, BRICKS)
8 Other manufactured products or equipment
(I.E. FURNITURE, TOOLS, ELECTRONICS, VEHICLES)
9 Waste, refuse, recycling
(I.E. HAZARDOUS WASTE, TRASH RECYCLABLE PRODUCTS)
10 Miscellaneous (I.E. MAIL & COURIER, MIXED FREIGHT)
666 NONE
777 OTHER SPECIFY
888 DON'T KNOW
999 REFUSED

OUT2 What percentage of your outbound truck shipments to destinations in Maricopa, Pinal, and Yavapai Counties are linked trips – that is, a trip that makes multiple stops within the region before returning to your facility?

__% OF MULTIPLE STOPS
888 DON'T KNOW
999 REFUSED

OUT2A **[IF OUT2 NE 0, 888, 999]** For a typical trip with multiple stops, what is the typical number of stops?

___ TYPICAL NUMBER OF STOPS
888 DON'T KNOW
999 REFUSED

OUT3A [IF IN Q2A % OF HEAVY TRUCKS NE 0%] Measured from your facility, about what percentage of the outbound trips made by your Heavy or Combination Unit Commercial. Vehicles [AS NEEDED: 3 plus axles and 6 plus tires] travel…?

Out3AA_About what percentage of the outbound trips made by your Heavy or Combination Unit Commercial. Vehicles [AS NEEDED: 3 plus axles and 6 plus tires] go out of your facility between the hours of?

OUT3B [IF IN Q2A % OF MEDIUM TRUCKS NE 0%] Measured from your facility, about what percentage of the outbound trips made by your Medium or Single Unit Commercial

Vehicles and your Vehicles with Dual Tires [AS NEEDED: 2 plus axles and 6 plus tires and those with 2 axles and 6 tires] travel…?

Out3BB_About what percentage of the outbound trips made by your Medium or Single Unit Commercial Vehicles and your Vehicles with Dual Tires [AS NEEDED: 2 plus axles and 6 plus tires and those with 2 axles and 6 tires] go out of your facility between the hours of?

[RESPONSE CATEGORIES FOR OUT3A TO OUT3B] READ EACH CATEGORY AND RECORD PERCENT]

__% 0 – 5 miles?
__% 6 – 10 miles?
__% 11 – 15 miles?
__% 16 – 20 miles?
__% 21 – 30 miles?
__% 31 – 50 miles?
__% 51+ miles?
888 DON'T KNOW
999 REFUSED

[MUST ADD UP TO 100%]

[RESPONSE CATEGORIES FOR OUT3AATO OUT3BB] READ EACH CATEGORY AND RECORD PERCENT]

__% 0 – 5 miles?
___ % AM Peak period - 6 AM to 9 AM
___ % Midday - 9AM to 3PM
___ % PM Peak Period - 3 PM to 6 PM
___ % -Night - 6 PM to next day 6AM
888 DON'T KNOW
999 REFUSED

[MUST ADD UP TO 100%]

DIS1 About how many destinations does your facility ship to within Maricopa, Pinal, and Yavapai Counties?

0 NONE [SKIPTO
1 Less than 5
2 5 to 10
3 11 to 25
4 26 to 50
5 50 or more
888 DON'T KNOW

[THE FOLLOWING TWO QUESTIONS WILL BE ASKED FOR EACH COMMODITY THEY SHIP.]

DIS01A_ALT_Thinking about your outbound shipments of **[INSERT COMMODITY TYPE],** what percent of shipments from your facility to destinations within Maricopa, Pinal, and Yavapai Counties are going to each of the following types of facilities?

___ % House/Other residential
___ % Office/Bank/Medical/Repair
___ % Government building/School/Military base/Hospital
___ % Retail/Store/Restaurant/Mall

___ % Construction site
___ % Warehouse/Wholesale store
___ % Industrial (e.g. manufacturing factory)
___ % Transportation Hub (e.g. port/rail/truck terminal/airport)
___ % Farm
___ % Mine
___ % Other (describe the location)
888 DON'T KNOW
999 REFUSED

[MUST ADD UP TO 100%]

DISO2A About how many outbound shipments of **[INSERT COMMODITY TYPE],** leave your facility in a given day?

___ ENTER NUMBER OF OUTBOUND SHIPMENTS
888 DON'T KNOW
999 REFUSED

DISO2A.1 Of those outbound shipments of **[INSERT COMMODITY TYPE],** what is the average payload in pounds?

