NCHRP SYNTHESIS 298

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Truck Trip Generation Data

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD

NATIONAL RESEARCH COUNCIL

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 298

Truck Trip Generation Data

A Synthesis of Highway Practice

CONSULTANT

MICHAEL J. FISCHER
Cambridge Systematics, Inc.
and
MYONG HAN
Jack Faucett Associates

SUBJECT AREAS

Planning and Administration and Highway Operations, Capacity, and Traffic Control

Research Sponsored by the American Association of State Highway and Transportation Officials
in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD — NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY PRESS
WASHINGTON, D.C. — 2001

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communication and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

NCHRP SYNTHESIS 298

Project 20-5 FY 1999 (Topic 31-09)
ISSN 0547-5570
ISBN 0-309-06908-4
Library of Congress Control No. 2001 135527

Price $32.00

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

The Transportation Research Board evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

and can be ordered through the Internet at:

http://www.nationalacademies.org/trb/bookstore

Printed in the United States of America

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis report will be of interest to state transportation departments and their staffs, as well as to the consultants that work with them in the areas of truck trip generation. Its objective is to identify available data and to provide a balanced assessment of the state of the practice in meeting the needs for and uses of these data by transportation engineers, travel demand modelers, and state and federal transportation planners. The synthesis was accomplished through a review of recent literature and a survey of representatives from state transportation agencies. The data collected in the study are summarized and presented in appendices for use by practitioners.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board presents a summary of key issues that affect the collection and use of truck trip generation data. Conclusions and suggestions for future study are also provided.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the available information was assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the author's research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

ACKNOWLEDGMENTS

Michael J. Fischer, Cambridge Systematics, Inc., Oakland, California, was responsible for collection of the data and preparation of the report. Myong Han, Jack Faucett Associates, Walnut Creek, California, assisted in the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Frank Baron, Transportation Systems Specialist, Miami Urbanized Area Metropolitan Planning Organization; Russell B. Capelle, Jr., Assistant Director, Bureau of Transportation Statistics/Office of Motor Carrier Information, U.S. Department of Transportation; Lee Chimini, Freight Operations, Federal Highway Administration; Robert J. Czerniak, Associate Professor, Department of Geography, New Mexico State University; Ted Dahlburg, Manager, Urban Goods Program, Delaware Valley Regional Planning Commission; Alan Danaher, Principal Engineer, Kittelson & Associates, Inc.; Steven R. Kale, Senior Planner/Economist, Oregon Department of Transportation; Thomas M. Palmerlee, Transportation Data Specialist, Transportation Research Board; Charles Sanft, Senior Investment Analyst, Minnesota Department of Transportation; Robert Snyder, United Parcel Service; and Carol H. Walters, Senior Research Engineer, Texas Transportation Institute.

This study was managed by Donna L. Vlasak, Senior Program Officer, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in project scope development was provided by Stephen F. Maher, P.E., Manager, Synthesis Studies. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 Committee and the Synthesis staff.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

TRUCK TRIP GENERATION DATA

SUMMARY

The increased importance of truck activity in both transportation engineering and planning has created a need for truck-oriented analytical tools. A particular planning need is for trip generation data that can be used to estimate truck traffic patterns, beginning with the ability to estimate truck trips generated by a variety of common land uses. However, the current state of the practice in truck trip generation data falls short of the needs of today's transportation engineers and transportation planners.

The objective of this synthesis report is to identify available truck trip generation data and provide an assessment of the current state of the practice. The synthesis begins by identifying the needs for and uses of truck trip generation data. In each case, the critical issues and problems associated with meeting these needs are defined and discussed.

The needs of transportation engineers, travel demand modelers, and state and regional transportation planners for truck trip generation data vary considerably. This synthesis report attempts to provide a balanced assessment of the state of the practice in truck trip generation data for all different groups of practitioners.

The data collected in the study are summarized and presented in appendixes for use by other practitioners. A summary of key issues that affect the collection and use of truck trip generation data is presented and the state of the practice is assessed with reference to these issues.

There are a number of factors that affect the form of truck trip generation data and how they are developed. These factors include:

- Uses of truck trip generation data.
- Trip purposes/classification of trip generation activities.
- Independent variables.
- Estimation techniques.
- Methods of data collection.

The state of the practice in truck trip generation data is fairly primitive compared with trip generation data practices used in analyzing passenger vehicle movements. Recently, more attention has been devoted to developing truck trip generation data and methodologies for statewide/regional modeling than to transportation engineering applications.

Truck trip generation data applicable to transportation engineering data identified in this study tend to be limited to those land uses most commonly identified with truck use. These include truck, intermodal, and marine terminals; industrial parks; specialized warehouse and distribution facilities; and selected manufacturing sites. Noticeably absent from

most truck trip generation studies for engineering applications reported over the last decade are land uses such as offices, retail trade, shopping centers, and other types of commercial/ service businesses. In addition, data on truck size/configuration and vehicle dwell times are generally not available.

There are two types of truck models, vehicle-based and commodity-based. Vehicle-based truck trip generation rates used in statewide and regional travel demand models are generally estimated based on land-use categories that match up well with employment by industry sectors corresponding to the data that metropolitan planning organizations (MPOs) typically have and/or forecast. A significant problem with this method is that these categories of land use are very broad and trip rates vary considerably within these categories from region to region.

Commodity-based models generally do not develop truck trip generation rates. Trip generation is usually calculated by converting annual commodity tonnage data into daily truck trips using a payload conversion factor. The national Commodity Flow Survey and the Transearch database developed by Reebie Associates are the most commonly used sources of commodity flow data, and the national Vehicle Inventory and Use Survey (VIUS) and locally collected intercept surveys are the most commonly used sources of payload data. These methods tend to underestimate trips in urban areas, because they do not account for trip chaining and local pickup and delivery activity.

Most truck trip generation data include attempts to classify trucks, recognizing that different types of trucks have different missions and therefore different truck trip generation characteristics. Typical approaches to classifying vehicles include gross vehicle weight categories, configurations (i.e., single-unit and combination vehicle), or number of axles. Unfortunately, there is little consistency from study to study, making it difficult to compare trip generation rates.

In vehicle-based truck trip generation models, the most common approach to estimating trip generation rates is by land use as a function of employment. Typically, surveys are conducted and used to determine land use at each trip end. Expanded survey data can then be used to relate trip ends by land use (either by zone or for the region as a whole) to employment corresponding to each land-use category. These models often require calibration to produce accurate results. Sources of error include the inherent variability of trip rates for aggregate land-use/employment categories, the inaccuracy of self-administered travel diary surveys, and the inappropriateness of employment as an explanatory variable. A number of analysts have noted that trip generation is more likely to be a function of industrial output than of employment. The relationship between output and employment (labor productivity) varies within broad industry categories, from firm to firm (often related to economies of scale), and over time.

As described previously, commodity-based trip generation models generally start with an estimate of commodity flow tonnage, generally county-to-county or state-to-state flows. The annual tonnage flows are then converted to daily truck trips using payload factors. When commodity-based models are used in regional applications, the flows are typically allocated to traffic analysis zones (TAZ) using employment shares by industry/TAZ. Employment for detailed industry categories is generally difficult to obtain at the TAZ level.

For vehicle-based regional modeling applications, travel diary surveys are the most frequently used source of data for estimating trip generation rates. This type of data collection is particularly difficult for trucking, because the owners and operators of the vehicles are not always the same (leading to complicated processes for obtaining a driver's participation), are concerned about taking time away from revenue-producing activities to fill out forms, are concerned about revealing confidential customer information, and because of growing distrust of government in some areas. Response rates tend to be low. In addition, obtaining a complete sampling frame including all of the vehicles that make trips within a particular modeling area can be difficult if a high percentage of trips are made by out-of-area vehicles.

Truck trip generation data for transportation engineering applications is typically obtained from vehicle classification counts. Accuracy of equipment for automated counts and selection of locations at which to take counts (in order to capture all traffic associated with a particular site and only traffic associated with the site) can be a challenge. Most studies reported in the literature calculate rates based on extremely small samples (fewer than 10 observations), with high variability from site to site (as high as an order of magnitude difference).

Survey results suggest the following activities to help improve the collection and analysis of truck trip generation data.

- Because limited information is available on truck trip generation rates for use in transportation engineering applications, undertake a comprehensive and systematic data collection program to address the serious deficiencies in truck trip generation data. Efforts should focus on land uses such as industrial parks, manufacturing facilities, warehouses, office buildings, and various categories of service and retail industries.
- Prepare a new state of the practice manual for statewide truck trip generation modeling using commodity flow information. As part of this program, truck trip generation rates per employee at the 2-digit Standard Commodity Transportation Group level of detail from different commodity-based state models might be compared to determine if such rates might be transferable from one state to another. Another important area of research supporting commodity-based models would be to improve data on average payloads for conversion of tonnage flows to truck trips and for estimating axle loadings in order to support pavement design initiatives.
- A rethinking of the VIUS survey to redefine "major commodity" to agree with the SCTG system and "sample size" to provide sufficient samples by strata to meet the commodity-based models' disaggregation requirements by commodity and truck size.
- Collect data from external roadside intercepts to identify the number of internal trips typically made by trucks registered outside of a region.
- Conduct research to estimate the commodity distribution practices of different industries.
- Compile truck trip generation data and re-estimation of trip rates in a constant manner to determine how variable these rates are.

In the future, it is likely that some MPOs will continue to experiment with commodity-based trip generation models. The utility of commodity-based models could be further extended if additional research is conducted to estimate the commodity distribution practices of different industries. Commodity-based models provide little information about the various reload distribution movements between the initial production and end-user consumption trip ends, which results in an underestimation of trips. Further investigation is needed to determine if trip generation relationships that capture these intermediate moves can be estimated.

CHAPTER ONE

INTRODUCTION

STATEMENT OF THE PROBLEM

Over the past 10 years there has been an explosion of interest in freight transportation planning. Once the exclusive province of freight industry analysts and a small cadre of private sector logistics planners, freight transportation has now become a critical element in improving industrial productivity and is receiving attention throughout corporate America. Trucks play an essential role in the freight transportation system. According to the 1997 U.S. Bureau of the Census *Commodity Flow Survey* (1999), 69.4 percent of total tonnage and 71.7 percent of total value shipped in the United States was carried by trucks. Trucks provide both a high level of transport reliability and enormous flexibility in terms of the origins and destinations they can serve, the commodities they can carry, and the range of services they can provide. In addition, they provide the key link among most other modes of freight transportation. With increasing use of just-in-time inventory practices, forward positioning of supplies and inventory, and growth in small-package-expedited delivery and e-commerce distribution services, the significance of truck traffic continues to grow.

Public policy initiatives in the 1990s also created new interest in truck traffic issues. Beginning with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) and continuing with the Transportation Equity Act for the 21st Century (TEA-21), states and metropolitan planning organizations (MPOs) are required to consider freight transportation issues in state and metropolitan transportation plans.

The increased importance of trucks in transportation engineering and transportation planning has contributed to a need for truck-oriented analytical tools with the broad range of capabilities that are currently available for passenger transportation planning/engineering. One such need is for trip generation data that can be used to estimate truck traffic volumes. The needs for truck trip generation data are varied and include:

- Estimating the impact of new and expanding development on local traffic patterns, air pollution, and noise.
- Design of off-street loading dock space at a variety of different types of business establishments.
- Estimating the needs for access improvements and parking facilities for major freight terminals, freight activity centers, mixed-use development, retail and office buildings, and high-rise residential uses in constrained urban areas.
- Planning for urbanized traffic management in downtown areas.
- Planning for major corridor, subregional, or regional infrastructure investments and roadway maintenance requirements.
- Development of efficient truck routes that expedite rather than penalize goods movement.
- Forecasting regional and statewide truck travel demand in fulfillment of federal and state transportation and air quality planning mandates.

The state of the practice of passenger trip generation data is well advanced and appears to meet most of the current needs of transportation planners and transportation engineers.

- The Institute of Transportation Engineers (ITE) published *Trip Generation* (6th Edition; 1997), a definitive resource for transportation engineers with extensive passenger trip generation data. Although vehicle trip rates provided here include all vehicles, rates that distinguish truck trips are not provided.
- State and metropolitan planning agencies have been developing and refining four-step urban travel models for more than 40 years, and techniques for estimating trip generation rates for these models are well established. The types of independent variables and survey techniques used for estimating new region-specific rates are well known and well documented.

Truck trip generation data sources are more limited.

- Appendix A of the *Trip Generation Handbook* (ITE 1998) provides information about some truck trip generation studies. However, these are not considered recommended practices, procedures, or guidelines.
- Most states and MPOs have not developed truck travel demand models. To the extent that truck traffic is estimated in existing models, these are mostly calculated as fixed percentages of total vehicle flows. Although there has been increasing interest in truck travel demand modeling among states and MPOs during the last 10 years, there is no well-accepted methodology for these models nor are there well-accepted methods for estimating truck trip generation.

As interest in truck traffic grows, there are some significant issues that will need to be addressed in order to advance the state of the practice of truck trip generation data.

- Appropriate categories of land uses that are related to variation in truck trip generation rates need to be defined and are likely to be different than the categories previously defined for passenger vehicles.
- Appropriate categories of trip purposes need to be defined for truck trips, because trip generation rates will vary according to purpose. Trip purposes defined for passenger trips bear little relationship to truck trips.
- Appropriate categories of truck types need to be agreed upon, because trip rates are likely to vary among trucks of different sizes and uses.
- Appropriate categories of independent variables need to be agreed upon. The relationships between passenger vehicle trips and standard land-use and socioeconomic data may offer limited application in the estimation of truck trip generation.
- Appropriate methods of collecting truck trip generation data and acceptable accuracy and precision standards will need to be developed based on the unique characteristics of truck trips and the variability of trip rates.

SCOPE OF THE INQUIRY

Although a synthesis report does provide an assessment of the current state of the practice, it is not a definitive and exhaustive review of the subject, but a reasonable evaluation of the state of the practice derived from representative data. The objective of this synthesis report is to provide an assessment of the current state of the practice in truck trip generation data for the various groups of practitioners including transportation engineers, travel demand modelers, and metropolitan and state transportation planners. Specifically, the final scope for this project states: "This synthesis will identify available truck trip generation data. Trip rates associated with economic activities and land uses are of particular interest . . . The validity of the data, collection methods and challenges, and the organizational sources and attitudes toward sharing data will be addressed."

The synthesis begins by identifying the needs for and uses of truck trip generation data. In each case, the critical issues and problems associated with meeting these needs are defined and discussed. Through a combination of a literature review, surveys of practitioners, and more in-depth discussions with leading practitioners, the report attempts to provide a snapshot of the current state of the practice.

METHODOLOGY

Three principal methods were used to develop the information used in this assessment.

- Both contractors for this synthesis have conducted numerous projects related to freight and truck demand analysis and forecasting. Through these projects, these firms have compiled truck trip generation data, surveys of the relevant literature, and extensive practitioner contacts, all of which were drawn upon in the preparation of this report.
- A detailed literature review was the second approach to compiling information for this report.
- The third approach to compiling information for this report was a survey of practitioners (see Appendix A). The questionnaire was sent to AASHTO liaisons from each state department of transportation; representatives of states and MPOs, who have conducted freight planning and/or modeling studies; consultants and academic researchers, who have published on freight and truck data collection/analysis techniques; and members of the ITE Consultants Council and Goods Movement Council. Over 300 surveys were sent out and 42 responses were received.

ORGANIZATION OF THE REPORT

The second chapter of this report provides a summary introduction, the scope of inquiry, methodology, organization, and discussion of the following key considerations used in the development of truck trip generation data.

- The uses of truck trip generation data (including trip rates).
- Classification of trip purposes/trip generating activities and how this affects the presentation and needs for truck trip generation data and rates.
- Independent variables and techniques for estimating truck trip generation data, rates, and their appropriateness.
- The techniques for data collection and how effective these are for developing the necessary truck trip generation data and rates.
- The transferability of existing truck trip generation data and rates, and factors that affect transferability.

The third chapter of this report presents a review of available sources of data. Chapter 4 presents an assessment of the current state of the practice in truck trip generation data. The state of the practice is described in terms of the same issues that are discussed in chapter 2. Chapter 5 presents conclusions and recommendations.

In chapters 3, 4, and 5 the discussion of truck trip generation data distinguishes between engineering and planning applications. Throughout the research for this report, it became clear that this distinction was critical for understanding the variety of information resources, data issues, and recommendations for future research.

The report also includes a glossary of key terms, a copy of the survey questionnaire (Appendix A), a list of survey participants (Appendix B), and a summary of all the truck trip generation data and rates collected for this project (Appendix C).

CHAPTER TWO

KEY CONSIDERATIONS IN THE DEVELOPMENT OF TRUCK TRIP GENERATION DATA

To appreciate the current state of the practice of truck trip generation data it is necessary to understand a number of fundamental topics associated with the application of truck trip generation rates, the estimation of truck trip generation rates/models, and the collection of truck trip generation data. These topics are outlined in this chapter.

USES OF TRUCK TRIP GENERATION DATA

The uses of truck trip generation data can be broadly classified in two major categories: (1) transportation engineering applications, and (2) statewide, regional, and subregional planning applications. Each of these categories of truck trip generation data applications creates different needs with respect to classification of trip purposes, level of land use and industrial detail, and classification of truck types. A clear statement of the need for and potential applications of truck trip generation data for transportation engineering and planning practice is provided here.

Transportation Engineering Applications

- Uses
  - Traffic impact fee assessment
  - Traffic operation studies
  - Site impact analysis
  - Street design
  - Provision of off-street and on-street loading facilities
  - Provision of off-street and on-street parking

- Issues
  - Requires high level of accuracy for wide range of land-use types
  - Requires accuracy at microscale level
  - Trip rates must be highly transferable
  - Clear and consistent procedures for estimating rates and presenting the data are needed

Statewide, Regional, and Subregional Planning Applications

- Uses
  - Travel demand modeling
  - Development of state, regional, and local transportation plans
  - Evaluation of transportation improvement program projects
  - Identification of system operational deficiencies and evaluation of improvements
  - Corridor studies and plans
  - Activity inputs to air quality analysis programs
  - Intermodal access studies

- Issues
  - Widely varying levels of geographic detail
  - Widely varying levels of precision of estimate required
  - Transferability of results
  - Compatibility of rates and socioeconomic and/or land-use data

The potential needs for reasonably accurate estimates of truck trips for engineering applications fall into three general categories: traffic operations, street and road design, and public and political concerns (ITE 1998).

Transportation engineering applications of trip generation data require very accurate estimates of trip generation for a wide range of land-use types. These rates must be accurate at the microscale because they are used to design local streets, designate or revise truck routes, estimate traffic impacts and design mitigations, assess traffic impact fees, and regulate provision of off-street loading space. The trip generation rates developed for these applications also need to be widely transferable. Clear and consistent procedures for the collection of trip generation data and the estimation and presentation of trip rates must be developed.

Statewide, metropolitan, and subregional planning applications of truck trip generation data are generally associated with the estimation and use of travel demand models. These models are used for

- Development of state and metropolitan transportation plans;
- Evaluation of transportation improvement program projects;
- Identification of system operational deficiencies and evaluation of the traffic benefits of improvements;
- Conducting corridor studies;
- Identification and evaluation of National Highway System connector needs; and
- Development of activity inputs to air quality analysis programs.

Each of these applications requires different levels of geographic detail and accuracy.

TABLE 1
CLASSIFICATION SCHEMES AND THEIR ASSOCIATED ISSUES

Classification Schemes	Classification Issues
Land-use categories	• Are categories in ITE *Trip Generation* appropriate for all freight activities? • What land-use categories are correlated with truck trip generation characteristics? • What level of land-use data is available for model applications and how well correlated is this with truck trip generation characteristics?
Truck size/configuration categories	• Definitions of what is a truck (e.g., all commercial vehicles, number of axles, gross vehicle weight rating) • Each application suggests different categories
Goods movement vs. non-goods movement	• Goods movement truck trips are related to commodity flows, but not all trips are goods movement trips
Production/attraction rates	• Different economic activities produce and attract trips • Facilities may both produce and attract trips • At the same facility different truck types may be used for trip productions and attractions, and productions and attractions may occur at different times of day • Links are needed between activities that produce trips and those that attract these trips by category
Time of day	• Trip rates by time of day vs. factoring 24-hour rates based on counts
Linked trips vs. "garage-based" trips	• Different rates for tour vs. non-tour trips
Activity types	• Pick-up, delivery, service calls, fueling, personal business, etc.

TRIP PURPOSES/CLASSIFICATION OF TRIP GENERATING ACTIVITIES

The classification of truck trips for the purposes of calculating trip generation rates presents some significant challenges. The underlying economic activities that generate truck activity are highly variable, which makes it difficult to apply truck trip generation rates outside of the very localized area in which the data were collected. On the other hand, highly disaggregate trip purposes/classifications tax available data and make forecasting extremely difficult. Table 1 summarizes different classification schemes and associated issues.

Each of these classification schemes is described in more detail here.

- **Land-use categories**—Trip generation rates for transportation engineering applications are traditionally provided for specific land-use categories. ITE *Trip Generation* (1997) provides a well-defined and accepted set of land-use categories for estimating trip rates. These categories were developed because they are of particular interest in traffic impact studies and well explain the variability in trip rates. It is not yet clear if these land uses will work well for all truck trip generation. Although these categories will be useful in describing truck activities at non-truck intensive land uses (e.g., office or retail trade), land-use categories and/or economic activity types need to be defined so that they reflect major freight activity generators. Furthermore, they need to be defined so that the land-use categories are correlated with the variations in truck trip productions and attractions. In addition, truck trip rates are needed for certain land uses that are not usually considered in freight studies, but for which truck traffic and access is important (e.g., shopping centers). Intensity of land use is generally described by socioeconomic variables (e.g., households and number of employees by industry).

- **Truck size/configuration categories**—The first issue to be addressed with respect to this classification is what is the definition of a truck. Some studies define trucks as any commercial vehicle that is not an automobile, others include any vehicle that has at least two axles and six tires, and still others define trucks based on a minimum gross vehicle weight rating. Inconsistency in the definition of what vehicles are classified as trucks clearly affects the trip generation rate.

  The types of vehicles that are appropriate to include in the definition of a truck depend on the purpose of the study. For example, for provision of off-street loading areas it may be important to include all vehicles involved in pick-up and delivery activities, whereas design of access facilities may only require a separate analysis of vehicles with unique geometric requirements.

  Once trucks have been defined, the classification of truck types is important, because it is correlated with trip generation rates. The variety of approaches used to define truck size categories makes it very difficult to compare rates developed in different studies.

- **Goods movement versus non-goods movement**—This classification of trip purpose is receiving more attention among metropolitan and statewide modelers than among transportation engineers, because it can be related to the manner in which trip generation is estimated. In state and regional studies that focus on freight and goods movement transportation there is a growing interest in looking at commodities moved as a means for estimating the number and type of truck trips that are generated. However, when the results of these modeling approaches are compared to actual highway truck volumes, the estimates often fall short of the observed counts. To some extent this can be traced to the exclusion of truck trips related to construction, service, and utility applications that are not involved in goods movement; incomplete consideration of empty trucks; and the lack of methods for including trips in multistop tours. Methods for estimating the generation of these latter types of trips, distinct from commodity-based trip generation rate estimation methodologies, are still evolving.

- **Production/attraction rates**—Transportation engineers and travel demand modelers are interested in distinguishing between trip production rates and trip attraction rates. In transportation engineering applications it is important to understand that for truck trips, different types of activities tend to initiate trips at a location than those activities that attract trips. For truck trips, this is more easily understood in terms of inbound trips versus outbound trips. For example, at a manufacturing facility supplies and services constitute inbound truck trips, whereas shipments of product constitute outbound truck trips. The rate at which trucks arrive inbound is very different from the rate at which they leave with outbound shipments. In addition, the types of trucks making inbound trips may be very different from those making outbound trips. All of these factors can affect the traffic impacts that a facility will have on adjacent roadways and communities.

  Similar concerns relate to travel demand modeling because the approaches and rates used to estimate trip productions and attractions may be different. For example, it is rare that manufacturers will ship their products directly to households. However, if manufacturer productions and household attractions are not distinguished in a model, this type of unlikely distribution pattern can result in the model.

- **Time of day**—In many applications of truck trip generation data, the time of day distribution of the trips is very important. For example, understanding the variation in truck traffic as it relates to peak versus off-peak traffic conditions is often important. In many transportation engineering applications, these time-of-day characteristics are resolved by estimating different trip generation rates for different times of the day. In most current truck travel demand models the approach is to estimate 24-hour trip generation rates and to then factor the resulting traffic assignment volumes into time periods based on ground counts from different time periods.

- **Linked trips versus "garage-based" trips**—This area of trip classification has greater relevance to travel demand modelers than to transportation engineers, and the issue is more significant in the trip distribution step of modeling than in the trip generation step. In most traditional 4-step urban travel demand models, trip generation is first estimated by traffic analysis zone (TAZ), and then the zone-to-zone trip distribution patterns are estimated. Many models use a gravity model formulation for trip distribution, which makes the trips attracted to a zone from any other zone directly proportional to the total trips of that type attracted to the zone and inversely proportional to some measure of impedance between the zones (e.g., travel time or distance). "Friction factors" are estimated in these models based on the trip length frequency distribution of all trips of a particular type.

  Some modelers have observed that in the case of truck trips there is a distinct difference in trip lengths for trips that go back and forth between a base location and their delivery/customer locations (garage-based) and those that make many intermediate stops before returning to home base (linked). Figure 1 illustrates the characteristics of each of these types of trips. The ability to capture this distinction in trip distribution models cannot be accomplished without first estimating trip generation for each type of trip independent of the other.

- **Activity types**—Trucks are involved in a wide range of activities. As noted previously, some of these activity classifications are related to the type of truck. In other cases, however, the same truck may be involved in different activities. Truck activity classifications that appear in the literature include pick-up, delivery, service calls, fueling, and personal business.

INDEPENDENT VARIABLES/ESTIMATION TECHNIQUES

Methods of Estimating Truck Trip Generation Data

The following are three major, widely reported approaches to estimating truck trip generation data: estimation of simple rates (total truck trips generated divided by a single independent variable), linear regression models (truck trips estimated as a function of variables using the least-squares-regression analysis technique), and commodity flow models (truck trips estimated directly from tonnage flows of commodities from one area to another).

Trip generation rates are the simplest approach to estimating truck trip generation. This is the approach most often

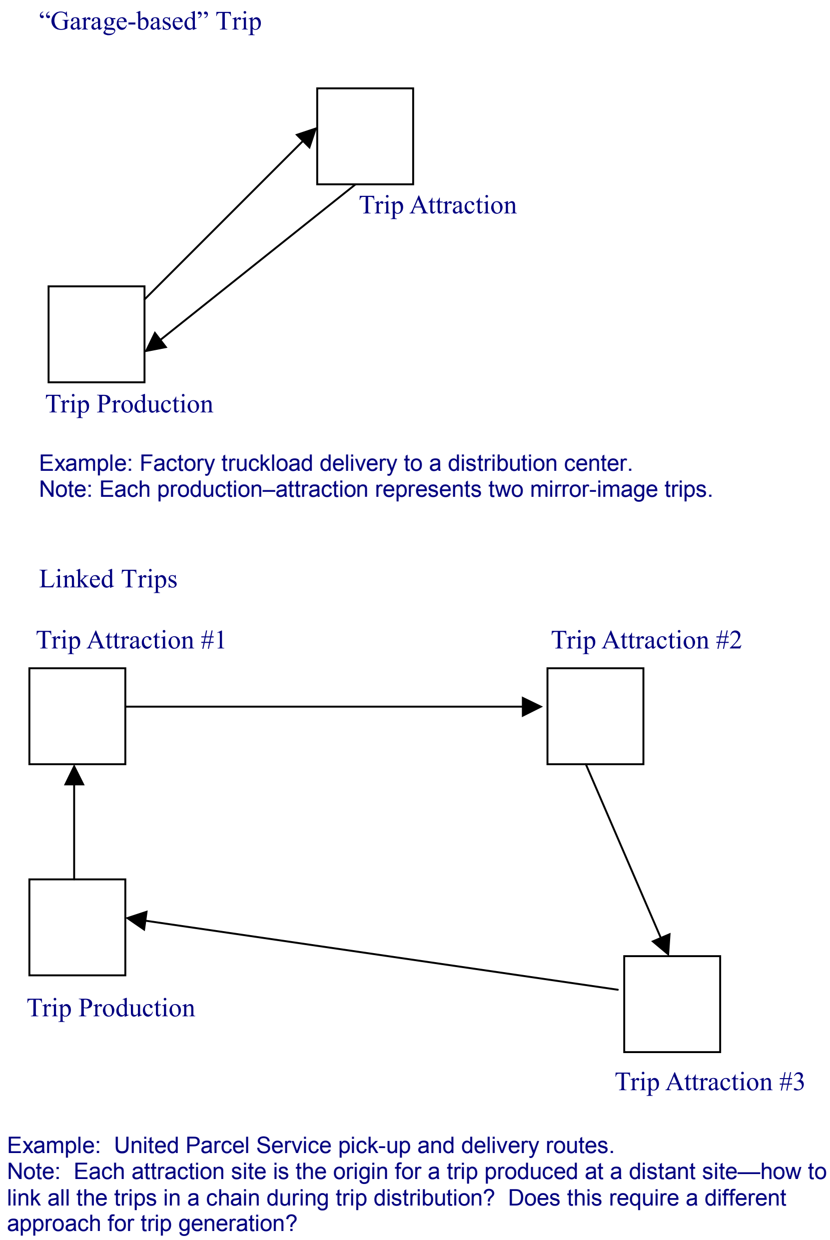

FIGURE 1 "Garage-based" versus linked trips.

used in transportation engineering applications. It has also been used extensively for travel demand modeling applications. The general approach is to select land-use categories and estimate trip generation rates for each category as a function of a single independent variable that measures the intensity of land use or activity at the land use. Typical examples of independent variables used include

- Acreage of land used,
- Square feet of building floor area, and
- Employment or activity indicators (e.g., number of container lifts, import/export container moves).

As noted previously, the selection of land-use categories is a critical question and one for which little guidance is available. The general approach in modeling applications is to use land-use categories that correspond closely to industry/employment categories, which are forecast at the zonal level in regional socioeconomic models. This presents serious limitations. In the best cases, these may include 10–12 categories that correspond to major industry groups in the North American Industrial Classification System (NAICS), which recently replaced the Standard Industrial Classification (SIC) system as the preferred system for classifying industries. Trip rates estimated at the major industry level of detail (i.e., 10–12 categories) are not only highly variable from one region to another, but may even vary significantly within regions. Some regional travel demand models attempt to solve this problem by estimating different subregional trip generation rates for the same land-use category.

Another common approach used to deal with this problem in regional models is to identify "special generators," which are responsible for significant truck activity and for whom the regional trip rates would either over- or underestimate trip generation. Clearly, this problem demonstrates the lack of interregional transferability of results estimated using this type of approach at this level of detail.

Linear regression models have much in common with simple trip rate estimation, although the method for calculating the rates differs. In transportation engineering applications, the ITE has established a standard format for presenting results estimated with regression models. In this application, trip generation volumes are estimated for many different sites in the same land-use category. The regression model attempts to fit a straight line to the data and the slope of the line represents the constant trip generation rate.

Regression models are also used to estimate regional and statewide trip generation. These models generally estimate the number of trips generated in large zones, or districts, based on the expansion of survey data. Trips are then regressed against an independent variable or variables measuring activity levels in each zone or district. These models can be developed individually for each land-use type or a single model can be developed with multiple independent variables representing the different activities in the zone (e.g., different employment variables). Regression models are often used in regional studies when the survey data collected for truck trips do not include valid classifications of land use at each trip end. The regression models suffer from most of the same problems identified previously for simple trip rates.

Commodity flow techniques for estimating truck trip generation are relatively new approaches and do not seem to be applicable to transportation engineering applications. First proposed for statewide modeling applications (Memmott 1983), this approach is beginning to be applied in metropolitan models and corridor studies as well.

The basic approach (see Figure 2) is to use economic data and forecasts of industrial output and consumer final demand along with economic input–output models to estimate annual production and consumption of goods. Data from sources such as the U.S. Economic Census provide much of the information needed to make these estimates on a state-by-state basis and local employment data are then often used to disaggregate state level production and consumption estimates to more disaggregate zones (counties, cities, or TAZs). The origin–destination patterns of the flows are developed from a variety of data sources including the U.S. Commodity Flow Survey (CFS), locally conducted origin–destination surveys, and estimates from calibrated gravity models.

Because most of the economic data and models used to estimate production and consumption of goods is measured in value (dollars), they must first be converted to tonnage of shipments (using value-to-weight ratios derived from various public and private proprietary sources), then split by freight mode (often using fixed modal shares by commodity and origin–destination pair based on data such as the CFS), and finally converted to truck trips. This last step is the critical link to traditional truck trip generation data and is the subject of some controversy. Many studies convert tonnage flows into truck trips using average payload factors. These payload factors may come from local surveys or from national data, such as the Vehicle Inventory and Use Survey (VIUS). VIUS is a truck survey conducted every 5 years by the U.S. Bureau of the Census as part of the Economic Census. The survey collects extensive data about equipment and activity characteristics of the nation's truck fleets.

The degree of disaggregation of commodities in the data used to estimate average payloads will ultimately influence the accuracy of results and often suffers from the same data aggregation problems described previously for trip rates and regression models. Critics of this approach to estimating truck traffic also note that the commodity flow and payload data tend to neglect the many local pick-up and delivery trips that constitute the majority of truck trips within urban areas. These local trips also include many non-goods movement trips that are not estimated in commodity flow models.

Another important element of truck trip generation that must be addressed in commodity flow models is the estimation of empty truck trips, which are not accounted for in the production–consumption estimation techniques and must, therefore, be added at the truck trip conversion step.

Choice of Independent Variables

Table 2 summarizes different variable categories used for estimating truck trip generation rates.

The previous discussion indicated that in most cases where trip rates or regression models are used to estimate truck trip generation, the independent variables used will either be land-use variables (i.e., building floor area or acres of land used) or employment variables. Although these variables may be appropriate for estimating truck trip

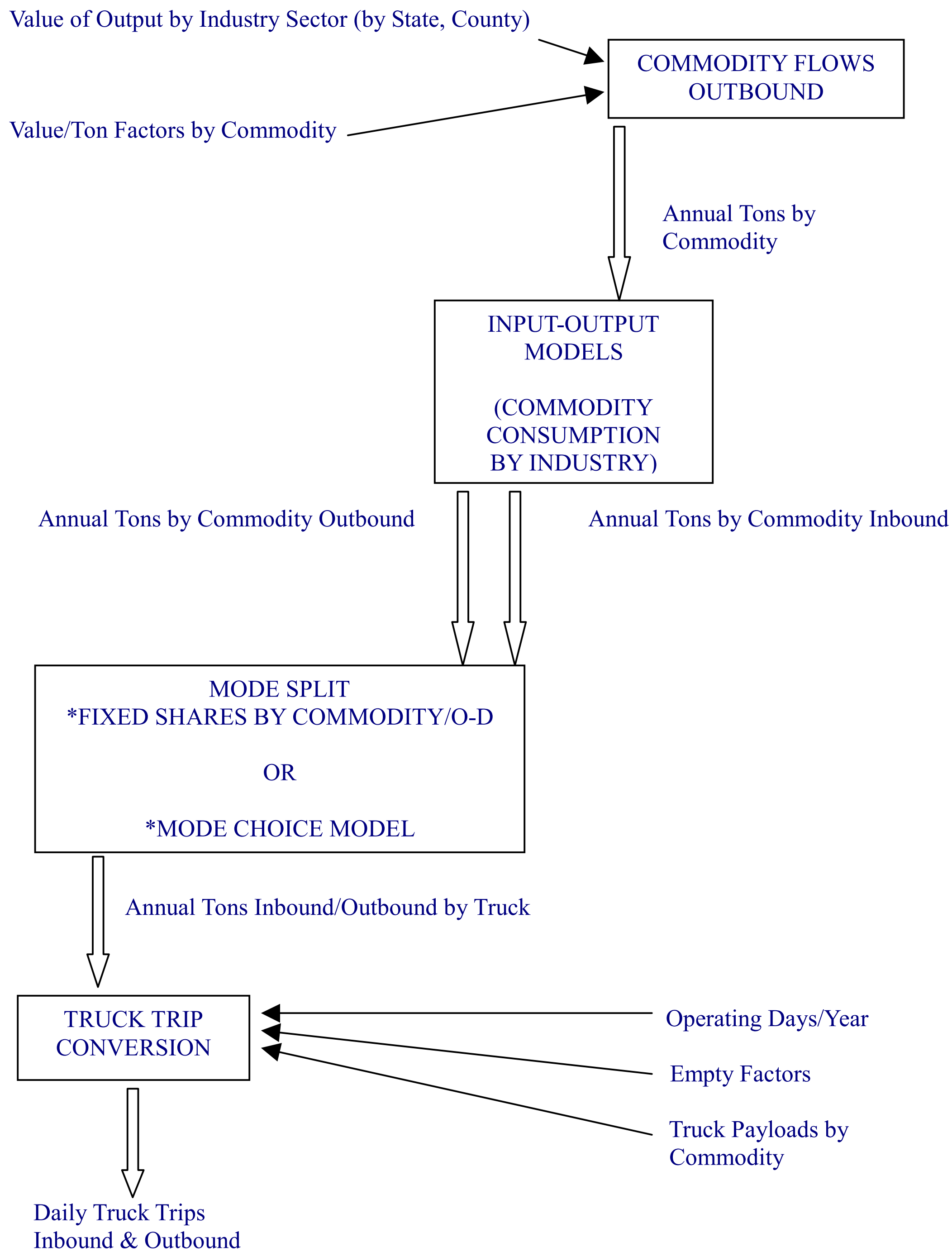

FIGURE 2 Commodity flow techniques for estimating truck trip generation.

TABLE 2
INDEPENDENT VARIABLES FOR ESTIMATING TRUCK TRIP GENERATION RATES

Variable Categories	Variable Examples	Typical Applications
Land use (or activity at the land use)	Acreage of land used, square feet of building floor area "light industrial park," "office," etc.	Simple trip rates or linear regression models
Employment by (major) industry	"Manufacturing," "construction," "agriculture," etc.	Simple trip rates or linear regression models
Economic output	"Annual sales," "revenue," "value of shipments," etc.	Commodity flow models
Non-highway modal activity at intermodal terminals (rail, port)	Number of import/export container moves, TEU	Special generator models using simple trip rates or regression models.

Note: TEU = twenty-foot equivalent unit.

attraction, there is considerable debate as to the effectiveness of these variables in estimating truck trip production. The source of this concern can be traced to industrial production function and factor productivity issues and is most clearly illustrated through discussion of the use of employment as a predictor of truck trips.

Each industry uses factor inputs differently to produce a unit of output, and the relationship between inputs and outputs is described in a production function. Labor, being a factor of production, is one of these inputs, and there is a distinct relationship between output and employment for each industry. If output is thought of as a measure of goods that need to be shipped from a place of production, then it is clearly related to truck trip generation and the relationship between employment and output is the basis for the relationship between employment and truck trips. Economic data clearly demonstrate that labor productivity varies substantially from industry to industry. Therefore, if employment is to be used to estimate truck trip generation, the industry/land-use categories may need to be very disaggregate in order to produce accurate results. This problem may even exist from business to business within a particular industry. It is well-documented that some production processes exhibit economies of scale. In these cases we would expect to see different truck trip generation rates per employee for large businesses than for small businesses.

A final problem with employment as a predictor of truck trips is that labor productivity for a given industry changes over time. A very significant issue for freight forecasting is that manufacturing employment in the United States over the last 20 years has remained relatively flat, while manufacturing output, and associated freight transportation demand, has experienced healthy growth (U.S. Bureau of the Census, *Commodity Flow Survey* 1999; U.S. Bureau of the Census, *Economic Census* 1999). Clearly, using a constant trip generation rate based on employment could result in a gross underestimation of future truck trips if productivity improvement is not taken into account. Commodity flow models attempt to circumvent this problem by using economic models of production and consumption of goods to estimate truck trips.

There is a new class of special generator models being developed that bears mention here, because the types of independent variables they use are somewhat unique. This type of model has seen the greatest recent application at container ports. In these models, truck trips through a port or intermodal terminal gate will be estimated as a function of the non-truck mode activity. For example, truck trips at a container port may be estimated as a function of import–export Twenty-Foot Equivalent Unit (TEU) throughputs on the wharfside. [TEU is a commonly accepted measure of container traffic and derives from the original containers used in ocean shipping, which were generally 20 feet long. Many modern containers actually measure 40 feet in length (Forty-Foot Equivalent Units or FEU). However, TEU is still the most widely used measure of container traffic at ports and intermodal terminals.] Several trip generation models of this type are described in more detail in the next chapter.