1 Less than 10,000 lbs
2 10,001 lbs to 25,000 lbs
3 25,001 lbs to 50,000 lbs
4 50,001 lbs to 75,000 lbs
5 75,001 lbs to 100,000 lbs
6 Greater than 100,000 lbs
888 DON'T KNOW
999 REFUSED

DISO2B About how many outbound shipments of **[INSERT COMMODITY TYPE],** leave your facility in a given day?

___ ENTER NUMBER OF OUTBOUND SHIPMENTS
888 DON'T KNOW
999 REFUSED

DISO2B.1 Of those outbound shipments of **[INSERT COMMODITY TYPE],** what is the average payload in pounds?

1 Less than 10,000 lbs
2 10,001 lbs to 25,000 lbs
3 25,001 lbs to 50,000 lbs
4 50,001 lbs to 75,000 lbs
5 75,001 lbs to 100,000 lbs
6 Greater than 100,000 lbs
888 DON'T KNOW
999 REFUSED

INBOUND SHIPMENTS
[ALL INB IF Q1 GT 0]

INBINT For the next couple questions I want you to think about your inbound truck trips originate from within Maricopa, Pinal, and Yavapai Counties.

INB1 Thinking only about the commodities / goods that you receive at your facility that originate from within Maricopa, Pinal, and Yavapai Counties, which of the following best describes the **primary** commodity or good that you receive?
[READ LIST AND ACCEPT ONE RESPONSE]

1 Raw agricultural & animal products (I.E. CROPS, LIVESTOCK, ANIMAL FEED)
2 Food products, alcohol, & tobacco
(I.E. MEAT, BAKERY PRODUCTS, DAIRY PRODUCTS)
3 Forestry, wood, and paper products (I.E. LOGS, LUMBER, PAPER, NOT FURNITURE)
4 Chemicals & chemical products (I.E. FERTILIZERS, PHARMACEUTICALS)
5 Petroleum products (I.E. PLASTICS & RUBBER GASOLINE, FUEL OIL)
6 Mining materials (I.E. COAL, SAND, GRAVEL, ORE CRUDE PETROLEUM)
7 Manufactured metal & mineral products
(I.E. METAL BARS, PIPES, CONCRETE, CEMENT, BRICKS)
8 Other manufactured products or equipment
(I.E. FURNITURE, TOOLS, ELECTRONICS, VEHICLES)
9 Waste, refuse, recycling
(I.E. HAZARDOUS WASTE, TRASH RECYCLABLE PRODUCTS)
10 Miscellaneous (I.E. MAIL & COURIER, MIXED FREIGHT)
666 NONE
777 OTHER SPECIFY
888 DON'T KNOW
999 REFUSED

INB1A What other commodities / goods do you receive at your facility that originate within Maricopa, Pinal, and Yavapai Counties?

[READ LIST AND CHECK ALL THAT APPLY]

1 Raw agricultural & animal products (I.E. CROPS, LIVESTOCK, ANIMAL FEED)
2 Food products, alcohol, & tobacco
(I.E. MEAT, BAKERY PRODUCTS, DAIRY PRODUCTS)
3 Forestry, wood, and paper products (I.E. LOGS, LUMBER, PAPER, NOT FURNITURE)
4 Chemicals & chemical products (I.E. FERTILIZERS, PHARMACEUTICALS)
5 Petroleum products (I.E. PLASTICS & RUBBER GASOLINE, FUEL OIL)
6 Mining materials (I.E. COAL, SAND, GRAVEL, ORE CRUDE PETROLEUM)
7 Manufactured metal & mineral products
(I.E. METAL BARS, PIPES, CONCRETE, CEMENT, BRICKS)
8 Other manufactured products or equipment
(I.E. FURNITURE, TOOLS, ELECTRONICS, VEHICLES)
9 Waste, refuse, recycling
(I.E. HAZARDOUS WASTE, TRASH RECYCLABLE PRODUCTS)
10 Miscellaneous (I.E. MAIL & COURIER, MIXED FREIGHT)
666 NONE
777 OTHER SPECIFY
888 DON'T KNOW
999 REFUSED

INB3AA_About what percentage of the inbound shipments you receive on Heavy or Combination Unit Commercial. Vehicles [AS NEEDED: 3 plus axles and 6 plus tires] arrive at your facility between the hours of?