DATA COLLECTION

The next chapter of this report describes some of the major sources reporting truck trip generation rates and data. The processes by which these data have been and continue to be collected raise a number of important issues about truck trip generation data. The three most widely used data collection techniques for developing truck trip generation data are vehicle classification counts (both manual and automated), roadside intercept surveys, and travel diary surveys. Issues associated with each of these techniques are described here (Table 3).

Vehicle Classification Counts

Vehicle classification counts are widely used to develop truck trip generation data for specific land uses in transportation engineering applications. They are also used to estimate certain types of metropolitan and statewide models and to validate these models. Manual classification counts involve the direct observation of vehicles and classifying the vehicles as they are counted. Direct visual observation of the vehicles in question eliminates some of the ambiguity about truck classification that is often a problem with automated counts. For example, the number of axles, vehicle configuration (e.g., single unit versus combination), and body style (e.g., distinguishing between recreation vehicles and true trucks) are all aspects of truck classification that are best accomplished through visual observation.

Automatic vehicle classification can be accomplished with pneumatic tube counters or loop detectors, although the accuracy of certain aspects of the vehicle classification is compromised. The ability to capture these classification characteristics accurately plays a significant role in estimating trip generation rates.

Another important issue associated with using vehicle classification counts to estimate truck trip generation rates is ensuring that the counts are taken in locations that accurately capture all of the truck traffic associated with the site of interest. When counts are used to establish rates at a special generator site for transportation engineering applications, this is most easily accomplished by conducting driveway counts at all points of entry or egress from the site. When accomplished properly, the results will be reasonably accurate. As the site gets larger and involves

TABLE 3
TRUCK TRIP GENERATION DATA COLLECTION METHODS

Method	Characteristics
Vehicle classification counts	• Used most frequently for trip rates to support engineering analysis • Manual counts provide more flexibility in setting classification categories and may eliminate some ambiguity • Automatic counts may be less expensive, but accuracy of equipment is a concern • Count locations must be chosen to capture all relevant traffic, but to eliminate background traffic • All traffic can be counted
Roadside intercept surveys	• Usually involves sampling • Locations must be selected where traffic can be safely intercepted • Data on land-use characteristics and trip purpose can also be collected and correlated with trip generation • Payload factors, day-of-week distributions, and time-of-day distributions can be collected for commodity flow models • Expansion of partial day data to 24-hour trip rates is an issue
Travel diary surveys	• Used most frequently to support travel demand models • Good sampling frames with complete truck population are often unavailable • Expansion of data must account for out-of-service vehicles • Underreporting of trips is a problem • Truck trip diary surveys have very low response rates and may be subject to non-response bias

internal circulation, as it may in an industrial park or airport, this type of data collection can become more difficult.

Roadside Intercept Surveys

Roadside intercept surveys are often used to develop truck trip generation data for metropolitan and statewide models. Intercept surveys have many of the benefits of vehicle classification counts (if appropriate sites can be identified) and are often conducted simultaneously with classification counts. The advantage of the intercept survey is that it can be used to collect trip information that can be used in other aspects of metropolitan modeling. The primary problem associated with intercept surveys is that they are difficult and costly to conduct, and it is frequently impossible to find locations where traffic can be properly intercepted. This is the reason why they are most often used to estimate trip generation for trips that have at least one trip end external to the region (intercept surveys are often easier to conduct at regional boundaries).

Drivers are asked about their trip origin–destination and characteristics at the internal trip ends that can be related to socioeconomic or land-use variables for trip generation estimation. The general approach is to expand the survey data to external cordon counts (counts taken at regional boundaries) and use this as a production rate. Internal attraction rates can then be estimated with the expanded trip data using the trip rate or regression model techniques described previously. Data about truck classification and trip purpose can also be collected to allow for the estimation of more disaggregate trip rates. These data are also often used to develop average payload factors, day-of-the-week distributions of trips, and time-of-day distributions for use in commodity flow models.

There are a host of issues that need to be addressed with regard to how trip data from roadside intercept surveys are expanded, especially if these data are only collected for a portion of the day and need to be expanded to 24-hour trip generation rates. Some examples of these issues include how to account for seasonal and day-of-the-week variation in trip generation and how to adjust the control totals to account for periods of the day during which surveys were not being conducted.

Travel Diary Surveys

Travel diary surveys are the approach to data collection most frequently used to estimate internal trip generation rates in subregional, metropolitan, and statewide truck travel demand models. The basic approach is to select a sample of registered trucks or businesses and to obtain 24-hour travel diaries from truck drivers. The drivers are asked to record information such as origin, destination, trip mileage and duration, trip time of day, land use at trip end, and activity at trip end. The survey data are then expanded based on the percentage of the vehicle population sampled (often stratified sampling or expansion is conducted) and the data are used to estimate trip rates (by taking the expanded trip end totals by land-use category and dividing by the appropriate independent variable) or to estimate regression models (by regressing expanded trips by super district against appropriate independent variable values).

There are numerous issues and problems associated with travel diaries. Sampling can be extremely complex because of the lack of good sampling frames (i.e., complete lists with names, addresses, phone numbers, and points of contact for the vehicles to be surveyed). Sampling from the vehicle population is best accomplished by using vehicle registration records. In the case of trucks, this can be a significant source of error, because trucks making internal trips in a region may include a very high proportion of vehicles that are not registered within the region. This affects the computation of the sampling fraction and the expansion of the data and may be one of the single greatest contributing factors to the low trip generation rates that often result from this approach. It is also very important to account for trucks that are not in use on the survey day, because most studies have found that a very high percentage of the truck fleet will not be in service on any given day. Underreporting of trips is always a factor in trip diary surveys and truck travel surveys are no exception.

Perhaps the biggest problem associated with truck travel diary surveys is low response rate. Truck owners often refuse to participate in travel diary surveys citing the interruptions of a driver's workday and the potential to reveal confidential customer information. Because participation in travel diary surveys is usually voluntary, low response rates raise questions about survey bias that must be addressed in reviewing and comparing the rates developed using this technique.

In the future, the application of Intelligent Transportation Systems may create new data sources that overcome the deficiencies of current sources. Weigh-In-Motion systems, global positioning systems for vehicle tracking, and video imaging systems are all examples of technologies that can be used to improve automated truck data collection. However, until these technologies are in wider use, their application to truck trip generation data will be limited.

In the next chapter, the sources of truck trip generation data are identified and discussed providing the basis for assessing the state of the practice in chapter 4.

CHAPTER THREE

REVIEW OF AVAILABLE DATA SOURCES

A major objective of this synthesis report was to identify and compile existing data sources that can be used for the estimation of truck trip generation. This chapter summarizes the information collected/identified and classifies it in the following categories:

- Compendia of Trip Generation Data—Identifies three sources in the literature search that included information from multiple sources of truck trip generation data.
- Engineering Studies—Describes data collected by private consultants or data vendors that have been used to estimate truck trip generation data for engineering applications.
- Special Generator Studies—Examines a study on transferability of trip generation rates data for special generators.
- Port and Intermodal Terminal Data Resources—Describes several of the more significant efforts currently underway that are looking at port truck trip generation.
- Vehicle-Based Travel Demand Models—Describes a number of important travel demand models that use vehicle-based approaches. Truck trip generation data from these studies are included in this section.
- Commodity-Based Travel Demand Models—Summarizes specific studies and models that use commodity-based approaches to estimate truck trip generation rates.
- Other Critical Data Resources—Presents a number of data resources that, while not including truck trip generation data themselves, are useful in estimating truck trip generation.

The following list provides a summary of the data sources presented in each of these categories. The data sources described in this chapter were identified in the literature review and in the survey of practitioners. In cases where the data can be found in a report or study, the reference information is provided. In cases where the study was identified in the survey of practitioners and reports were not identified, only the name of the organization from which the data can be obtained is provided.

- **Compendia of Trip Generation Data**
  - *Trip Generation Handbook* (ITE 1998)
  - *Quick Response Freight Manual* (Cambridge Systematics et al. 1996)
  - *Characteristics of Urban Freight Systems* (Wegmann et al. 1995)

- **Engineering Studies**
  - *Trip Generation Rates, Peaking Characteristics, and Vehicle Mix Characteristics of Special West Virginia Generators* (French et al. 2000)
  - *Trip Generation Study for T.M. Lee Warehouse Distribution Center Development* (Lancaster Engineering 1998)
  - *Trip Generation Study for Rail-Oriented Industrial Complex* (DeShazo, Tang & Associates 2000)
  - *West Hayden Island* (Parametrix 1999)

- **Special Generator Studies**
  - "Transferability of Trip Generation Rates for Selected Special Generators" (McKinstry and Nungesser 1991)

- **Ports and Intermodal Terminal Data Sources**
  - "Truck Trip Generation Models for Seaports with Container and Trailer Operation" (Al-Deek et al. 2000)
  - "Intermodal Container Ports: Application of Automatic Vehicle Classification System for Collecting Trip Generation Data" (Guha and Walton 1993)
  - Port of Long Beach Transportation Master Plan Model (under development by Meyer, Mohaddes Associates)
  - Survey of Truck Issues at Port of New York (underway at The City College of New York)
  - *Truck Trip Generation at Intermodal Facilities in the Delaware Valley Region* (DVRPC 2000)

- **Vehicle-Based Travel Demand Models**
  - "Development of Urban Commercial Vehicle Travel Model and Heavy Duty Emissions Model for Atlanta Region" (Thornton et al. 1998)
  - "Development of a Statewide Truck-Travel Demand Model with Limited Origin-Destination Survey Data" (Park and Smith 1996)
  - "Truck Travel in the San Francisco Bay Area" (Schlappi et al. 1993)
  - Chicago Area Transportation Study (1986)
  - Maricopa Association of Governments Model (1992)

- Greater Buffalo–Niagara Regional Transportation Council Goods Movement Study (1999)
- Southern California Association of Governments (SCAG) Heavy Duty-Truck Model and VMT Estimation (1999)
- Bangor Area Comprehensive Transportation System (BACTS) Truck Route Study (1998)
- Lower Mainland Truck Freight Study (2000)
- Denver Regional Council of Governments Regional Travel Demand Model (underway)
- Ohio Department of Transportation—trip generation data for statewide and regional travel demand modeling
- North Carolina Department of Transportation—trip generation data for regional models

- **Commodity-Based Travel Demand Models**
  - "Skagit Countywide Air, Rail, Water, and Port Transportation System Study" (Sorensen et al. 1996)
  - "Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems" (Krishnan and Hancock 1998)
  - "Development of a Statewide Truck Trip Forecasting Model Based on Commodity Flows and Input-Output Coefficients" (Sorratini and Smith 2000)
  - "Assessment of Market Demand for Cross-Harbor Rail Freight Service in the New York Metropolitan Region" (Cutler et al. 2000)
  - "External Urban Truck Trips Based on Commodity Flows: A Model" (Fischer et al. 2000)
  - Indiana Department of Transportation Statewide Truck Trip Model (1997)
  - *Multimodal Freight Forecasts for Wisconsin* (Wilbur Smith Associates in association with Reebie Associates 1996)
  - *Analysis of Freight Movements in the Puget Sound Region* (SAIC 1997)
  - *Portland, Oregon Commodity Flow Tactical Model System: Functional Specifications* (Cambridge Systematics 1998)
  - Michigan Statewide Truck Travel Model (1998)
  - New South Wales, Australia, Commercial Vehicle Model (1999)
  - Connecticut Department of Transportation Statewide and Corridor Studies
  - Kentucky Department of Transportation Statewide Truck Model
  - Kansas Statewide Agricultural Commodity Model

- **Other Critical Data Resources**
  - Vehicle Inventory and Use Survey (VIUS), U.S. Department of the Census
  - Highway Performance Monitoring System (HPMS), Federal Highway Administration
  - Commodity Flow Survey (CFS), U.S. Department of the Census and Bureau of Transportation Statistics
  - Transearch Database, Reebie Associates

Appendix C provides summary tables of trip generation rates and equations developed in many of these studies. As will be discussed in the next chapter, the variety of approaches to estimating truck trip generation rates makes it difficult to compare these rates and equations. In addition, the reported data often provide little detail on the statistical validity of the results. Therefore, no attempt is made to assess the quality of these data.

COMPENDIA OF TRIP GENERATION DATA

The following three significant sources of truck trip generation data were identified in the literature review:

- *Trip Generation Handbook* (Institute of Transportation Engineers 1998).
- *Quick Response Freight Manual* (Cambridge Systematics et al. 1996).
- *Characteristics of Urban Freight Systems* (Wegmann et al. 1995).

The ITE *Trip Generation Handbook* provides guidelines for the preparation and application of trip generation data for a wide range of land-use categories to be used in traffic impact studies and other transportation engineering applications. The *Handbook* is used in conjunction with another ITE publication, *Trip Generation* (1997), which provides actual trip generation rate data. In general, the trip generation data provided in *Trip Generation* are total vehicle rates that purport to include trucks; however, specific truck trip generation rates are only provided for truck terminal and industrial park uses, and these are based on very limited data. Appendix A of the *Handbook* is intended to provide information, but "not recommended practices, procedures, or guidelines," for engineers to use when estimating truck trip generation for particular sites.

The appendix also provides data from these other reports.

- *Urban Goods Movement: A Guide to Policy and Planning* (Ogden 1992).
- *Baltimore Truck Trip Attraction Study* (Reich et al. 1987).
- *Technical Memorandum No. 2: Truck/Taxi Travel Survey* (Gannett Fleming, Inc. 1993).
- *Truck Trip Generation Characteristics of Nonresidential Land Uses* (Tadi and Balbach 1994).
- *Urban Transportation Planning for Goods and Services: A Reference Guide* (Christiansen 1979).

TABLE 4
CHARACTERISTICS OF DATA FROM SELECTED SOURCES

Source	Location	Land Uses	Truck Types	Dependent Variable	Comments
Urban Goods Movement: A Guide to Policy and Planning (Ogden 1992)	Australia	• Office • Retail (regional center, major supermarket, local supermarket, department store, other) • Manufacturing • Warehouse • Light industry and high technology • Truck depots	• Courier vans • Light rigid trucks • Heavy rigid trucks • Articulated trucks	1,000 sq. ft. of gross leasable area	No information provided regarding sample size or statistical reliability.
Baltimore Truck Trip Attraction Study (Reich et al. 1987)	Baltimore, MD	• Prepared foods • Variety/pharmacy • Personal services • Office buildings • Soft retail • Retail food		Floor area	Suburban sites
Technical Memorandum No. 2: Truck/Taxi Travel Survey (Gannett Fleming 1993)	Tampa, FL	• Retail • Office • Light industrial	• Light trucks • Heavy trucks	Employment	12-hour rates only
Truck Trip Generation Characteristics of Nonresidential Land Uses (Tadi and Balbach 1994)	Fontana, CA	• Warehouse • Industrial • Industrial park • Truck terminal • Truck sales and leasing	• Number of axles	• Square footage • Acres	24-hour, morning peak hour, evening peak hour, site peak hour rates. In most cases based on three or fewer data points for each land-use category/truck category

- *Truck Terminal Trip Generation* (ITE Technical Council Committee 6A-46 1995).
- *Characteristics of Urban Freight Systems* (Wegmann et al. 1995).
- *Trip Generation Rates, Peaking Characteristics, and Vehicle Mix Characteristics of Special West Virginia Generators* (French and Eck 1998).

More detailed information about the characteristics of data contained in the first four of the aforementioned studies is summarized in Table 4. The Christiansen report is a classic work that contains some truck trip generation data; however, because these data may be somewhat dated, their use is limited in the current practice. The ITE Technical Council Committee report is useful for those engineers who may be looking for trip generation rates for truck terminals. Rates are provided as a function of terminal doors and employees and were based on contacts with 19 companies. More detailed descriptions of the data in Wegmann et al. and French and Eck are provided later in this chapter.

The trip generation data reported in the *ITE Handbook* (1998) are summarized in Appendix C, Tables C-1A–C-1G of this synthesis report. In presenting these data, ITE provides the following cautions:

- The data are based on inconsistent definitions of trucks,
- The data are based on inconsistent definitions of truck trips,
- Much of the data are out of date,
- The land-use categories for which the rates are calculated are too broad, and
- The independent variables used to calculate the rates need to be enhanced.

The FHWA developed the *Quick Response Freight Manual* (1996) so that a simple resource for conducting freight analysis would be available to states and MPOs that were getting involved in freight studies with the advent of the ISTEA. The manual describes methodologies for developing freight models, truck models, and site impact studies. Appendix D of the *Quick Response Freight Manual* provides a comprehensive summary of truck trip generation rates and regression equations from various other studies. Although the rates reported are quite extensive, the sources they are derived from are limited and include:

- The Maricopa Association of Governments' (Phoenix, Ariz.) truck model, *Development of an Urban*

Truck Travel Model for the Phoenix Metropolitan Area (Ruiter and Cambridge Systematics 1992).
- Data reported in *Characteristics of Urban Freight Systems* (Wegmann et al. 1995).
- Data reported in *Analysis of Freight Movements in the Puget Sound Region* (SAIC and Harvey Consultants 1997).
- Trip generation rates developed for analysis of the Central Artery Project in Boston, Mass. (no citation given).

These data are also presented in Appendix C-3 (*Quick Response Freight Manual*) of this synthesis report. A more detailed description of these reports is presented later in this chapter.

Characteristics of Urban Freight Systems (Wegmann et al. 1995) was developed to support urban goods movement and freight planning by states and MPOs in response to ISTEA. The document was designed as a compilation of current data from a variety of sources. *Characteristics of Urban Freight Systems* includes a chapter on truck trip rates drawn from a variety of sources including the following:

- *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area* (Ruiter and Cambridge Systematics 1992).
- *Trucking in Greater Vancouver: Demand Forecast and Policy Implications,* Transport 2021 Technical Report 7 (Greater Vancouver Regional District and Province of British Columbia 1993).
- *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts* (Habib 1981).
- "Analysis of Truck Deliveries in a Small Business District" (Aherns et al. 1977).
- "Service and Supply Trips at Federal Institutions in Washington, D.C. Area" (Spielberg and Smith 1977).
- *Baltimore Truck Trip Attraction Study* (Reich et al. 1987)—This study is also cited in the ITE *Trip Generation Handbook*.
- *Technical Memorandum No. 2: Truck/Taxi Travel Survey* (Gannett Fleming, Inc. 1993)—This study is also cited in the ITE *Trip Generation Handbook*.
- A survey of an industrial park in Brooklyn, N.Y., and a cargo area at John F. Kennedy International Airport conducted for the New York Metropolitan Transportation Council.
- *Truck Trip Generation Characteristics of Nonresidential Land Uses* (Tadi and Balbach 1994)—This study is also cited in the ITE *Trip Generation Handbook.*
- *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements* (Brogan and Heathington 1977)—These data are also used in the *Quick Response Freight Manual*.

Characteristics of Urban Freight Systems makes no effort to evaluate the data presented and no effort is made to assess the quality of the data. In addition, most of the references are dated and very little information is provided about the studies from which the data are cited. Table 5 summarizes the types of data found in the sources presented in *Characteristics of Urban Freight Systems*.

ENGINEERING STUDIES

Private transportation engineering and transportation planning consultants have on occasion conducted truck trip generation studies as part of larger traffic studies for private developers. These have not been compiled and/or published in any systematic format and are therefore not generally available to others. The transportation engineering literature does not report much of these data and ITE has not yet conducted a survey of existing data from among its membership. Several consultants did provide information from truck trip generation studies as part of the survey effort conducted for this synthesis project. Other private consultants were reluctant to provide data due to confidentiality agreements with clients.

Another source of truck trip generation data that was not tapped effectively for this synthesis was data from traffic impact studies and permitting required by cities. Although a few cities were contacted for the survey, it was beyond the scope of this study to conduct the type of comprehensive survey of cities that would have been necessary to report this source of data.

Sources of trip generation data from engineering studies are presented below and summarized in Table 6.