INB3B [IF IN Q1A % OF MEDIUM TRUCKS NE 0%] Measured from your facility, about what percentage of the outbound trips made by your Medium or Single Unit Commercial

Vehicles and your Vehicles with Dual Tires [AS NEEDED: 2 plus axles and 6 plus tires and those with 2 axles and 6 tires] travel…?

INB3BB_About what percentage of the inbound shipments you receive on Medium or Single Unit Commercial Vehicles and your Vehicles with Dual Tires [AS NEEDED: 2 plus axles and 6 plus tires and those with 2 axles and 6 tires] arrive at your facility between the hours of?

[RESPONSE CATEGORIES FOR INB3A TO INB3B] READ EACH CATEGORY AND RECORD PERCENT]

__% 0 – 5 miles?
__% 6 – 10 miles?
__% 11 – 15 miles?
__% 16 – 20 miles?
__% 21 – 30 miles?
__% 31 – 50 miles?
__% 51+ miles?
888 DON'T KNOW
999 REFUSED

[MUST ADD UP TO 100%]

[RESPONSE CATEGORIES FOR INB3AATO INB3BB] READ EACH CATEGORY AND RECORD PERCENT]

__% 0 – 5 miles?
___ % AM Peak period - 6 AM to 9 AM
___ % Midday - 9AM to 3PM
___ % PM Peak Period - 3 PM to 6 PM
___ % -Night - 6 PM to next day 6AM
888 DON'T KNOW
999 REFUSED

[MUST ADD UP TO 100%]

[THE FOLLOWING TWO QUESTIONS WILL BE ASKED FOR EACH COMMODITY THEY RECIEVE.]

DIS01A_1Thinking about your inbound shipments of **[INSERT COMMODITY TYPE],** what percent of shipments coming into your facility from origins within Maricopa, Pinal, and Yavapai Counties have come from each of the following types of facilities?

___ % House/Other residential
___ % Office/Bank/Medical/Repair
___ % Government building/School/Military base/Hospital
___ % Retail/Store/Restaurant/Mall
___ % Construction site
___ % Warehouse/Wholesale store
___ % Industrial (e.g. manufacturing factory)
___ % Transportation Hub (e.g. port/rail/truck terminal/airport)
___ % Farm
___ % Mine
___ % Other (describe the location)
888 DON'T KNOW
999 REFUSED

[MUST ADD UP TO 100%]

DISI2A About how many inbound shipments of **[INSERT COMMODITY TYPE],** do you receive in a given day?

- ___ ENTER NUMBER OF OUTBOUND SHIPMENTS
- 888 DON'T KNOW
- 999 REFUSED

DISI2A.1 Of those inbound shipments of **[INSERT COMMODITY TYPE],** what is the average payload in pounds?

- 1 Less than 10,000 lbs
- 2 10,001 lbs to 25,000 lbs
- 3 25,001 lbs to 50,000 lbs
- 4 50,001 lbs to 75,000 lbs
- 5 75,001 lbs to 100,000 lbs
- 6 Greater than 100,000 lbs
- 888 DON'T KNOW
- 999 REFUSED

DISI2B About how many inbound shipments of **[INSERT COMMODITY TYPE],** do you receive in a given day?

- ___ ENTER NUMBER OF OUTBOUND SHIPMENTS
- 888 DON'T KNOW
- 999 REFUSED

DISI2B.1 Of those inbound shipments of **[INSERT COMMODITY TYPE],** what is the average payload in pounds?

- 1 Less than 10,000 lbs
- 2 10,001 lbs to 25,000 lbs
- 3 25,001 lbs to 50,000 lbs
- 4 50,001 lbs to 75,000 lbs
- 5 75,001 lbs to 100,000 lbs
- 6 Greater than 100,000 lbs
- 888 DON'T KNOW
- 999 REFUSED

[ASK FOR EVERY COMMODITY THEY PUT INB1A; AS DISI2C, DISI2C.1 ETC.]

[ALL]

DIS 13 What percentage of trucks coming into and going out of your facility come in and leave loaded?

- __% ENTER PERCENTAGE TRUCKS COME IN AND LEAVE LOADED
- 888 DON'T KNOW
- 999 REFUSED

FIRM INFORMATION

FACINT Finally, I am going to ask you a couple questions regarding your facility.

FAC1 Which of the following best describes your business?

1 Manufacturing
2 Wholesale Trade
3 Transportation and Warehousing
4 SOMETHING ELSE [SPECIFY]
888 DON'T KNOW
999 REFUSED

FAC1C **[IIF FAC1 = 1]** What type of industry is your company in?