Trip Generation Rates, Peaking Characteristics, and Vehicle Mix Characteristics of Special West Virginia Generators (French et al. 2000)—This study is one of the few studies conducted by state or local government agencies in which trip generation rates were estimated for specific special generator land-use categories to be used in traffic studies. The data collection methodologies were selected to be comparable to those reported in the ITE *Trip Generation Manual*, focusing primarily on the collection of vehicle classification count data. Only three of the special generator categories had appreciable truck percentages (light industrial parks, poultry-related facilities, and timber processing facilities). Trip rates are provided in Appendix C, Section C-9.

Trip Generation Study for T.M. Lee Warehouse Distribution Center Development Proposed for N. Ramsey Boulevard in the Rivergate area of Portland, OR (Lancaster Engineering 1998)—Local regulations allow developers to apply for alternative System Development Charges if

TABLE 5
CHARACTERISTICS OF DATA FROM SELECTED SOURCES IN THE *CHARACTERISTICS OF URBAN FREIGHT SYSTEMS*

Source	Location	Land Uses	Truck Types	Dependent Variable	Comments
Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area (Ruiter and Cambridge Systematics 1992)	Phoenix, AZ	• Office • Retail • Industrial • Government • Households • Other businesses	0–8,000 lb 8,001–28,000 lb 28,001–64,000 lb >64,000 lb	• Employment • Households	
Trucking in Greater Vancouver (GVRD and Province of British Columbia 1993)	Vancouver, BC	Light Trucks • Wholesale • Non-wholesale • Households Heavy Trucks • Wholesale • Manufacturing	4,500–20,000 kg >20,000 kg	• Employment • Population	Regression models for each truck size
Curbside Pickup and Delivery Operations and Arterial Traffic Impacts (Habib 1981)		• CBD office • CBD residential • CBD light industry and warehousing • CBD hotels • CBD retail and service • CBD foods (retail and prepared)		• Floor area • Dwelling units • Employment • Rental units	Regression models. Information also provided for shipment sizes, temporal pick-up and delivery patterns, and vehicle dwell times.
"Service and Supply Trips at Federal Institutions in Washington, D.C. Area" (Spielberg and Smith 1977)	Washington, D.C.	• Government offices		• Floor area • Employment	
New York Metropolitan Transportation Council (no citation)	Brooklyn, NY	• Manufacturing • Distribution • Food preparation • Trucking • Retail • Couriers • Forwarders • Brokers		• Employment	A study conducted at an industrial park in Brooklyn and a cargo area at JFK International Airport.
An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements (Brogan and Heathington 1977)	Knoxville, TN Modesto, CA Rochester, NY Saginaw, MI	• Wholesale grocery • Wholesale hardware • Retail general merchandise • Retail apparel and accessories • Retail furniture		• Floor area • Employment	Unpublished doctoral dissertation

Note: GVRD = Greater Vancouver Regional District; CBD = Central Business District.

they can demonstrate that the proposed development has trip generation characteristics similar to other developments for which traffic data can be collected. Vehicle classification counts were conducted for automobiles, single-unit trucks, and tractor-trailers. Data for combined total truck trip generation rates are reported in Appendix C, Section C-11.

Trip Generation Study for Rail-Oriented Industrial Complex (DeShazo, Tang & Associates, Inc. 2000)—The engineers in this study believed that because the facility was rail-oriented, it might have significantly lower trip generation rates than a standard industrial park as reported in the ITE manual. Vehicle classification count data were collected at two comparable facilities in Fort Worth. Data from the study are presented in Appendix C, Section C-12.

West Hayden Island, Portland, Oregon (Parametrix 1999)—This study was conducted to estimate site traffic impacts from a new auto distribution terminal facility at

TABLE 6
CHARACTERISTICS OF DATA FROM ENGINEERING STUDIES

Source	Location	Land Uses	Truck Types	Dependent Variable	Comments
Trip Generation Rates, Peaking Characteristics, and Vehicle Mix Characteristics of Special West Virginia Generators (French et al. 2000)	West Virginia	• Light industrial parks • Poultry-related facilities • Timber processing facilities		• Employment • Site acreage • Gross floor area	Estimated total vehicle trip rates and then provided truck trip percentage.
Trip Generation Study for T.M. Lee Warehouse Distribution Center Development (Lancaster Engineering 1998)	Portland, OR	• Warehouse distribution center	• Single-unit trucks • Tractor-trailers	• Employment	Calculated peak and off-peak rates for inbound and outbound traffic. Trip rates were significantly lower than those reported for comparable land uses in the ITE manual.
Trip Generation Study for Rail-Oriented Industrial Complex (DeShazo, Tang & Associates, Inc. 2000)	Fort Worth, TX	• Rail-oriented industrial park		• Floor area	Rates were calculated for AM and PM peak hours on adjacent streets and midday and afternoon site-related peak. Trip rates were significantly lower than ITE rates for industrial parks and light industrial land uses
West Hayden Island (Parametrix 1999)	Portland, OR	• Port-related automobile distribution terminal		• Cargo throughput	

the port of Portland. Estimates of trip generation rates were made based on data from two existing terminals and these were used to estimate trip generation given probable cargo throughput at the new facility. The trip rates presented in this study are difficult to apply because of insufficient background data explaining how they were derived.

SPECIAL GENERATOR STUDIES

"Transferability of Trip Generation Rates for Selected Special Generators" (McKinstry and Nungesser 1991)—The surveys conducted for this study included household, workplace, commercial truck, external, and special generators. The purpose of the special generator survey was to provide information on those unique land uses with special trip generating characteristics not adequately reflected by normal trip attraction rates. This paper investigates the transferability of the special generator rates by comparing the 1990 trip generation rates for two areas in Texas, as well as rates from other published sources. The foundation for comparing rates and assessing the transferability begins with the methodology and data gathered in the surveying process. A brief outline of the survey design is included. All rates referred to in this paper are total trip rates or rates by trip ends.

PORT AND INTERMODAL TERMINAL DATA RESOURCES

Trip generation models for ports and intermodal terminals are presented as a separate category of data source because considerable effort over the last several years has been devoted to estimating port/intermodal models. Five port/intermodal trip generation studies are discussed in detail here.

"Truck Trip Generation Models for Seaports with Container and Trailer Operation" (Al-Deek et al. 2000)—This paper describes the development of trip production and attraction models for the port of Miami. Data provided by the port on loaded freight trucks and import/export freight units (containers, trailers, etc.) were used to develop simple regression models. A key feature of the research was determining how to group days of the week for import/export activity and inbound/outbound trucking volumes for the regression analysis. Use of the models contained in this paper for forecasting requires an exogenous trade forecast of import/export freight units moving through a port.

"Intermodal Container Ports: Application of Automatic Vehicle Classification System for Collecting Trip Generation Data" (Guha and Walton 1983)—The results of a case study of a container port (Houston's Barbours Cut) are reported, and the impact of existing container port operations on urban infrastructure and mobility is addressed. The application of an automatic vehicle classification system used to collect the necessary traffic data is presented. Commercially available photoelectric sensors were used to collect traffic volume and classification data over a period of 7 days. The data collection procedures provide quantitative information on the traffic characteristics of the container port. Mathematical models were then developed to forecast travel demand for use in planning and designing transportation facilities. The results of the analysis provide trip generation rates for both average weekday and peak hour of generator, and they show the variation in traffic demand by vehicle types. The trip rates calculated were consistent with the ITE trip generation rates. The other interesting finding is that only 30 percent of the total traffic were container trucks; the remaining traffic consisted of two- or three-axle vehicles.

The Port of Long Beach Transportation Master Plan Model, under development by Meyer, Mohaddes Associates (Information obtained from survey. No paper/report citations available)—This project is an attempt to build a state-of-the-art port model. The port of Long Beach and Meyer, Mohaddes collected extensive data on truck movements from terminals at the port, conducted origin–destination surveys at intercept locations, and collected information about container and commodity movements. The trip generation model uses information about terminal gate moves and cargo volumes to estimate truck trips. Model results are now available.

Survey of the Port of New York, City College of New York (Information obtained from survey. No paper/report citations available)—The City College of New York is conducting a major survey of the port of New York to develop an understanding of truck movements and truck access issues. At the time this synthesis report was written, the study was just getting underway and no results were available.

Truck Trip Generation at Intermodal Facilities in the Delaware Valley Region (Delaware Valley Regional Planning Commission 2000)—In this study, the Delaware Valley Regional Planning Commission gathered data, performed statistical analyses, and identified formulae and rates for estimating daily truck trips at port and rail terminal facilities in the region using data supplied by facility owners/operators. Twenty-nine intermodal port and rail/truck terminal facilities were surveyed to obtain information on facility attributes (acreage, building size, employment, operating days, etc.), truck trips generated and classification (single-unit or combination vehicles), interconnecting mode(s) and activity levels (ship arrivals, rail car arrivals, etc.), and commodity activity (TEU, number of lifts, tonnage). A simple linear regression for all facilities was calculated as

$$\text{Total Truck Trips/Day} = (2.62 \times \text{Acres}) + 40$$

The adjusted R^2 value was 0.56 with a standard error of approximately ±37 truck trips. The corresponding trip rate was 3.08 trips/acre.

The simple linear regression for port trips was

$$\text{Total Truck Trips/Day} = (2.02 \times \text{Ship Arrivals/Year}) - 20$$

The adjusted R^2 value for this equation is 0.80 and the standard error is ±54 trips. The corresponding trip rate is 1.90 trips/ship arrival per year.

For rail terminals the simple linear regress equation was

$$\text{Total Truck Trips/Day} = (0.0095 \times \text{Rail Cars/Year}) + 24$$

The adjusted R^2 value for this equation was 0.50 and the standard error was ±31 truck trips. The trip rate is 0.0114 trip/rail car per year.

VEHICLE-BASED TRAVEL DEMAND MODELS

Table 7 summarizes sources of truck trip generation data found in vehicle-based travel demand models.

Chicago Area Transportation Study (Rawling and Reilly 1987)—The *CATS Commercial Vehicle Survey of 1986* was one of the most significant attempts at developing truck data for use in commercial vehicle travel demand modeling. Although the reports on the data collected and the model developed do not actually report trip generation rates, the data are available from CATS and the implicit trip generation rates used to estimate trips can be derived. Trip diaries were collected for both locally registered and out-of-state registered trucks. Data on land use/activity at trip ends were collected. After the trips were expanded, they were allocated to zones based on employment shares for industry groups that roughly matched the land-use categories.

Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area (Ruiter and Cambridge Systematics 1992)—The Maricopa Association of Governments (MAG) truck model represents another significant attempt to develop truck travel demand models for urban areas and is the basis for the *Quick Response Freight Manual*. The MAG internal trip model was developed using travel diaries for trucks registered in the Phoenix metropolitan area. A total of 606 diaries were collected for 3,402 trips. Land use at trip end was collected so that trip rates could be calculated. Linear regression models and land-use-based rates were estimated. Separate models were estimated for each truck weight class. The land-use-based rates had lower coefficients of variation than the regression models and included all variables, and thus were used as final rates. Initial rates are provided in Appendix C, Section C-5. Final rates were adjusted by a factor of 1.623 to get total vehicle miles traveled estimated by the model to agree with estimates developed from Highway Performance Monitoring System (HPMS) data. This adjustment accounts for the net effect of internal trips by all commercial vehicles versus those by vehicles registered in Maricopa County (the sampling frame) and of any underreporting or underestimation in any of the Phoenix models that affect the number of truck and non-truck vehicle trips.

"Truck Travel in the San Francisco Bay Area" (Schlappi et al. 1993)—This paper describes the development of a truck travel demand model for Alameda County in California. The model was developed during a study of congestion in the I-880 corridor and was used to understand how trucks contribute to this congestion. Trip generation models were separated between external trips and internal trips. A major innovation of this study was to estimate separate models for "garage-based" trips (from a dispatch facility to a delivery point and back in a single round trip) and "linked" trips (multistop runs). For garage-based trips, separate production and attraction equations were developed, whereas for linked trips productions equal attractions and a single trip end equation is calculated. Data were collected through a survey of businesses (for the internal model) and through external intercept surveys (for the external model). Businesses with trucking fleets were asked to complete trip diaries and the expanded data were aggregated by city and used to compute the trip generation equations. For garage-based productions, the equations were based on simple rates, where the expanded number of trips by land-use category in each city was divided by employment in the corresponding industry category. In the case of garage-based attractions and linked trips, regression equations were estimated using the same data as described previously. Different sets of independent variables were used in each equation (see Appendix C, Section C-6). The model results were recalibrated based on comparing assigned volumes with actual ground counts in an iterative process. These calibrations were quite substantial.

"Development of a Statewide Truck–Travel Demand Model with Limited Origin–Destination Survey Data" (Park and Smith 1996)—This paper reports on a simple statewide truck travel demand model for Wisconsin.

"Development of Urban Commercial Vehicle Travel Model and Heavy Duty Vehicle Emissions Model for Atlanta Region" (Thornton et al. 1998)—This paper reports on the results of a truck model developed in Atlanta. The same general approach as used in Phoenix was undertaken here. Data from this study are presented in Appendix C, Section C-4.

Bangor Area Comprehensive Transportation System (BACTS) Truck Route Study (Wilbur Smith Associates 1998)—The trip generation rates used in this study were based on those provided in the *Quick Response Freight Manual* with one significant enhancement. The BACTS study notes that employment is not the best independent variable for use in estimating trip generation rates. They suggest that employment-based rates need to be adjusted to account for industrial productivity gains (constant or declining employment can still result in increased production and shipment volumes). The productivity increases were derived from economic forecasts by the University of Southern Maine's Center for Business and Economic Research.

Greater Buffalo–Niagara Regional Transportation Council Goods Movement Study (Jack Faucett Associates 1999)—This study estimated truck trip generation rates in order to develop internal truck trip tables for a regional travel demand model. Jack Faucett Associates (JFA) used the same basic approach as was used in the MAG model. Trip diaries were collected from a sample of fleets and the data were expanded using data on vehicle registrations from the New York State Department of Motor Vehicles. Land use at each trip end was also collected.

Unlike the MAG model, JFA attempted to estimate the number of trucks registered in the region that were making internal trips (as a fraction of total trucks registered in the region) based on a survey of carriers, and this estimate was used to expand the data.

The internal truck trips were divided into three separate categories: parcel delivery trips, mail trips, and all other truck trips. Attempts were made to generate estimates for different weight classes, but insufficient data were available. Because the U.S. Postal Service provided data on all truck trips, no trip generation rates were developed for this type of truck trip. In the case of parcel delivery trips, data were available only for the largest carrier in the region. Trip rates were estimated for this carrier for trips to residences (trips per person) and trips to commercial/industrial establishments (trips per employee). In the case of all other truck trips, an attempt was made to estimate trip generation equations, but the coefficient of determination was so low in all possible models that this approach was abandoned. Ultimately, trip rates were estimated.

To validate the results of the trip table estimates, the internal trip tables were added to external trip tables previously estimated by the MPO, and these combined trip tables were assigned to a network and compared to screenline counts. The validated data showed that the trip

TABLE 7
CHARACTERISTICS OF DATA IN VEHICLE-BASED MODELS

Source	Location	Land Uses/Industries	Truck Types	Dependent Variable	Comments
"Chicago Area Transportation Study" (Rawling and Reilly 1986)	Chicago, IL	• Residential • Retail • Manufacturing • Terminal/warehouse • Public/government • Office/service • Construction • In-transit • Landfill • Agriculture • Other	• 0–8,000 lb • 8,001–28,000 lb • 28,001–64,000 lb • >64,000 lb		No trip rates are provided. Total regional trips were estimated for each category by expanding the survey data (trip diaries). Trips were allocated to TAZs based on employment for each industry type. Thus, there is an implied trip rate per employee.
Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area (Ruiter and Cambridge Systematics 1992)	Phoenix, AZ	• Office • Retail • Industrial • Government • Residential • Other industries	• 0–8,000 lb • 8,001–28,000 lb • 28,001–64,000 lb • >64,000 lb	• Employment • Households	Trip rates are only for trips with one trip end internal to the region. Trip diaries were used to collect data.
"Truck Travel in the San Francisco Bay Area" (Schlappi et al. 1993)	Alameda County, CA	• Manufacturing • Business services • Retail • Other	• 2-axle • 3-axle • 4+-axle	• Employment	Regression models for each truck type. Included separate models for linked and garage-based trips.
"Development of a Statewide Truck–Travel Demand Model with Limited Origin–Destination Survey Data" (Park and Smith 1996)	Wisconsin			• Population	Rates were calculated for both trip productions and attractions. Both internal and external trip rates were estimated.
"Development of Urban Commercial Vehicle Travel Demand Model and Heavy-Duty Vehicle Emissions Model for Atlanta Region" (Thornton et al. 1998)	Atlanta, GA	• Industrial • Retail • Office • Population	• Light (<8,000 lb) • Heavy (>8,000 lb)	• Employment • Population	Data collected with trip diaries in similar process as Phoenix. Data limitations made it impossible to provide for more disaggregate weight categorizations.
BACTS Truck Route Study (Wilbur Smith Associates 1998)	Bangor, ME	• Retail • Industrial/low commercial • Services/office/ institutional • Household	• Same as *Quick Response Freight Manual* (QRFM)	• Employment • Population	Applied QRFM rates, but adjusted the forecast to take into account changes in labor productivity.
Greater Buffalo–Niagara Regional Transportation Council Goods Movement Study (Jack Faucett Associates 1999)	Buffalo, NY	• Residential • Manufacturing • Retail • Wholesale • Other	• Parcel delivery • Non-parcel • U.S. Postal Service	• Employment • Population	Data from local parcel carrier and the postal service made it possible to calculate independent rates for these trips.

TABLE 7 *(Continued)*

Source	Location	Land Uses/Industries	Truck Types	Dependent Variable	Comments
Southern California Association of Governments (SCAG) Heavy-Duty Truck Model and VMT Estimation (Meyer Mohaddes et al. 1999)	Southern California	• Households • Agriculture/mining/ construction • Retail trade • Wholesale trade • Government • Manufacturing • Transportation • Services	• 8,500–14,000 lb • 14,001–33,000 lb • >33,000 lb	• Households • Employment	Collected data from shipper surveys and combined these rates with rates from Phoenix and Alameda County to cover all land-use categories.
Lower Mainland Truck Freight Study (Reid Crowther et al. 2000)	Vancouver, BC	• Households • Primary industries • Manufacturing • Construction • Transportation, communications, utilities • Wholesale • Retail • Finance, insurance, real estate, and business services • Education, health, and safety	• 4,500–20,000 kg • >20,000 kg	• Population • Employment	In addition to the internal trip model, special generator models were developed for ports, intermodal rail, and air cargo with trip generation a function of cargo volumes. An external model based on expanded origin–destination surveys did not include trip generation rates.
Denver Regional Council of Governments (in progress)	Denver, CO				Model development in progress based on major trip diary survey, intercept survey, and classification counts. Trip rates will be calculated as a function of socioeconomic data.
Ohio DOT (no citation)	Ohio			• Employment	
North Carolina DOT (no citation)	North Carolina			• Employment	

rates overestimated actual trips. A 10 percent reduction factor was used in the final model. Final trip rates are presented in Appendix C, Section C-8.

Southern California Association of Governments (SCAG) Heavy Duty Truck Model and VMT Estimation (Meyer, Mohaddes Associates et al. 1999)—The SCAG truck model consists of an external, commodity-based model (described in the next section of this chapter) and an internal, vehicle-based model. Rates were developed for three truck weight classes that correspond to categories in the California emissions models. Initially, rates were estimated separately for inbound shipments and outbound shipments. These estimates were then balanced and converted to production and attraction rates for use in the model. Trip rates are presented in Appendix C, Section C-7.

Lower Mainland Truck Freight Study, Draft (Reid Crowther et al. 2000)—This multi-client study developed a new truck travel demand model for the Greater Vancouver region in British Columbia. Trip rates are presented in Appendix C, Section C-10.

Denver Regional Council of Governments (DRCOG) (Information obtained from survey. No report/paper citation available)—DRCOG is in the process of preparing an update to their regional travel demand model that will include a truck model. Data were collected through a combination of trip diaries, intercept surveys, and automatic vehicle counts. Trip rates are being calculated as a function of economic data.