1 AEROSPACE & AVIATION
2 AGRICULTURE & FOOD PROCESSING
3 BIO INDUSTRY
4 PLASTICS & ADVANCED COMPOSITES
5 HIGH-TECH
6 MINING & PRIMARY METALS
7 TRANSPORTATION & DISTRIBUTION
8 SUPPLIER INDUSTRIES [SPECIFY]
9 DEVELOPMENT INDUSTRIES [SPECIFY]
10 OTHER BASIC INDUSTRIES [SPECIFY]
888 DON'T KNOW
999 REFUSED

FAC2 How many employees are at your facility?

___ Enter number
999 999 OR MORE
8888 DON'T KNOW
9999 REFUSED

FAC2A [IF FAC2 GT 999] To the best of your knowledge which of the following categories best describes the number of employees at your facility?

1 Less than 5
2 5 to 10
3 11 to 25
4 26 to 100
5 101 to 500
6 500 to 999
7 1000 or <ore
888 DON'T KNOW
999 REFUSED

FAC2A Of that total how many are truck drivers?

____ ENTER NUMBER OF DRIVERS
888 DON'T KNOW
999 REFUSED

FAC3 What is the approximate square footage of your facility?

1 Less than 1,000
2 1,000 to 4,999
3 5,000 to 9,999
4 10,000 to 19,999
5 20,000 to 29,999
6 30,000 to 49,999
7 50,000 or more
888 DON'T KNOW
999 REFUSED

FAC4 What is your facility's operating hours on…?

____ Monday through Friday
____ The weekends
888 DON'T KNOW
999 REFUSED

FAC5 About how many destinations does your facility ship to within Maricopa, Pinal, and Yavapai Counties ?

1 Less than 5 **[SKIP TO FAC5B]**
2 5 to 10
3 11 to 25
4 26 to 50
5 50 or more
888 DON'T KNOW
999 REFUSED

[ALL]

GPSINT A lot of companies have been providing GPS logs or dispatch logs to us which has turned out to be very helpful with our modeling.

GPS1 Does your company keep GPS or dispatch logs?

1 YES BOTH
2 YES GPS LOGS
3 YES DISPATCH LOGS
4 NO **[SKIP TO THANK1]**
888 DON'T KNOW **[SKIP TO THANK1]**
999 REFUSED **[SKIP TO THANK1]**

GPS2 Would you be able to provide us with a copy of those from a peak day at our cost? **[IF NECESSARY: MAG will not be able to associate the dispatch logs with your company's name, etc.]**

1 YES
2 NO **[SKIP TO THANK1]**
888 DON'T KNOW **[SKIP TO THANK1]**
999 REFUSED **[SKIP TO THANK1]**

GPS3 Great, would you be able to email, fax, or send those to us? We will pay for postage / long distance.

1 EMAIL **[SKIP TO GPS4]**

2 FAX **[SKIP TO GPS5]**
3 MAIL **[SKIP TO GPS6]**
888 DON'T KNOW **[SKIP TO THANK1]**
999 REFUSED **[SKIP TO THANK1]**

GPS4 The email address you can send those to is **dmattingley@nwrg.com**. I would also like to get your email to send you a reminder. What is your email?

__ ENTER EMAIL
888 DON'T KNOW **[SKIP TO THANK2]**
999 REFUSED **[SKIP TO THANK2]**

GPS4A I entered ____________ for your email is that correct?

1 YES **[SKIP TO THANK2]**
2 NO **[SKIP TO GPS4]**

GPS5 The fax number is (208) 364-0181, please fax those as soon as possible. May I get your email to follow up with you?

__ ENTER EMAIL
2 NO / DON'T HAVE ONE **[SKIP TO THANK2]**
888 DON'T KNOW **[SKIP TO THANK2]**
999 REFUSED **[SKIP TO THANK2]**

GPS5A I entered ____________ for your email is that correct?

1 YES **[SKIP TO THANK2]**
2 NO **[SKIP TO GPS5]**

GPS6 The address you can send those to is Northwest Research Group, 225 North 9th Suite 200, in Boise, Idaho. Zip code is 83702. May I please get your email to follow up with you?

__ ENTER EMAIL
2 NO / DON'T HAVE ONE **[SKIP TO THANK2]**
888 DON'T KNOW **[SKIP TO THANK2]**
999 REFUSED **[SKIP TO THANK2]**

GPS6A I entered ____________ for your email is that correct?

1 YES **[SKIP TO THANK2]**
2 NO **[SKIP TO GPS6]**

THANK YOU

For Completed Recruits:

THANK1 Those are all of the questions I have. Thank you very much for participating in the Truck Survey. **[DISPOS = 40]**

THANK2 Those are all of the questions I have. Thank you very much for participating in the Truck Survey. We will call or email you in a couple days to remind you to send those GPS or electronic dispatch records. **[DISPOS = 40]**

THANK3 Thank you for your time, but we have completed the number of participants we need in your category. We appreciate your cooperation. Have a good day/night.

THANK30 Thank you for your time, but we can not complete this survey as you don't have any outbound or inbound truck trips.

THANK31 Thank you for your time, but we are completing this survey with companies who have inbound or outbound trucks larger than 2 axles and 4 tires.

THANK32 Thank you for your time, but we are completing this survey with companies who either own, lease, or subcontract the trucks that make their inbound and outbound trips.

THANK44 Thank you for your time, I will send you the link to complete the survey online right away.

THANKOQ Thank you for your time, but we have completed the number of participants we need in your category. We appreciate your cooperation. Have a good day/night.

For Refusals:

THANK5 Thank you for your time today. Have a good day / night **[INITIAL REFUSAL; DISPOS=5]**

THANK8 Thank you for your time, but we cannot continue without that information. Have a good day/night. **[SCREENER REFUSAL; DISPOS=8]**

THANK19 Thank you for your time today. Have a good day/night. **[REFUSED SURVEY PARTICIPATION IN INTRO 1; DISPOS=19]**

Answering Machine:

Hello, this is ____________ with Northwest Research Group, an independent opinion research firm calling on behalf of the Maricopa Association of Governments. Today/Tonight we are conducting a survey that will help MAG reduce traffic congestion and promote efficient movement of goods. Let me assure you this is not a sales call.

We will try to reach you at a more convenient time but in the meantime you can reach us toll-free at 1-866-461-0700. Please visit us on the web at www.nwrg.com. Thank you very much for your time and have a nice day/evening.

DISPOSITIONS

Disp#	Disposition	Display Type	Property	Incidence
		P/S/I/H	A/B/C/N/R/F	D/B/I
01	No Answer	P	A	D
02	Busy	P	B	D
03	Answering Machine	P	A	D
04	Message Left	H	A	B
05	Possible Disconnect	P	R	D
06	Targeted Respondent Not Available	S	F	D
07	Residential Number / Not a Business	P	F	D
08				
09	Spanish Language Barrier	S	F	D
10	Language Barrier (Other)	S	F	D
11	Other Communication Barrier	S	F	D
12	Require Supervisor Attention	S	F	D
13	Initial Refusal	S	R	D
14	Final Refusal	S	F	D
15	Never Call - SUPERVISOR	H	N	D
16	Screener Refusal	H	F	D
17	No Call List Mention	S	F	D
18	Privacy Manager	P	R	D
19	Refused Survey Participation (INTRO2)	H	F	D
20				
21	Callback Introduction	S	C	D
22	Interview In Progress	I	C	I
23	Mid-Terminate - SUPERVISOR	I	R	I
30	NQ- No Trucks In / Out (Q1 & Q2 = 0)	H	F	B
31	NQ – All Trucks In / Out = Light (Q1A & Q2A = 100% Light)	H	F	B
32	NQ - Don't own or subcontract trucks	H	F	B
33	NQ – ALL SHIPMENTS IN AND ALL SHIPMENTS OUT FROM OUTSIDE REGION	H	F	B
40	Complete	H	F	B
41	OQ – Medium	H	F	B
42	OQ – Heavy	H	F	B
43		H	F	B
44	Qualified send online version	H	F	B
45		H	F	B
46		H	F	B
47		H	F	B
48		H	F	B
49		H	F	B
50		H	F	B
51		H	F	B

Display Type:
P = Pre-Screener – First Screen With Contact Info (Prior To Contact With Respondent)
S = Screener – After First Screen, Before QAL (After Contact With Respondent)
I = Interview – Between QAL and CPL
H = Hidden – Not Available To Interviewer

Property:
A = Answering Machine / No Answer
B = Busy
C = Callback
N = Never Call
R = Refusal
F = Final

Incidence:
D = Don't include
B = Base only
I = Include

E. Geocoded Surveys