Ohio Department of Transportation (ODOT) (Information obtained from survey. No report/paper citation

TABLE 8
CHARACTERISTICS OF DATA IN COMMODITY-BASED MODELS

Source	Location	Method of Converting Tonnage to Truck Trips	Method of Allocating Truck Trips to Zones	Source of Commodity Flow Data	Comments
"Skagit Countywide Air, Rail, Water, and Port Transportation System Study" (Sorensen et al. 1996)	Skagit County, WA	Survey of 100 businesses conducted to estimate average truck payloads. Payload factors used to convert commodity tons to truck trips.	County-to-county flows allocated to zonal level based on employment shares.	Local economic data and surveys	Commodity flows aggregated to industrial, trade, and agriculture categories for disaggregation to zonal.
"Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems" (Krishnan and Hancock 1998)	Massachusetts	Tonnage flows converted to truck trips by truck category using locally collected data on commodity density, average payloads, and average percent empty by truck type (from HPMS).	Statewide flows allocated to five-digit zip code level using employment shares.	1993 Commodity Flow Survey	Commodities aggregated to a single category when estimating total truck tonnage flows.
"Development of a Statewide Truck Trip Forecasting Model Based on Commodity Flows and Input-Output Coefficients" (Sorratini and Smith 2000)	Wisconsin	Average truck payload data from Reebie Transearch.	Commodity flows allocated to counties using employment share by producing economic sectors.	Commodity Flow Survey Reebie Transearch Data	Truck trips calculated for both trip productions and attractions. Attractions based on consumption calculated from input–output data.
"Assessment of Market Demand for Cross-Harbor Rail Freight Service in the New York Metropolitan Region" (Cutler et al. 2000)	New York metropolitan area	Payload factors developed from TIUS.		Reebie Transearch	Payloads, and average percent empty by truck type (from HPMS)
"External Urban Truck Trips Based on Commodity Flows: A Model" (Fischer et al. 2000)	Los Angeles metropolitan area	Truck payload data by commodity developed from local roadside intercept surveys.	Employment shares by producing and consuming sectors (input–output models used to define industry consumption shares by commodity).	Reebie/DRI-McGraw Hill	Annual trip rates converted to daily trips based on day of the week distributions of truck traffic from weigh-in-motion data. Trip generation by three truck weight classes. Allocation of truck commodity tonnage by truck weight classes using TIUS.
Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment: Phase 2 (Black 1997)	Indiana			1977 Commodity Transportation Survey 1993 Commodity Flow Survey	Commodity flow data and input–output models used to develop production and attraction trip generation regression models using employment in the appropriate industry sector as the independent variable. Payloads, and average percent empty by truck type (from HPMS)

TABLE 8 *(Continued)*

Source	Location	Method of Converting Tonnage to Truck Trips	Method of Allocating Truck Trips to Zones	Source of Commodity Flow Data	Comments
Multimodal Freight Forecasts for Wisconsin (Wilbur Smith et al. 1996)	Wisconsin	Assumes a 24-ton maximum cargo weight and percent full based on percent full of carload rail shipments from the Carload Waybill Sample.	State-to-state flows are disaggregated to BEA regions using employment shares.	Reebie Transearch	
Analysis of Freight Movements in the Puget Sound Region (SAIC and Harvey Consultants et al. 1997)	Seattle metropolitan area	All commodity flows converted to truckload equivalents assuming 40,000 lb per truckload.	County-to-county flows allocated to TAZs based on employment shares.	Outbound flows estimated from NIPA value-added coefficients (value added per employee), County-Business Patterns employment by industry, and SAIC's proprietary value-per-pound data for 5-digit STCC commodities. Retail flows estimated from national input–output table final demand vectors.	
Portland Commodity Flow Tactical Model System: Functional Specifications (Cambridge Systematics 1998)	Portland, OR	Locally collected payload factors.	Retail and non-retail commodity flows allocated to TAZs based on employment shares.	Reebie Transearch and customized economic forecasts by ICF Kaiser.	For LTL trips, multistop tour factors were estimated from truck counts near reload facilities.
New South Wales (no citation 1999)	Sydney, Australia	Payload data collected in a large commercial vehicle survey.	Establishment database provides employment by TAZ.	Regional input–output model and industrial establishment database. Commodity flows initially calculated in terms of dollar output and converted to tonnage flows using value-to weight-ratios collected in prior economic surveys.	
Connecticut DOT (no citation)	Connecticut	Truckload equivalents based on Reebie payload data.		Reebie Transearch	
Kentucky DOT (no citation)	Kentucky			Reebie Transearch	
Kansas DOT (no citation)	Kansas			Local agricultural production data	
Florida DOT (Cambridge Systematics 2001)	Florida	Payload data from VIUS; payloads by commodity by length of haul.	Developed tonnage production and attraction regression models using county level commodity data regressed against population and employment data.	Reebie Transearch	

available)—ODOT reports having developed truck trip generation data for both statewide and regional travel demand modeling. The data were collected primarily from intercept surveys. Trip generation equations were estimated with regression equations.

North Carolina Department of Transportation (Information obtained from survey. No report/paper citation available)—Barton Aschman developed truck trip generation data for regional models in North Carolina. The rates were developed primarily from trip diary surveys. Separate production and attraction rates were estimated by land-use/industry type.

COMMODITY-BASED TRAVEL DEMAND MODELS

Table 8 summarizes sources of truck trip generation data found in commodity-based models.

"Skagit Countywide Air, Rail, Water, and Port Transportation System Study" (Sorensen et al. 1996)—This paper reports on a commodity flow study of Skagit County, Washington, and presents a methodology for estimating truck flows based on commodity data. This is one of the few commodity-based trip generation studies that provides sufficient socioeconomic data for the computation of equivalent trip rates per 1,000 employees. These data are presented in Appendix C, Section C-2.

"Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems" (Krishnan and Hancock 1998)—This paper presents an approach to modeling statewide truck flows based on commodity flow data. Trip generation data are developed at the five-digit zip code level for the state of Massachusetts. The general procedures used for trip generation in this study are similar to those used in other studies based on commodity flows, although the specific commodity flow data and truck payload data are somewhat unique.

"Development of a Statewide Truck Trip Forecasting Model Based on Commodity Flows and Input-Output Coefficients" (Sorratini and Smith 2000)—This work builds on that of Park and Smith by creating a more complete commodity-based statewide truck trip model for Wisconsin. The model estimates trip productions and attractions from a combination of commodity flow data and economic input–output models. Consumption by economic sector was estimated using economic input–output models.

"Assessment of Market Demand for Cross-Harbor Rail Freight Service in the New York Metropolitan Region" (Cutler et al. 2000)—This paper describes an analysis of potential diversion of cross-harbor truck traffic to rail in the event that a new harbor rail freight tunnel is provided. Like most of the other commodity-based methodologies, the basic approach to trip generation was to use tonnage flows by commodity group and to translate these to truck trips using truck payload factors by commodity group.

"External Urban Truck Trips Based on Commodity Flows: A Model" (Fischer et al. 2000)—This paper describes the approach to modeling external truck trips in the recently developed regional heavy-duty truck travel demand model of SCAG. The SCAG truck model includes an internal trip generation and distribution model that uses procedures more akin to 4-step urban travel demand models (the trip generation data from this element of the model are described earlier in this chapter) while the external model is based on a commodity flow model. Two-digit Standard Transportation Commodity Classification (STCC) categories were used in the development of the model.

Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment: Phase 2 (Black 1997)—This is a statewide truck trip model that was originally developed for the Indiana DOT by Indiana University (Black 1997) and later incorporated by Cambridge Systematics in the Indiana Statewide Travel Demand Model. This is a commodity-based model that categorizes truck trips on the basis of payloads, and average percent empty by truck type (from HPMS) of 19 different commodity groups (based on the STCC system), mail (data from the postal service), and express mail (based on data from Federal Express). The initial trip generation equations are not mode specific. A set of mode split equations was developed based on the mode split for Indiana in the 1993 CFS. The mode shares were developed for different commodities and lengths of haul.

Multimodal Freight Forecasts for Wisconsin (Wilbur Smith Associates and Reebie Associates 1996)—This study, prepared by Wilbur Smith Associates in association with Reebie Associates, represents the culmination of a number of studies aimed at developing a statewide freight model based on commodity flow data and input–output economic modeling techniques. The study only looks at intercity truck trips. The starting point for the analysis was Reebie Transearch data. The approach to developing these data is to start with Census of Manufacturers value of shipment data. This is converted to tonnage based on value-to-weight ratios in Reebie's proprietary database and allocated to states of origin based on employment shares in producing industries. Modal share is determined by subtracting known modal tonnage from federal data sources. The residual is assumed to be truck. State-to-state flows are estimated using data obtained by Reebie from trucking firms in a data exchange program, as are the distribution of flows by sub-mode (e.g., truckload, less-than-truckload, and private trucking fleets). The commodity flows are further disaggregated to Business Economic Areas [multi-county aggregates developed by the U.S. Bureau of Economic Analysis (BEA)] using employment shares and the inbound commodity flows are developed using input–output coefficients. Secondary movements (distribution traffic primarily from wholesalers to retailers) are estimated based on information from the Reebie data exchange program. Nonmanufactured goods are added using production and consumption data developed locally. Conversion to truckloads was accomplished using a 24-ton maximum cargo weight for each truck and using the percentage of full carload ratios for each commodity from the Interstate Commerce Commission's (now Surface Transportation Board) Carload Waybill Sample data applied to truckloads. The Waybill sample provides data on a sample of rail moves in the United States. These data include the carload weights. By comparing average carload weights for each commodity group as compared to maximum carload weight a ratio was calculated and this ratio was applied to truck data to estimate payloads for each commodity when carried by a truck. Annual truckload equivalents were divided by 310 operating days to get daily truck trips. These were disaggregated to the county level based on employment shares. Empties were also added.

Because there is no direct calculation of trip generation rates, the methodology is perhaps the most useful piece of this study (see Fig. 3).

Analysis of Freight Movements in the Puget Sound Region (SAIC and Harvey Consultants 1997)—The truck trip generation rates developed in this study are reported in truckload equivalents (TLEs), although there appears to be some effort to convert these to actual truck trips. After calibration to truck counts, the resulting trip generation rates have been used for corridor studies in the Puget Sound Region. Four categories of truck trips are identified for estimating truck trip generation rates.

> Long haul—Trips into and out of an area with destinations more than 250 miles away from the origin. These truck trips are made primarily by for-hire motor carriers. Most of the outbound trips come from the manufacturing sector.
>
> Short haul—These trips move within approximately a 250-mile radius of the origin. A major source of these trips is wholesale to retail movements. They also include many trip chains returning to home base empty at the end of the day. This category also includes raw materials moving in local markets. Carriers are often private fleets with drivers domiciled at home or regional less-than-truckload/specialty carriers. The category also includes some movements of manufacturing inputs through wholesalers.
>
> Local Traffic—Such trips are primarily local delivery operations and are small shipments. This category includes some wholesale to retail movements and wholesale to local manufacturer movements. These are primarily linked trips and account for the preponderance of trips in a local area. It also includes service vehicles. In addition, this category includes the movement by truck from one mode to another (drayage).
>
> Through Traffic—Trips with both origin and destination outside the Puget Sound region.

To develop manufacturing truck flows, the consultant used industry-sector National Income and Product Account (NIPA) value-added coefficients (dollar value added per employee), as reported by the BEA, to represent the value of output from each economic sector, measured in dollars. These were divided by value-per-pound coefficients from proprietary data collected by SAIC/Transmode at the five-digit STCC level. This provided tonnage shipment rates (shipment tons per employee) by commodity. Rates were multiplied by U.S. Bureau of the Census County Business Patterns data (employment by industry sector for each county in the region) to get estimates of county level commodity flows.

Retail and wholesale flows were developed using the final demand vector of the national input–output tables (obtained from the BEA) to estimate the quantity of each commodity flowing to retail markets. The personal consumption component of the final demand vector represents the amount of each commodity consumed by end-users. Population shares by county/TAZ were then used to estimate flows by destinations (assuming that retail outlets are sited close to population centers and the relative consumption of retail goods is proportional to demand, measured in terms of the relative size of the consuming public).

After long-haul and short-haul trips are computed, local truck trips are derived from long-haul TLEs assuming four trucks per TLE (each at 10,000 lb) and multiplied by 12.75 stops per delivery vehicle. Apparently these trips were then used to compute trip rates by employment category, although none are explicitly reported.

Portland Commodity Flow Tactical Model System: Functional Specifications (Cambridge Systematics 1998)—The Portland commodity flow model is an all-modes freight model that includes a truck model. The truck model focuses on heavy trucks only. The Tactical Model uses commodity flow inputs from a Strategic Model. Commodity flows are estimated by mode in the Strategic Model. Because the original commodity flow estimates for truck trips distinguish truckload and less-than-truckload shipments, additional truck trips associated with multistop pickup and delivery tours were estimated for the less-than-

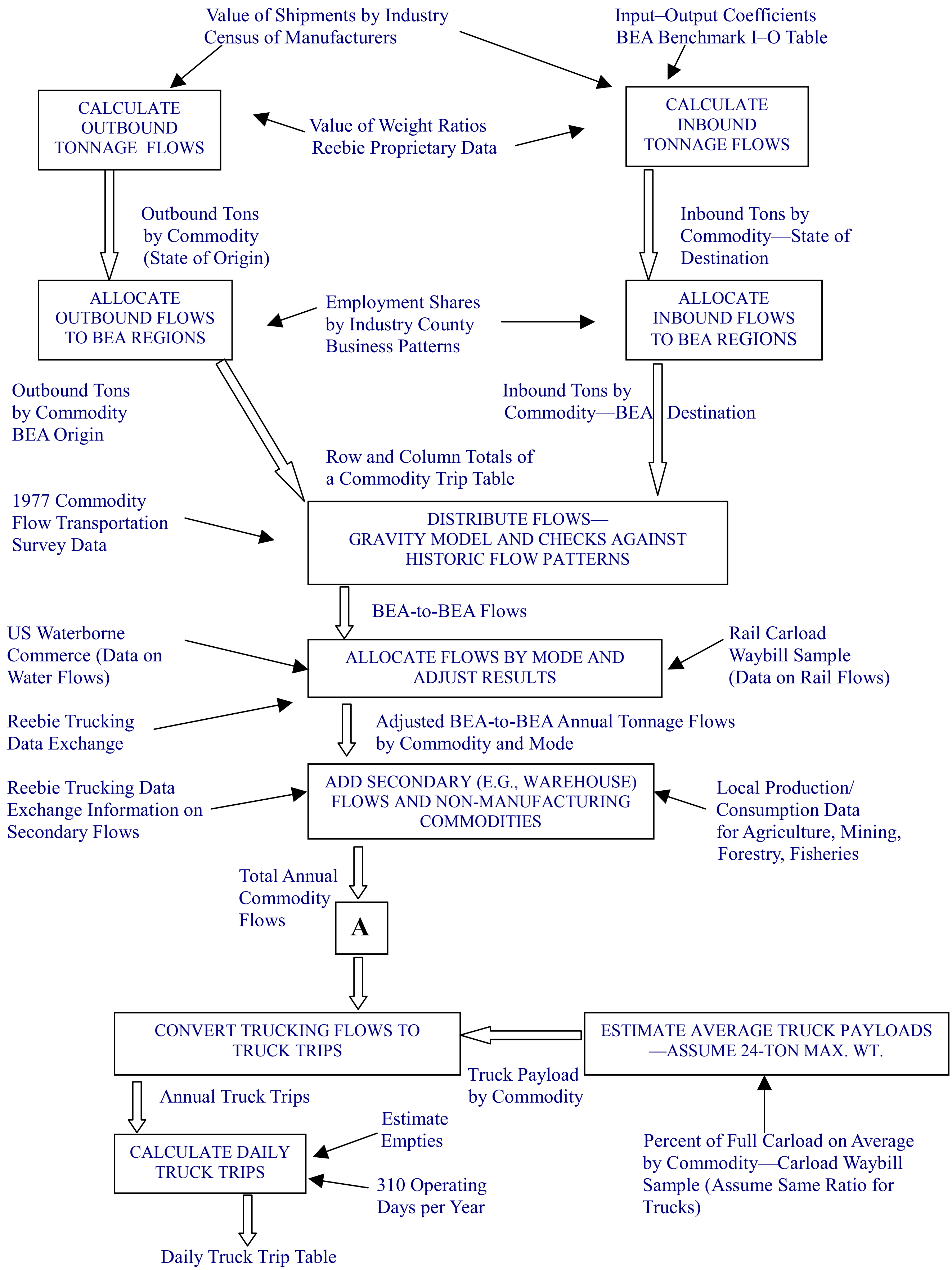

FIGURE 3 Multimodal freight forecast for Wisconsin.

truckload trips. Factors for these additional trips were estimated by comparing truck counts taken around truck terminals and truck reload facilities (e.g., warehouses) and truck trips generated from the commodity flow model. The ratio of the former to the latter was used to develop an adjustment factor.

The Second Generation Michigan Statewide Truck Travel Demand Forecasting Model, Draft for Review (Parsons Brinckerhoff Quade & Douglas 1998)—The model uses data from the 1993 CFS and applies employment data by producing industry to estimate trip productions. The CFS was then used to estimate trip destinations, and attraction rates were calculated by allocating the attractions to consuming industries using the national input–output tables and then dividing by employment in these industries to get attraction rates per employee. The trip rates could then be applied to forecasted employment data to estimate trip generation forecasts

New South Wales Australia 1999 (No publication cited. Information obtained through contacts with model developers)—New South Wales is in the process of developing a commercial vehicle model, the heavy truck component of which is based on commodity flow techniques.

Connecticut Department of Transportation (ConnDOT) (No publication cited. Information obtained in survey conducted for this project)—ConnDOT has done some statewide and corridor studies where truck trips were estimated from commodity flow data (truckload equivalents based on Reebie Transearch data).

Kentucky Department of Transportation (No publication cited. Information obtained in survey conducted for this project)—The Kentucky statewide truck model was developed by Wilbur Smith Associates and is a commodity-based model. Trip generation is embedded within the model and is not an explicit step in the modeling process. Reebie Transearch data are used for initial commodity flows. The commodity flow data are used to estimate an initial trip table that is used to seed a matrix estimation program, calibrated to truck traffic counts.

Kansas Department of Transportation (No publication cited. Information obtained in survey conducted for this project)—Kansas has developed a commodity-based truck model focused on the agricultural sectors.

Florida Department of Transportation (FDOT) (No publication cited. Information obtained from survey)—FDOT contracted with Cambridge Systematics to develop a commodity-based truck forecasting model for the state. The model focuses primarily on long-distance freight movements. The focus on commodity freight addresses the large trucks moving on the Florida Intrastate Highway System, the shipment of commodities between regions in Florida, and the shipment of freight between Florida and the rest of North America. The statewide commodity model does not address local delivery or service trucks, which are primarily regional in nature and are best modeled at the regional or the urban area level.

Trip generation for the base year in the model is developed from the Reebie Transearch database for Florida counties. Commodity flows within the state are provided with county level detail. More aggregate origin–destination regions are used outside of the state. Commodities in the Transearch database are aggregated to 14 basic commodity groupings. The VIUS is used to develop payload factors by commodity group and by length of haul groups, and these payload factors are applied to the tonnage flows to convert them to truck trips.

For the forecast years, the model calculated tonnage production and attraction rates. Production equations were calculated as a function of employment in the producing industry and in most cases a single industry was identified as the producing industry. Attraction equations are also generally a function of employment for a single consuming industry. The appropriate consuming industry was determined for each commodity using the Bureau of Economic Analysis' 1996 Input–Output tables. Using the county-level inbound and outbound tonnage data from the base year Transearch data and employment by industry sector for each county, regression equations were estimated for both productions and attractions for each commodity group. The production and attraction equations are applied at the TAZ level to estimate inbound and outbounding tonnage flows. The attraction tonnages by commodity group should be scaled to balance the production tonnages, including port tonnages developed separately.

The total tonnages by commodity are subsequently distributed among the origin–destination pairs, split among modes based on an incremental mode split, and truck tonnages are converted to trucks based on payload factors that vary by distance. Consequently, because of all of these additional steps, it is inappropriate to convert the trip generation rates directly to vehicle truck trips. The tonnage production and attraction equations are provided in Appendix C-13.

Oregon Department of Transportation (No publication cited. Information obtained in survey conducted for this project)—Oregon has a first generation, statewide, integrated land-use and transportation model. This model incorporates an input–output model of the Oregon economy and calculates truck trips based on estimates of monetary flows between each of 12 economic sectors and 122 zones. Yearly dollar flows are converted into average daily truck trips. The conversion factors were estimated from truck trip intercept survey data collected at five ports of entry in Oregon and truck survey data collected by the Washington DOT.

OTHER CRITICAL DATA SOURCES

Over the last few years, several efforts sponsored by the federal government have produced or compiled truck trip generation data, mostly for metropolitan and statewide travel demand modeling applications. The most significant of these efforts have been

- FHWA sponsorship of the *Quick Response Freight Manual* (1996) and the *Characteristics of Urban Freight Systems* report (1995), both of which contain compilations of previously developed truck trip generation rates.
- FHWA sponsorship of a Small Business Innovative Research project to develop freight destination choice, route choice, and mode choice models for state and MPO applications (being developed by JFA). Although the development of trip generation rates was not a specific requirement of this project, JFA has proposed a methodology that would include trip generation procedures based primarily on commodity flows (similar to methods used in the SCAG model) mixed with additional trip generation factors for reload (local distribution and delivery) and non-goods movement trips (approaches that may be based on more standard trip rate estimates developed from trip diary data collected in several modeling studies across the country). This project is still in the early stages of development and no trip generation data are yet available.

In addition, the federal government (again, primarily the FHWA) has sponsored or contributed to a number of regional truck modeling efforts that have included development of trip generation data.

The FHWA is currently sponsoring a major effort to develop national commodity flow data as part of a project entitled "Multi-Modal Freight Analysis Framework." The goal is to develop data and tools to analyze national freight movements and to assess their impacts on the national transportation network. A team of consultants including Reebie Associates, Batelle Memorial Institute, the WEFA Group, Wilbur Smith Associates, and Cambridge Systematics is developing county-to-county commodity flows and forecasts, assigning these to the highway network as trucking flows, and developing techniques for assessing freight carrying capacity on the national highway network. It is not clear the extent to which the detailed data underlying this analysis will be made available to practitioners outside the FHWA, but if some version of these data do become available, they will be extremely useful to those involved in commodity-based truck modeling.

The U.S. Bureau of the Census also produces a number of data sets that are important in the development of trip generation data. One area where these resources have proven particularly important is in the development of truck trip generation data from commodity flow analysis. Two principal sources of data are significant in this regard: the CFS and the VIUS (formerly TIUS). The former, along with Reebie Transearch data, is the most common source for basic commodity flow data by mode. VIUS/TIUS has been used as the principal source of truck payload data that are used to convert truck tonnage information into truck trips.

One area where private data sources have been important in the development of truck trip generation data is commodity flow and economic data sets. As noted in the descriptions of many of the state and regional modeling studies, Reebie Associates' Transearch database has provided the basic commodity flow data that many organizations have used to develop truck trip generation by commodity. The Reebie methodology has evolved over the last decade and now includes a wider range of commodities, a higher level of geographic detail for origins and destinations, and a more complete accounting of secondary truck movements (distribution traffic). The basic approach that Reebie uses to develop the Transearch data is to make use of a variety of public data sources including the Annual Survey of Manufacturers, the BEA benchmark input–output tables, the Surface Transportation Board's Rail Carload Waybill Sample (a sample of detailed information on rail shipments including tonnage and value by commodity and origin–destination information), the U.S. Army Corps of Engineers' Waterborne Commerce Data series (data on waterborne shipments by port with full commodity detail), and the U.S. Bureau of the Census' County Business Patterns (data on employment by industry at the county level) to derive the total freight flows and non-highway modal flows. This also provides an initial estimate of truck flows based on the residual from total commodity flows after all non-highway modes are accounted for. Reebie then uses data from a proprietary data exchange program with motor carriers to develop extensive data on truck movements, which provide information about the distribution of truck moves by type of carrier (truckload, less than truckload, and private), origin–destination, and truck payloads. This submodal detail for trucking has been used by a number of travel demand models to develop a more complete estimate of truck trips based on the type of carrier making the haul.

CHAPTER FOUR

CURRENT STATE OF THE PRACTICE

As the need to analyze truck movements and traffic patterns has grown, so has the need for good truck trip generation data. However, the state of the practice is still fairly primitive when compared with trip generation data/practices used in analyzing passenger vehicle movements. The variation in methodologies for estimating truck trip generation rates, in land-use categories, in truck classification categories, and in the rates themselves from one study to the next, suggest a still evolving practice. This evolution has also been somewhat uneven, with far more information available in the literature related to developing truck trip generation data and methodologies for statewide/metropolitan modeling than for transportation engineering applications. Given the unevenness of this evolution, the remainder of this chapter is presented as two separate discussions, one focusing on statewide/metropolitan modeling applications and the second focusing on transportation engineering applications.

Before presenting the two separate discussions, three tables (Tables 9–11) provide a summary of some of the main discussion matters in classifications of trip generating activities/trip purposes, independent variables and trip rates estimation approaches, and data issues. These issues cut across all applications of truck trip generation data and they present some of the major findings of this synthesis with respect to the state of the practice.

TABLE 9
TRIP GENERATING ACTIVITIES/TRIP PURPOSES

Trip Generating Activities/ Trip Purposes	Notes of Findings
Employment by industry (land use)	Variable categories may be too broad. Difficult to compare industry/land-use categories from one study to another.
Commodity carried	No explicit consideration of all reload and tour activities.
Truck size	GVW most commonly used. No uniformity in GVW cutoffs. Definition of production and attraction may be inconsistent.
Trip production vs. trip trip attraction (garage based vs. linked)	Definition of production and attraction may be inconsistent. Comparing production and attraction rates of different studies very difficult. Many statewide and regional models include special generators.
Special generators	Many statewide and regional models include special generators.
Overall	Lack of uniformity in classifications of trip generating activities/trip purposes.

TABLE 10
TRUCK TRIP RATE INDEPENDENT VARIABLES AND ESTIMATION TECHNIQUES

Estimation Techniques and Independent Variables	Notes of Findings
Vehicle-based models using simple trip rates approach and/or linear regression approach (employment, land use)	Employment data are often too aggregate. Limited accuracy when applied to small areas. Changing labor productivity implies rates per employee will be inconsistent over time.
Commodity-based models (commodity flows in tons)	Less accurate when disaggregating into smaller geographic areas. Most MPOs do not have own commodity data.

TABLE 11
COMMONLY USED DATA COLLECTION METHODS

Collection Methods	Notes of Findings
Travel diary surveys	Most commonly used in vehicle-based models. Subject to a self-selection bias of unknown magnitude. Low response rates. Difficulties in collecting data.
Intercept surveys and truck classification counts	More effective in collecting data for trip generation models. Often limited to small samples of counts. Commonly used for external trips, intercity trips and special generators.

STATEWIDE/METROPOLITAN MODELING

There has been much activity over the last 5–10 years in the development of truck trip generation modeling techniques for use in statewide and metropolitan travel demand models. These models have been used for a wide range of applications including statewide plan development, metropolitan plan development, project evaluation, corridor planning, and air quality analysis. In response to the survey conducted for this synthesis, state DOTs and MPOs most often cited statewide or metropolitan modeling as the reason that they collected or used truck trip generation data. In only one case did a state DOT (West Virginia) collect truck trip generation data for transportation engineering applications.

Types of Trip Generating Activities/Trip Purposes

The types of trip generating activities/trip purposes that are found in statewide and metropolitan planning applications are often tied directly to the approach used to model truck trips. The two principle approaches identified in this study are vehicle-based models and commodity-based models. The use of these two techniques seems to vary depending on whether the modeling application is statewide planning or metropolitan planning.

In most metropolitan planning applications of trip generation data, regional agencies need to account for all truck activity that occurs on major regional facilities (interstate, freeways, and principal arterials). Metropolitan travel demand modeling is also constrained to accepted methodologies due to regulatory requirements (primarily federal transportation planning and air quality regulations). As a result, most of the metropolitan truck trip generation models developed to date have been vehicle-based models that adhere to methodologies similar to those used in 4-step passenger models. A common approach for classifying trip-generating activities is to start with a separation of internal and external trips. This is because the economic activities that generate internal and external trips differ, the rates at which these trips are generated differ, and the types of equipment used differ. External trip models are most often simple expansions of external vehicle classification count data forecasted based on general traffic growth rate forecasts.

Internal vehicle-based models generally include trip generation rates based on land-use categories. Because most of the rates are functions of employment, the selection of land-use categories generally starts with the categories that correspond to the employment categories that are forecasted in regional small area economic models. From these categories, more aggregate categories may be selected to provide the best fits to the data. Examples of the different land-use/employment categories used in vehicle-based models are summarized in Table 12. More detailed categorizations of land use are generally impractical because the planning agencies involved do not have detailed land-use data and lack the data/techniques to forecast independent variables at higher levels of detail necessary. Because the definitions of these categories and the specific aggregations of different categories that appear in different models vary considerably from one model to another, it is very difficult to compare rates from one study to another. However, from the limited comparisons that have been made, the rates are highly variable from one region to another and may also vary within regions due to the highly aggregate categorization of trip generating activities.

The other alternative used to categorize trip generation activities is based on the commodity carried. Commodity-based trip generation models, because they use more disaggregate trip generation/commodity categories, are theoretically more appealing. However, because they do not include explicit consideration of all reload and tour activities,

TABLE 12
LAND-USE/EMPLOYMENT CATEGORIES USED IN VEHICLE-BASED MODELS (n = 12)

Land Use	Percent of Studies
Residential	58.3
Retail	66.7
Manufacturing	41.7
Terminal/warehouse	8.3
Public/government	25.0
Office/service	8.3
Construction	16.7
In-transit	8.3
Landfill	8.3
Agriculture	8.3
Office	16.7
Industrial	16.7
Business services	8.3
Industrial/low commercial	8.3
Services/office/institutional	8.3
Wholesale	25.0
Agriculture/mining/construction	8.3
Transportation	8.3
Services	8.3
Primary industries	8.3
Transportation/communications/utilities	8.3
FIRE and business services	8.3
Education, health, and safety	8.3
None given	33.3

Note: FIRE = finance, insurance, and real estate.

they may not produce the most accurate results in metropolitan area models. For studies that have more of a focus on freight transportation needs in long haul corridors, commodity-based approaches to trip generation are becoming more popular. This may explain why they have found the widest application in statewide models. Only a handful of metropolitan regions are using commodity-based models.

Table 13 illustrates the various approaches used to classify truck types in statewide and metropolitan planning applications. Most truck trip generation data classify truck trips by truck size and, in most cases, gross vehicle weight (GVW) is used as the classifying variable (although the number of axles has been used in some models). In statewide and metropolitan planning applications, classification of truck size is important because trucks of different sizes have different impacts on congestion, air quality, pavement maintenance requirements, etc. The most frequently used GVW cutoffs are 0–8,000 lb, 8,001–28,000 lb, 28,001–64,000 lb, and >64,000 lb. Some models do not include the light truck category and, in some of these cases, 10,000 lb GVW may

TABLE 13
CLASSIFICATION OF TRUCKS IN STATEWIDE/METROPOLITAN PLANNING APPLICATIONS (n = 11)

Classification	Percent of Studies
Gross vehicle weight	72.7
No. of axles	9.1
Business type	9.1

represent the minimum truck weight. The SCAG model classifies trucks using the same GVW cutoffs as are used in the air quality/emissions models and this may become more common in applications of truck modeling for conformity determinations. As in the case of land-use categories, the variety of definitions of what a truck is and the different classification schemes for types of trucks make comparisons of trip generation rates from one study to another extremely difficult.

A number of statewide and regional trip generation models include special generator components. The most frequent categories of special generators are ports, airports, and intermodal yards. Often, these trip generation models are built with data on cargo movement. Thus, these models can estimate truck trips as a function of container movements, commodity tonnage, or other units of import–export activity.

Quite a few statewide and metropolitan trip generation models have estimated separate trip production and attraction rates. The definition of what is a production and what is an attraction may vary, however, depending on the methodology used to estimate trip generation. For example, in commodity-based trip generation models, productions and attractions often refer to the activities of shippers (productions) and receivers (attractions). In these models, trip production models are based on economic production and attractions are based on economic consumption. The same definition of production and attraction is used in some vehicle-based models. However, in other vehicle-based models, trips are produced at the location where the trucks are domiciled and attractions occur at the locations of pickups and deliveries. In the Alameda County model, this definition of productions and attractions is applied to the garage-based trips only (this is also the only model that separates garage-based and linked trips). A further concern, which has generally not yet been addressed in many truck travel demand models, is a link between land uses that produce trips and those that attract trips.

The lack of uniformity in the classification of trip generating activities/trip purposes is a major impediment to comparing truck trip generation rates developed for statewide and metropolitan modeling applications.

Relationship of Independent Variables to Estimation Techniques

In vehicle-based truck trip generation models, the most common approach to estimating trip generation is to use trip generation rates by land-use category and as a function of employment by industry sector. As noted previously, the industrial classification schemes used for employment data tend to be fairly aggregate (typically, 1-digit SIC categories). Frequently, data used to estimate rates are collected in truck travel diary surveys (similar to household travel surveys), which ask for the land use at each stop. By matching land-use categories and employment categories, modelers can estimate the total number of trips in the region by land use. These trips are then divided by regional employment in the corresponding industry category to obtain an estimate of the rate. When land-use data are not obtained for each trip, or data other than trip diaries are used, trip generation models can be estimated using employment data and regression techniques. Typically, expanded survey data are aggregated by districts and the number of trips in a district and its corresponding employment by industry sector form observations that can be used to estimate regression models.

The vehicle-based truck trip generation models provide only limited accuracy when they are applied to small areas (e.g., within a TAZ). At the TAZ level, the results often require calibration to match ground counts. To some extent, this may be related to the inherent inaccuracy of self-administered travel diary surveys that often underreport travel. However, the inaccuracy of the rates may also be related to the variability of trip generation for such aggregate categories of land use/employment. Some models adjust for this variability by estimating subregional rates that account for the differences in industrial activity from one part of the region to another. Because these models are used in forecasting, estimating trip generation as a function of employment may present other problems. The fact that labor productivity has increased in most sectors suggests that in the future the trip rates per employee may increase and this will not be captured in employment-based rates that are estimated with today's data. Trip rates based on other measures of industrial activity, such as sales, may prove to be a better independent variable.

Given the problems associated with using employment as an independent variable, especially when the industry sectors are very aggregate, one might ask why this approach is used so often. The answer most frequently given by states DOTs and MPOs is that these are the only data measuring economic activity that are feasibly available to them, particularly at the TAZ level.

Commodity-based models attempt to circumvent the employment data problem by looking at commodity movements as the source of truck trips. Commodity flows are estimated in tons and are typically estimated at a level of detail that allows them to be linked to the industries that produce or consume them defined at either the 2- or 4-digit SIC level. Although this might appear to be a superior approach to estimating truck trip generation on the surface, the commodity-based models face many of the same problems as vehicle-based models.

Generally, commodity flows are first estimated as state-to-state flows and are then disaggregated to county-to-county flows. Depending on the source of the commodity flow data, the process of geographically disaggregating the flows may involve less and less accurate data, the more geographically disaggregate the estimates become. Although state-to-state flow data are generally reliable for most commodities, the statistical reliability of county-to-county flow data is not well documented. In metropolitan models, these flows are further disaggregated to the TAZ level. This is usually done by allocating the origins and destinations of the flows based on employment data. Some states and MPOs have developed estimates of employment by TAZ at the 2-digit SIC level using data such as Dunn & Bradstreet or American Business Information files, which list employment for individual businesses. However, the limitations that most MPOs face when trying to estimate vehicle-based models also apply to the disaggregation of county-to-county commodity flow data. The only advantage of commodity flow models in these cases would seem to be that at the county-to-county or state-to-state level they are estimated based on economic production and consumption measures that are better indicators of truck trips than are employment-based trip rates. This is probably why the current state of the practice in statewide modeling emphasizes commodity-based models, whereas MPOs generally favor vehicle-based approaches. The MPOs using commodity-based trip generation models have tended to use them to model external trips (interregional) or as control totals at the county-to-county or city-to-city level.

Because most states and MPOs do not estimate their own commodity flow data, the variable that becomes most important to them in developing trip generation estimates from commodity flows is the variable used to convert commodity flows to truck trips. In most models, this is a payload factor (average pounds per truck trip for each commodity). The payload factor may be developed uniquely for the state/MPO using locally collected data or it may be developed using data from the VIUS. National or state-level VIUS data can be used. The VIUS commodity categories do not exactly match any of the standard commodity classification systems, so a bridge must be developed to these categories. VIUS does classify truck activity based on the size of the vehicle and the length of haul, so it is possible to develop a unique set of average payload factors for long-haul trucks as distinct from local trucks and for trucks of different sizes. However, as VIUS data are made more highly disaggregate, its statistical reliability suffers.

Data Collection, Validity, and Challenges

Table 14 summarizes the most commonly used approaches to collecting data for truck trip generation. This table illustrates results from the survey of practitioners and the literature survey when truck trip generation rates were actually calculated. A number of respondents to the survey reported on truck data collection activities that were not used to calculate trip generation rates. However, these results do provide another indication of the types of truck data available to a growing number of state, metropolitan, and local planning agencies. The vast majority of these respondents had vehicle classification count data (89 percent) and several had conducted intercept surveys (44 percent).

TABLE 14
COMMONLY APPLIED DATA COLLECTION METHODS
(n = 30)

Classification	Percent of Studies
Trip diaries	33.3
Classification counts	23.3
Published commodity flow data	33.3
Collected commodity flow data	16.7
Shipper/carrier/special generator surveys	3.3
Intercept surveys	26.7
Published rates	3.3

With vehicle-based modeling applications, travel diary surveys are the most frequently used source of data for estimating truck trip generation rates. All of the trip generation models developed for these applications report difficulties in obtaining adequate responses. In most cases, potential survey participants are screened with some type of initial contact before being sent a travel diary. Because most of the reports on these models do not state how many candidates were contacted during this initial screening, it is impossible to determine what the response rates really are. The surveys are probably subject to a high degree of self-selection bias. Because there has been no systematic evaluation of these surveys, it is hard to know how important this self-selection bias is. The results of regression modeling with these data show mixed results (coefficients of determination are almost always lower than 0.75 and in some cases have been lower than 0.50). Virtually none (less than 10 percent) of the respondents to the survey conducted for this study indicated that they had made any attempt to assess the accuracy of the results of their data collection programs.

Collecting data from travel diaries poses special problems for trucking, because drivers are generally not surveyed directly. Approval must be obtained from dispatchers, fleet managers, and/or vehicle owners, who often are concerned about the impact of the survey on driver productivity and the potential for disclosure of confidential business information. In addition, management is often less receptive to reasonable incentives than individual drivers.

A more effective approach to collecting data for truck trip generation models is to use intercept surveys and vehicle classification counts. For these approaches to be effective, it is necessary to survey all routes into and out of the area of interest. Thus, these approaches are used most often for external trips in regional models, intercity trips in statewide models, and special generator models.

Table 15 illustrates the types of data that state and regional agencies reported collecting in their truck data collection programs. The time of day of trips is most often specified and this seems to be related to the methods used to collect data. Travel diaries, intercept surveys, and classification counts can easily be used to collect information on the time of day of trips. Although few respondents indicated that they estimated trip generation rates by time of day, modelers frequently estimate 24-hour trip generation rates and then factor 24-hour trip totals by time period using time-of-day data. Many of the respondents noted that they collect data on the commodity carried by trucks, but few seemed to use these data in the development of trip generation rates.

TABLE 15
TYPES OF DATA COLLECTED BY STATE/METROPOLITAN AGENCIES (n = 24)

Classification	Percent of Studies
Weight class	25.0
Axle configuration	45.8
Body type	29.2
Land use	29.2
Business	29.2
Time of day	50.0
Duration of stay	12.5
Wait time	12.5
Commodity carried	45.8
Cargo weight	20.8

Very few survey respondents indicated the reason why they selected the independent variables that they used for estimating trip generation rates. However, those who did answer this question overwhelmingly indicated that their choice was made because of the data that were available and their ability to forecast the independent variables (see Table 16).

TABLE 16
FACTORS AFFECTING SELECTION OF INDEPENDENT VARIABLES IN MODELS (n = 13)

Factor	Percent of Studies
Data availability	76.9
Ability to forecast	53.8
Goodness of fit	46.2

TRANSPORTATION ENGINEERING APPLICATIONS

A look at the truck trip generation literature shows a significant amount of interest and activity in the 1970s and early 1980s related to transportation engineering applications that has since been surpassed by the flurry of more recent activity focused on statewide and metropolitan planning and modeling applications. In recent years, this activity has slowed and many practitioners suggest that there is a need for renewed attention. That the ITE *Trip Generation Manual* does not offer trip generation rates other than to provide some reference material in the appendixes illustrates the lack of any comprehensive treatment of this topic within the transportation engineering profession. For this study, members of both the ITE Goods Movement Council and the Consultants Council were surveyed about truck trip generation data. Few responses were received and most of these indicated that the firms did not collect or use truck trip generation data.

Types of Trip Generating Activities/Trip Purposes

In the few cases where trip generation data were identified in traffic impact studies and other transportation engineering applications, the focus was on a very limited set of trip generation activities. As is the case with total vehicle trip generation data, engineering applications of truck trip generation tend to define activities in terms of the land uses that generate the trips. The areas that have received the most attention are ports, truck terminals, rail terminals (or rail-oriented industry), industrial parks, and warehouses. Specialized industry, as in the case of lumber and poultry processing in West Virginia, are occasionally included. Noticeably absent from any studies reported over the last decade are land uses such as offices, retail trade, shopping centers, and other types of commercial/service businesses. The categories of industrial land use are generally so broad that any examination of the data would show high variability in rates from one region to another simply because of the difference in the composition of manufacturers included in the sample. Categories such as “light industrial park” have been shown to exhibit high levels of variation in truck trip rates depending on the specific products, inventory practices, and production processes associated with businesses in the park. Sample sizes also tend to be very small.

In transportation engineering applications, truck size is important because of the impact that trucks of different sizes have on local traffic patterns, noise, pavement maintenance and design, roadway geometry, and design requirements for loading facilities. The classification of trucks also varies widely from one study to another. Most studies report some distinction between light and heavy trucks, although the definition of what is light and what is heavy is not consistent. Sometimes the distinction is based on GVW and sometimes it is based on truck configuration (e.g., single unit versus tractor-trailer).

Types of Independent Variables/Estimation Techniques

Consistent with the general approach used by ITE, truck trip generation rates tend to be developed as a function of either land-use variables (most often building floor area) or employment. The methodology for estimating the data generally involves averaging or plotting truck counts over several days and either estimating a regression model or estimating an average rate.

Collection and Validity of Data

Table 17 summarizes the methods used by survey respondents to develop trip generation data for transportation engineering applications. In most of the studies, the data have been collected by identifying suitable locations for conducting truck classification counts. These locations must isolate the facility of interest so that all trucks entering and exiting the site can be counted and that only trucks serving the site are counted. Counts are taken with a variety of equipment including the more recent application of video cameras and manual classification methods. Data collection is often limited to very small samples, usually several days at a small number of locations. Typically, counts are taken continuously throughout the day so that peak and 24-hour volumes can be used to compute the rates. On occasion, rates have been developed separately for trucks entering and trucks leaving a facility.

TABLE 17
METHODS USED TO DEVELOP TRIP GENERATION DATA FOR ENGINEERING APPLICATIONS (n = 14)

Methods	Percent of Studies
Trip diaries	14.3
Classification counts	64.3
Published commodity flow data	0.0
Collected commodity flow data	0.0
Shipper/carrier/special generator surveys	42.9
Intercept surveys	7.1
Published rates	0.0

ORGANIZATIONAL WILLINGNESS TO SHARE DATA

Of the 32 organizations that responded to the survey conducted for this study that reported having truck trip generation data, 53 percent expressed a willingness to share these data and only two organizations reported that they could not share their data. Most often, organizations stated that they would provide previously published data (38 percent of survey respondents). However, 19 percent of the respondents indicated a willingness to share data in electronic formats. This type of cooperation could be very useful for a more in-depth comparison of trip generation rates collected in different studies and in assessing the validity of the data.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The following lists of bulleted items identify the key points of the conclusions. These conclusions and the resulting recommendations are derived from a detailed literature review and a survey of practitioners.

Transportation Engineering

- Very little data on truck trip generation rates for transportation engineering applications compiled after 1990 is reported in the literature and efforts conducted in this study to compile these data from traffic engineers were largely unsuccessful.
- Data that are available are focused on a few highly specialized land-use categories.
- In the collection of truck trip generation data for transportation engineering applications, data on truck size classification is important for many applications.

Statewide and Metropolitan Planning

- Commodity-based modeling is the state of the practice in statewide modeling.
- Commodity-based trip rates are rarely published and are hard to derive from available data.
- VIUS is the source used most often for payload data to convert tonnage commodity flows to truck trips.
- Vehicle-based models are the most frequently used technique for estimating trip generation at the metropolitan level.
- The variation in truck classification categories, land-use categories, and trip type categories makes it very difficult to compare trip generation rates from one study to another.

Although there have been substantial efforts focused on the development of truck trip generation data and estimation methodologies during the last decade, the results have been uneven across different applications. The literature suggests that prior to the era of ISTEA and the greater interest in freight planning at the state and metropolitan level, most efforts to compile truck trip generation data were focused on collecting data from specific facilities/ establishments where trips could be counted accurately, land uses could be described with a high degree of specificity, and characteristics such as employment, floor area, acreage, etc., were well documented. The facility/establishment level data were most useful for site impact studies and very localized planning and transportation engineering applications. Although a few studies of this type appear in the literature after 1990, most of these data have become dated and it is not clear how useful this information is today.

Much has changed in the world of trucking in the last 25 years. Supply chain management and logistics processes have changed order cycles and stocking practices dramatically from manufacturers all the way to home delivery. The advent of e-commerce is expected to continue these trends. The types of equipment used to move goods have also changed. The increase in intermodalism has created new patterns of pickup and delivery at ports and rail–intermodal yards. In short, new data are needed for transportation engineering applications and this is the area that has seen the least activity, at least as is evidenced in the published literature and research sponsored by states, MPOs, the federal government, and university researchers. The readily available truck trip generation data for transportation engineering applications are very limited, focusing on only a few specialized land uses (primarily ports, specialized manufacturing facilities, distribution warehouses, and industrial parks) and are often based on data collected from only a handful of facilities.

The following are recommendations derived from study efforts.

- Undertake a comprehensive and systematic data collection program to address the serious deficiencies in truck trip generation data for transportation engineering applications.

Such efforts could focus attention on land uses such as industrial parks, manufacturing facilities of different types (a commodity-based approach might be considered), warehouse facilities of different types, office buildings, various categories of service industries, and different types of retail facilities for which little data have been collected. Additional attention could also be focused on intermodal facilities to address the heightened importance of National Highway System connector planning that has developed in recent years. A fairly disaggregate approach to data collection would be beneficial. Future research on the collection of truck trip generation data for transportation engineering applications might address how best to distinguish different truck types. Distinctions among passenger vehicle-sized commercial vehicles, single-unit trucks, and tractor-trailers could be incorporated in trip generation rates. Rates by number of axles might also be considered. Truck size is significant in the design of roadways for the prediction of axle loadings, intersection geometry, and signalization, as well as essential in terms of provision of specialized truck facilities, such as off-street loading docks or on-street loading zones.

- As more substantial study data becomes available, the assumption of a linear relationship between trips and such variables as employment, floor area, or acreage needs to be re-examined.

As noted previously, industrial productivity relationships have a strong impact on truck trips and there are a number of truck trip generating activities that exhibit economies of scale.

- Focusing on truck trip generation data for transportation engineering applications, collect data from facilities of different sizes to determine if the relationship between trip generation and independent variables such as employment, floor area, and acreage is linear or best expressed by some other functional form.
- Document commodity-flow approaches and produce a current state-of-the-practice manual for developing statewide truck trip generation data from commodity flows.
- Compare the truck trip generation rates per employee at the 2-digit SCTG level of detail from different state commodity-based models to determine if such rates would be transferable.

If rates are comparable, it may be possible to develop trip generation rates by commodity that could be used across the United States without developing a unique set of commodity flow data and average payload data for each new statewide model.

- A rethinking of the Vehicle Inventory and Use Survey may be in order. The definition of major commodity could be reclassified to match the SCTG system, and sample size could be redesigned to provide sufficient samples by strata to meet the disaggregation requirements described above.
- Collect data from external roadside intercept surveys to identify the number of internal trips typically made by trucks registered outside of a region.

With data available from a number of regions across the country, it might be possible to begin to estimate the impact of these trips on internal trip generation models.

- Research might involve the compilation of the data derived from the vehicle-based trip generation models and the re-estimation of trip rates in a consistent fashion to see how variable these rates really are.
- Extend the utility of commodity-based models by conducting research to estimate the commodity distribution practices of different industries.

Commodity-based models can do a reasonable job of estimating the number of truck trips associated with the production end and the consumption end of commodity moves. Further investigation is needed to determine if trip generation relationships that capture distribution movements in between these two ends can be estimated. For example, conduct an extensive survey of distribution warehouses to determine if a relationship exists between distribution movements and commodity groups, size of business, geographic region, etc.

REFERENCES

Aherns, G.A., K.W. Forstall, R.U. Guthrie, and B.J. Ryan, "Analysis of Truck Deliveries in a Small Business District," *Transportation Research Record 637*, Transportation Research Board, National Research Council, Washington, D.C., 1977, pp. 81–86.

Al-Deek, H.M., G. Johnson, A. Mohamed, and A. El-Maghraby, "Truck Trip Generation Models for Seaports with Container and Trailer Operation," *Transportation Research Record 1719*, Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 1–9.

Black, W.R., *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment: Phase 2*, Transportation Research Center and Department of Geography, Indiana University, Bloomington, 1997.

Brogan, J.D. and K.W. Heathington, *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements*, University of Tennessee, Knoxville, 1977, 264 pp.

Cambridge Systematics, *Portland Commodity Flow Tactical Model System: Functional Specifications*, Prepared for Portland Metro, Cambridge, Mass., 1998.

Cambridge Systematics, COMSIS Corporation, and University of Wisconsin–Milwaukee, *Quick Response Freight Manual*, Prepared for the Federal Highway Administration, the Federal Transit Administration, the Office of the Secretary of Transportation, and the U.S. Environmental Protection Agency, Washington, D.C., 1996.

Christiansen, D.L., *Urban Transportation Planning for Goods and Services: A Reference Guide,* Federal Highway Administration, Washington, D.C., 1979, 71 pp.

Cutler, M. et al., "Assessment of Market Demand for Cross-Harbor Rail Freight Service in the New York Metropolitan Region," *Transportation Research Record 1719*, Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 17–26.

Delaware Valley Regional Planning Commission (DVRPC), *Truck Trip Generation at Intermodal Facilities in the Delaware Valley Region,* DVRPC, Philadelphia, Pa., 2000.

DeShazo, Tang & Associates, Inc., *Trip Generation Study for Rail-Oriented Industrial Complex*, Prepared for Jones & Carter, Houston, Tex., 2000.

Fischer, M., J. Ang-Olson, and A. La, "External Urban Truck Trips Based on Commodity Flows: A Model," *Transportation Research Record 1707,* Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 73–80.

French, L.J., R.W. Eck, and R.W. Balmer, *Trip Generation Rates, Peaking Characteristics, and Vehicle Mix Characteristics of Special West Virginia Generators,* West Virginia Department of Transportation Research Project 125, West Virginia University, Morgantown, February 2000.

French, L.J. and R.W. Eck, *West Virginia Special Generators Study*, 68th Annual Meeting of the Institute of Transportation Engineers, Toronto, Ontario, Canada, ITE, Washington, D.C., 1980.

Gannett Fleming, Inc., *Technical Memorandum No. 2: Truck/Taxi Travel Survey*, Tampa, Fla., July 1993.

Greater Vancouver Regional District and Province of British Columbia, *Trucking in Greater Vancouver: Demand Forecast and Policy Implications*, Transport 2021 Technical Report 7, Victoria, British Columbia, Canada, 1993.

Guha, T. and C.M. Walton, "Intermodal Container Ports: Application of Automatic Vehicle Classification System for Collecting Trip Generation Data," *Transportation Research Record 1383*, Transportation Research Board, National Research Council, Washington, D.C., 1993, pp. 17–23.

Habib, P.A., *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts,* Report FHWA/RD-80/020, Prepared for the Federal Highway Administration, Office of Research and Development, Washington, D.C., 1981, 134 pp.

Institute of Transportation Engineers (ITE), *Trip Generation*, 6th ed., ITE, Washington, D.C., 1997.

Institute of Transportation Engineers (ITE), *Trip Generation Handbook*, ITE, Washington, D.C., 1998.

Institute of Transportation Engineers (ITE) Technical Council Committee 6A-46, *Truck Terminal Trip Generation*, ITE, Washington, D.C., 1995.

Jack Faucett Associates, *Greater Buffalo–Niagara Regional Transportation Council Goods Movement Study,* Prepared for the Greater Buffalo–Niagara Regional Transportation Council, Buffalo, N.Y., 1999.

Krishnan, V. and K. Hancock, "Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems," *Transportation Research Record 1625,* Transportation Research Board, National Research Council, Washington, D.C., 1998, pp. 156–164.

Lancaster Engineering, *Trip Generation Study for T.M. Lee Warehouse Distribution Center Development Proposed for N. Ramsey Boulevard in the Rivergate Area of Portland, OR,* Prepared for VLMK Consulting Engineers, Portland, Ore., November 1998.

McKinstry, D.L. and L.G. Nungesser, "Transferability of Trip Generation Rates for Selected Special Generators," In *Transportation Planning Methods Applications, Proceedings, Third National Conference on Transportation Planning Methods Applications*, Dallas, Tex., April 22–26, 1991, Transportation Research Board, National Research Council, Washington, D.C.

Memmott, F.W., *NCHRP Report 260: Application of Statewide Freight Demand Forecasting Techniques,* Transportation Research Board, National Research Council, Washington, D.C., 1983.

Meyer, Mohaddes Associates, Jack Faucett Associates, Advanced Transportation Systems, Cordoba Corporation, Urban Analysis Group, and DRI/McGraw–Hill, *Southern California Association of Governments (SCAG) Heavy Duty Truck Model and VMT Estimation,* Prepared for the SCAG, Los Angeles, October 1999.

Ogden, K.W., *Urban Goods Movement: A Guide to Policy and Planning*, Ashgate Publishing Co., Brookfield, Vt., 1992, 417 pp.

Park, M.-B. and R.L. Smith, Jr., "Development of a Statewide Truck–Travel Demand Model with Limited Origin–Destination Survey Data," *Transportation Research Record 1602*, Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 14–21.

Parsons Brinckerhoff Quade & Douglas, Inc., *The Second Generation Michigan Statewide Truck Travel Demand Forecasting Model*, Draft for Review, Prepared for the Travel Demand Analysis Section of the Michigan Department of Transportation, Lansing, Mich., September 21, 1998.

Rawling, F.G. and J.P. Reilly, "CATS Commercial Vehicle Survey of 1986: A Discussion of Project Management and Issues," *CATS Research News*, Vol. 26, Nos. 1 and 2, 1987, pp. 5–27.

Reich, Anderson, and Drake, *Baltimore Truck Trip Attraction Study*, Department of Planning, City of Baltimore, Md., 1987.

Reid Crowther, Jack Faucett Associates, Cambridge Systematics, and Transys International, *Lower Mainland Truck Freight Study,* Prepared for Translink, Vancouver, B.C., Canada, 2000.

Ruiter, E.R. and Cambridge Systematics, *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Prepared for the Arizona Department of Transportation, Phoenix, February 1992, 91 pp.

SAIC and Harvey Consultants, *Analysis of Freight Movements in the Puget Sound Region,* Prepared for the Puget Sound Regional Council, San Diego, Calif., September 1997.

Schlappi, M.L., R.G. Marshall, and I.T. Itamura, "Truck Travel in the San Francisco Bay Area," *Transportation Research Record 1383*, Transportation Research Board, National Research Council, Washington, D.C., 1993, pp. 85–94.

Sorensen, P.C., E. Irelan, B. Winningham, and T.A. Noyes, "Skagit Countywide Air, Rail, Water, and Port Transportation System Study," *Transportation Research Record 1602*, Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 4–13.

Sorratini, J.A. and R.L. Smith, Jr., "Development of a Statewide Truck Trip Forecasting Model Based on Commodity Flows and Input-Output Coefficients," *Transportation Research Record 1707,* Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 49–55.

Spielberg, F. and S.A. Smith, "Service and Supply Trips at Federal Institutions in Washington, D.C. Area," *Transportation Research Record 834*, Transportation Research Board, National Research Council, Washington, D.C., 1977, pp. 15–20.

Tadi, R.R. and P. Balbach, "Truck Trip Generation Characteristics of Nonresidential Land Uses," *ITE Journal*, Vol. 64, No. 7, 1994, pp. 43–47.

Thornton, M., et al., "Development of Urban Commercial Vehicle Travel Model and Heavy-Duty Vehicle Emissions Model for Atlanta Region," Presented at the 77th Annual Meeting of the Transportation Research Board, Washington, D.C., January 1998.

U.S. Bureau of the Census, *Commodity Flow Survey, 1997*, Washington, D.C., 1999.

U.S. Bureau of the Census, *Economic Census, 1997: Census of Manufacturers and County Business Patterns*, Washington, D.C., 1999.

Wegmann, F.J., A. Chatterjee, M.E. Lipinski, B.E. Jennings, and R.E. McGinnis, *Characteristics of Urban Freight Systems*, Federal Highway Administration, Washington, D.C., 1995, 410 pp.

Wilbur Smith Associates, *BACTS Truck Route Study,* Prepared for the Bangor Area Comprehensive Transportation System, Bangor, Maine, 1998.

Wilbur Smith Associates in association with Reebie Associates, *Multimodal Freight Forecasts for Wisconsin,* 1996.

GLOSSARY

Business Economic Areas (BEA)—A number of counties grouped together for the purpose of reporting economic data. BEA regions are established by the U.S. Bureau of Economic Analysis.

Coefficient of determination (R^2)—A statistical measure computed for regression equations, the coefficient of determination measures the degree to which variation in the dependent variable is explained by the independent variables in the equation. R^2 always has a value between 0 and 1. The higher the value, the more that the equation can be said to explain the variation in the dependent variable. Because the R^2 value will always increase with the addition of more independent variables, a value called "adjusted R^2" is often computed that does not increase with the addition of independent variables unless they provide increased explanatory value.

Combination vehicle—A truck that includes a separate power unit (usually referred to as a tractor) and one or more cargo carrying units (trailers or semi-trailers). Combination vehicles will legally carry one or two (tandem) trailers. In some locations, triple trailers are legal.

Commodity—As used in most freight studies, commodity refers to the cargo carried by the truck. There are several standard commodity classification systems in use in North America.

Commodity flow—A quantity of a specified commodity moving between a specified origin and destination region. Commodity quantities are usually given in terms of weight (tons) or value, and origin–destination regions are typically specified in terms of states/provinces, counties, or cities.

Commodity Flow Survey (CFS)—A survey conducted in the United States every 5 years as part of the Economic Census. The first CFS was conducted in 1992 (completed in 1993) and the second survey was conducted in 1997. The survey collects information about outbound goods shipments. Certain limitations in shipment coverage exist and are explained in literature provided by the Bureau of Transportation Statistics and the U.S. Bureau of the Census.

Commodity-based truck models—Truck models that estimate truck trip generation and trip distribution using data from commodity flow databases. Commodity flows are generally disaggregated geographically and converted from annual tonnage flows to daily truck traffic flows prior to assignment to a roadway network.

Distribution traffic—Truck traffic moving from a warehouse or regional distribution center to retail outlets or final consumers.

Drayage—The movement of goods, generally by truck, from the primary shipper (or to the receiver) from the main shipment mode (e.g., goods trucked from a shipper to a port for export). Drayage moves are generally short-haul moves made by specialized carriers.

E-commerce—Electronic commerce refers to a wide range of business-to-business and business-to-consumer transactions conducted by means of the Internet or other electronic media.

Expedited delivery—A range of delivery services provided by specialized carriers to ensure high speed and high reliability in transportation. Services may include same day, next day, or second day delivery systems.

External trip ends—The end of a trip that occurs outside of the region in question.

Factor productivity—Factors of production include all inputs to the production process and factor productivity refers to the efficiency with which these factors are used to produce a unit of output. An example would be labor productivity, which refers to the units of labor required to produce a dollar of output.

Final demand—A term used in economic input–output models to refer to the quantities of demand that are delivered for final consumption (i.e., not used as an input for a production process).

Forty-foot equivalent unit (FEU)—A unit of measure used for containerized cargo. Standard container sizes include twenty-foot lengths (TEU) and forty-foot lengths (FEU).

Forward positioning—The placement of goods (inventory) closer to the point of final consumption than the point of production. A logistics practice used to ensure speed of delivery to customers.

Four-step urban travel model—A standard methodology for estimating urban travel demand. The four steps include: (1) trip generation—estimating the number of trips generated by different activities/land uses in the region, (2) trip distribution—the method of linking the origins and destinations of trips, (3) mode split/choice—assignment of trips to the various modes of travel that are available, and (4) assignment—the assignment of traffic volumes to network routes.

Garage-based trips—A term coined by Barton Aschman in the Alameda County truck model to refer to trips that move from a garage location to a delivery location and then back to the garage location.

Global Positioning Systems (GPS)—A satellite-based system of tracking the location of a transmitter/receiver. The system uses microwave communication with orbiting satellites to track the whereabouts of vehicles. These systems are increasingly used by trucking companies to obtain real-time information on the location of assets.

Gravity model—A method of estimating trip distribution in a four-step urban travel demand model. Trips are assigned a destination zone based on a measure of attractiveness (usually a measure of the relative number of trips being attracted to the zone) and a measure of impedance over the network. Impedance is generally measured in terms of distance, travel time, or travel cost. Trip distribution is usually directly proportional to the attractiveness variable and inversely proportional to the impedance variable.

Gross Vehicle Weight Rating (GVWR)—A manufacturer rating that indicates the maximum rated weight of the vehicle including all cargo and the weight of the empty vehicle. GVWR is usually a function of the vehicle suspension system and the power unit.

Highway Performance Monitoring System (HPMS)—A data system maintained by each state as required by the FHWA. HPMS contains information about highway pavement condition, roadway configurations, and traffic volumes. HPMS provides ground count data for a sample of roadway segments in a state that can be used to estimate vehicle miles traveled by roadway functional class.

Impedance—See gravity model.

Industry production function—The specific mix of factor inputs required to produce a unit of output from a specific industry.

Input–output models—First developed by the economist Vassily Leontif, this model uses matrix algebra to relate all of the input quantities in an economy to output levels. If volumes of output are known by industry, the input–output model can be used to estimate the amount of inputs by commodity group.

Intelligent Transportation Systems (ITS)—Advanced transportation systems that incorporate information and control technologies to provide traveler information and vehicle control systems.

Internal trip ends—The ends of trips that occur within the region in question.

Just-in-time inventory—A logistics practice used to minimize on-site inventory for a producer. Rather than storing inventory on-site to meet production demands, small shipments that meet immediate production needs are taken by the producer to reduce storage costs.

Less-than-truckload (LTL)—Shipments that do not, by themselves, fill an over-the-road truck. Specialized LTL carriers handle these shipments. Typically, LTL carriers use smaller, “city” trucks to pick up loads from customers. These loads are brought to a central sorting facility in the region and assembled into full truckloads for over-the-road movement. The process is reversed at the other end of the shipment.

Linked trips—A series of truck trips in which several pickup and/or delivery stops are made before the truck returns to its home base.

Logistics—The practices that combine freight transportation and materials management in manufacturing and distribution enterprises.

North American Industrial Classification System (NAICS)—A multi-tiered industrial classification system. Major industry groups are assigned a single numerical digit. Within each major group are more disaggregate industry categories (2-digit, 3-digit, 4-digit, etc.).

Payload—The cargo carried by a truck.

Private trucking fleet—A fleet of trucks owned by the shipper or receiver of goods. Trucks in private fleets are not for hire by other users.

Reebie Transearch Database—A commodity flow database developed and sold by Reebie Associates of Stamford, Connecticut. Commodity flows available from Transearch can include either 2-digit or 4-digit STCC detail and origins and destinations can be specified for states, BEA regions, or counties. The commodity flows are developed using a variety of economic data from the U.S. Bureau of Census, shipment data from the U.S. Surface Transportation Board and the U.S. Army Corps of Engineers, and a proprietary data exchange program with trucking fleets.

Reload facilities/sites—Sites at which cargo are transferred to another mode or stored temporarily before final delivery. Typical reload sites include terminals and warehouses.

Roadside intercept survey—A survey conducted by intercepting vehicles at a roadside location for the purpose of conducting a data collection interview.

Screenlines—An artificial line drawn across a set of facilities that generally serve the same origin and destination subareas within a metropolitan area. Screenlines are used to validate travel demand models by comparing the predicted traffic volumes at the screenline with those obtained from traffic counts.

Secondary movements—Movements of goods from warehouses and distribution centers to retail outlets or final consumers.

Single-unit truck—A truck where the power unit and cargo carrying unit are combined on a single chassis.

Standard Industrial Classification (SIC)—A classification system similar to NAICS. The SIC system was recently superceded by the NAIC system.

Standard Transportation Commodity Classification (STCC)—A standard commodity classification system similar in structure to the NAIC system of classifying industries. The STCC system has been superceded by the STCG system.

Standard Transportation Commodity Group (STCG)—See STCC.

TEU—See FEU.

Tour—A set of linked trips beginning and ending at home base.

Tractor-trailer—See combination vehicle.

Traffic Analysis Zone (TAZ)—Used in urban travel demand models as a location where trips originate and terminate.

Traffic assignment—Routing of traffic in an urban travel demand model network. Traffic assignment logic generally takes into account travel time or cost on alternative paths between origin and destination.

Travel diaries—A survey instrument used to collect information on individual trips. Travel diaries generally ask the user to record information on each trip including starting and ending location, time of trips, distance of trips, land use at trip ends, etc.

Trip chains—See tours and linked trips.

Trip length frequency distribution—A distribution showing the frequency at which trips of different lengths are taken in a regional travel demand model.

Truckload (TL)—Full truckload shipments usually handled by a specialized TL carrier (see LTL).

Value added—An economic term referring to the value added in a production process or service above and beyond the costs of raw materials and supplies.

Vehicle classification counts—Traffic counts that classify the vehicles being counted. Classification counts distinguish trucks from automobiles and may distinguish trucks based on axle configuration, truck configuration, or body type. Vehicle classification counts can be taken manually (visual observation) or with machines.

Vehicle Inventory and Use Survey (VIUS)—A survey of truck owners conducted every 5 years as part of the U.S. economic census. Formerly referred to as the Truck Inventory and Use Survey (TIUS), VIUS collects information about the equipment and activity characteristics of the U.S. trucking fleet.

Vehicle-based truck models—A type of truck model that estimates trip generation directly and uses trip generation, trip distribution, and traffic assignment methodologies similar to those used in standard urban travel demand models.

Weigh-in-motion (WIM)—A technology that allows vehicles to be weighed while they move over sensors embedded in the pavement and does not require diverting trucks through standard weigh station scales.

APPENDIX A

Questionnaire

TRANSPORTATION RESEARCH BOARD (TRB)
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Project 20-5, Topic 31-09

Truck Trip Generation Data
Questionnaire

Name of Respondent: ____________________
Agency: ____________________
Title: ____________________
Telephone No: ____________________
FAX: ____________________
E-mail address: ____________________

INSTRUCTIONS

The information collected will be used to develop a National Cooperative Highway Research Program (NCHRP) synthesis report on "Truck Trip Generation Data." If you or your agency have collected and/or used data on truck trip generation for freight transportation planning, please review and respond to this survey.

The main purpose of this survey is to enhance the state-of-the-practice in the areas of freight transportation modeling and planning and truck traffic impact analysis. In light of the recognized importance of freight transportation, the ability to estimate truck traffic is vital. This synthesis will directly benefit agencies engaged in regional freight transportation planning and in review of site development proposals where trucks have an impact on site access and circulation design.

This questionnaire should be completed by that person(s) with knowledge of your organization's activities related to freight transportation planning, modeling, and/or site traffic impact analysis and circulation design. Please answer as many of the following questions as possible. **Since the questionnaire covers data used both for regional and site impact studies, some questions will be applicable to one application and not the other**. You may skip any questions that do not apply to data you collected. Attach additional sheets if necessary. **Please note that if you have collected or compiled truck trip generation data in more than one instance, we would like you to fill out this survey form for each set of truck trip generation data you have collected.** Please send copies of reports/studies documenting the Truck Trip Generation data as soon as possible and your completed questionnaire(s) by 15th May, 2000 to:

Myong Han
Western Regional Office
Jack Faucett Associates
2855 Mitchell Drive, Suite 203
Walnut Creek, CA 94598

If you have any questions, do not hesitate to contact Mr. Myong Han of Jack Faucett Associates
By telephone (925) 943-2177 or by e-mail: han@jfaucett.com

WE APPRECIATE YOUR RESPONSE – THANK YOU

PART I: General & TTG Data Collection (Questions 1 through 7).

1. Have you used truck trip generation (TTG) data that was collected during the last ten years for any of the following applications (check all that apply)? Please provide name/title of your study/project you used/collected TTG data for. *Please fill out form for each data source*

   - ❑ Regional and/or sub-regional modeling ______________________
   - ❑ Statewide modeling ______________________
   - ❑ Site access and circulation design ______________________
   - ❑ Sizing of loading dock facilities ______________________
   - ❑ Curbside loading space allocation ______________________
   - ❑ Corridor and MIS ______________________
   - ❑ Inventories ______________________
   - ❑ Other (Please describe) ______________________

2. Did your organization collect (or fund the collection of) the TTG data you used?

   - ❑ Yes (Go to Question #3)
   - ❑ No – What was the source? ______________________
     – Please provide contact info. If available: ______________________
     ____
     – Go to Question #4

3. If you hired a firm to collect the data for you please provide name and contact information.
   ____
   ____
   ____

4. What was the source of the funding for your data collection effort?
   ____
   ____

   And, what sources of funding are available to you to update/upgrade your data?
   ____
   ____

5. How was truck trip data collected?

   - ❑ Trip diary survey or travel log
   - ❑ Shipper/receiver survey
   - ❑ Intercept survey
   - ❑ Manual vehicle classification counts
   - ❑ Automatic vehicle counts
   - ❑ Video
   - ❑ Other (Please describe) ______________________

6. What types of data were collected about truck trips? Indicate the classification system used for each box checked or provide a copy of your questionnaire/code sheet.

   - ❑ Truck weight class: ______________________
   - ❑ Axle configuration: ______________________
   - ❑ Body type: ______________________
   - ❑ Land use at trip origin/destination: ______________________
   - ❑ Business/industry at trip origin/destination: ______________________
   - ❑ Time of day (i.e., hour:min. / day of week / peak v. off-peak) ______________________
   - ❑ Duration of stay at the site: ______________________

- ❑ Wait time at the site: ____________________
- ❑ Commodity carried: ____________________
- ❑ Cargo weight: ____________________
- ❑ Other (Please describe) ____________________

7. How was data geo-referenced?

- ❑ Street address
- ❑ Traffic Analysis Zone (TAZ) or other zones
- ❑ x-y coordinates
- ❑ Zip codes
- ❑ City
- ❑ County
- ❑ Other (Please describe) ____________________
- ❑ Not applicable

PART II: Data Sampling & Quality of Data (Questions 8 through 12).

Note—some questions in this section may not be applicable to all respondents. Data sampling may not be applicable to trip generation data developed from counts and used for site impact analysis. Please take a moment to review all questions, and feel free to skip this section if it does not apply to your experience, or mark "not applicable" when answering the questions that are not applicable to you.

8. How was sample selected and what was the source of the sampling frame?

- ❑ Department of Motor Vehicles (DMV) registration files
- ❑ International Registration Plan (IRP) registration files
- ❑ Private fleet directories
- ❑ Business directories
- ❑ Yellow pages
- ❑ Trade association membership lists
- ❑ Freight advisory committee or steering committee
- ❑ Random roadside selection
- ❑ Other (Please describe) ____________________
- ❑ Not applicable

9. How was sample stratified? (indicate strata)

- ❑ Truck size: ____________________
- ❑ Fleet size: ____________________
- ❑ Business type: ____________________
- ❑ Geographic boundaries: ____________________
- ❑ External trips vs. internal trips: ____________________
- ❑ Other (Please describe) ____________________
- ❑ No sample / Not stratified

10. What was your sample size (number and % of population)? When providing the number of respondents, please indicate the units (e.g., trucks, fleets, trips)

    Number: ________ % of population: _________%
    ❑ Not applicable

11. What was response rate (number and % of population)?

    Number: ________ % of population: _________%
    ❑ Not applicable

11(a). Percentage of the collected data that were actually useable? __________%

❑ Not applicable

11(b). What factors had the greatest positive and negative impacts on your response and quality of data?

Positive Factor: ____
____
____

Negative Factor: ____
____
____

12. Was there any noticeable response bias by the following strata? Please describe the direction of bias.

❑ Truck size: ____
❑ Fleet size: ____
❑ Business type: ____
❑ Geographic boundaries: ____
❑ External trips vs. internal trips: ____
❑ Other (Please describe) ____
❑ No sample / Not stratified

Part III: Trip Generation Rates, Equations (Questions 13 through 15).

Note—some questions in this section may not be applicable to all respondents. Please take a moment to review all questions, and feel free to skip or mark "not applicable" when answering the questions that are not applicable to you.

13. What categories of truck trips were trip rates/equations calculated for (provide categories)?

❑ Land use types: ____
❑ Business/industry types: ____
❑ Special generators (e.g., ports, truck terminals, event centers): ______________________
❑ Truck size categories (weight, axle): ____
❑ Commodity type (including non-goods movement): ______________________________
❑ Empty vs. loaded: ____
❑ Garage-based vs. linked: ____
❑ Separate production and attraction rates: ______________________________________
❑ Activity type (e.g., pickup, delivery, fueling): ______________________________________
❑ Other (Please describe) ____

14. What independent variables were used to calculate trip generation rates/eqns. (describe categories)?

❑ Employment: ____
❑ Land use (sq. footage of building space, acres): ______________________________
❑ Commodity flow data: ____
❑ Business output measures (e.g., shipping units): ______________________________
❑ Sales: ____

15. Why did you select this (these) variable(s) and the level of detail in describing the variable?

- ❑ Data availability
- ❑ Ability to forecast data
- ❑ Goodness of fit to survey results
- ❑ Other (Please describe)______________________________

15(a). Please use the space below to elaborate on your choice of variables.
(Attach additional sheets if necessary.)

15(b). Are there any other variables that you think would provide greater explanatory power than those you used? Please explain why you were unable to use these variables.

____
____
____
____
____

Part IV: TTG Data Validity (Questions 16 through 20).

Note—some questions in this section may not be applicable to all respondents. Please take a moment to review all questions, and feel free to skip or mark "not applicable" when answering the questions that are not applicable to you.

16. Did you use any other published data sets to condition (or to estimate) your survey data/control totals?

- ❑ Truck Inventory and Use Survey (TIUS)
- ❑ Commodity Flow Survey (CFS)
- ❑ Reebie Transearch
- ❑ Carload Waybill sample
- ❑ Army Corps of Engineers Waterborne Commerce
- ❑ Port Import Export Reporting Service (PIERS)
- ❑ Private economic forecasts
- ❑ Other (Please describe) ______________________________

17. How were data expanded? (provide the name of the source for each)

- ❑ Vehicle population data
- ❑ Ground counts
- ❑ Economic data (employment, sales)
- ❑ Commodity flow control totals
- ❑ No, data were not expanded

18. How were trip generation rates/equations estimated (please provide results, attaching additional sheets if necessary)?

- ❑ Regression
- ❑ Trip rates
- ❑ Other (Please describe) ______________________________

19. Did you measure accuracy and precision of results? (e.g., coefficient of variation, variance, R^2) Provide results. (Attach additional sheets if necessary.)

20. Did you validate and/or calibrate results? Please describe process.
(Attach additional sheets if necessary.)

Part V: Data Sharing/Availability & Other Issues (Questions 21 through 25).

Note—some questions in this section may not be applicable to all respondents. Please take a brief moment to review all questions, and feel free to skip or mark "not applicable" when answering the questions that are not applicable to you.

21. In what format is data stored?

- ❑ Electronic raw data files
- ❑ Electronic response forms
- ❑ Electronic summaries
- ❑ Tabulated summaries
- ❑ Hard copy response forms

22. Would you be willing and able to share data with others?

- ❑ Reports
- ❑ Data summaries
- ❑ Electronic data files
- ❑ Raw data files
- ❑ No, not willing / able to share data

23. How effective was the private sector involved in your data collection program? Please rank effectiveness of the private sector involvement using scale of "1" to "5" with "5" being "very effective."

	not helpful 1	2	3	4	very effective 5
Special steering committee					
Standing freight advisory committee					
Trade groups					
Public meetings					
One-on-one meetings with businesses					

24. What issues do you think are most significant for advancing the state-of-the practice in truck trip generation data? Use space below to describe these issues.

25. Do you know of any other organizations that may have collected truck trip generation data or commercial vehicle studies that you would recommend we contact? Please provide name and contact information.

Reminder: Please don't forget to send us copies of available data and reports/studies if you are able to share them with us.
Thank you

APPENDIX B

Survey Participants

DOTs and State Agencies
Arkansas State Highway Commission
Caltrans
ConnDOT
Georgia DOT
Illinois DOT
Indiana DOT
Kansas DOT
Kentucky Transportation Cabinet
LA DOT
Louisiana Transportation Research Center
MD State Highway Administration
Montana DOT
NCDOT
NJDOT
NYMTC
Ohio DOT
Oklahoma DOT
Ontario Ministry of Transportation
Oregon DOT
PennDOT
TN DOT
Virginia DOT
Washington State DOT
WisDOT
WVDOT

MPOs/Regional Transportation Agencies
Baltimore Metropolitan Council
City of Los Angeles Department of Transportation
Delaware Valley Regional Planning Council
Denver Regional Council of Governments
Greater Buffalo–Niagara Regional Transportation Council
Kanlacon MPO
New York Metropolitan Transportation Council

Ports
Port of Long Beach
Port of Portland

Other
City College of New York
Clough, Harbour & Associates
DeShazo, Tang & Associates
JRH
Pennoni Associates
Texas Transportation Institue
Urbitran Associates

APPENDIX C

Tables Containing Relevant Trip Generation Rates

SECTION C-1 ITE TRIP GENERATION HANDBOOK

TABLE C-1A
DAILY TRUCK TRIP GENERATION RATES BY LAND USE (AUSTRALIA)

Truck Trips Per 1,000 GSF Development Type	Courier Vans	Light Rigid Trucks	Heavy Rigid Trucks	Articulated Trucks	Total
Office	1.9	0.4	0.0	0.2	2.5
Retailing*					
Regional Center	0.4	0.9	0.6	0.1	2.0
Major Supermarket	0.2	0.4	0.4	0.2	1.2
Local Supermarket	0.1	0.9	0.5	0.2	1.7
Department Store	0.2	0.5	0.9	0.1	1.7
Other	0.7	0.9	0.4	0.0	2.0
Manufacturing	0.1	0.1	0.1	0.2	0.5
Warehouse	0.1	0.0	0.2	0.2	0.5
Light Industry & High Technology	1.9	0.6	0.5	0.1	3.1
Truck Depots	0.9	0.9	1.4	3.7	6.9

Source: Ogden 1992 (as presented in ITE *Trip Generation Handbook).*
*Rate for retail is expressed in truck trips per 1,000 square feet of Gross Leasable Area.
Note: GSF = gross square feet.

TABLE C-1B
DAILY TRUCK STOPS BY LAND USE (SUBURBAN BALTIMORE)

		Daily Truck Trips per 1,000 GSF		
Land Use	Number of Sites	Low	Average	High
Prepared Foods	24	0.7	3.9	61.4
Variety/Pharmacy	8	0.1	0.6	10.9
Personal Services	22	0.5	2.3	5.7
Office Building	9	0.1	0.2	4.0
Soft Retail	14	0.4	2.0	16.7
Retail Food	18		5.2	

Note: GSF = gross square feet.

TABLE C-1C
TRUCK TRIP RATES (12-HOUR) PER EMPLOYEE IN TAMPA

Land Use	Number of Observations	Low	Average	High
Commercial				
Light	5 sites	0.071	0.178	0.432
Heavy	5 sites	0.009	0.047	0.075
Office				
Light	5 sites	0.019	0.038	0.075
Heavy	5 sites	0.003	0.009	0.015
Industrial				
Light	5 sites	0.077	0.285	0.718
Heavy	5 sites	0.039	0.164	0.335

TABLE C-1D
WEEKDAY DAILY TRUCK TRIP GENERATION RATES (Fontana, CA)

Land Use	Independent Variables	2- & 3-Axle Trucks	4- to 6-Axle Trucks	All Trucks
Warehouse				
Light	1,000 gsf	0.17	0.21	0.38
Heavy	1,000 gsf	0.1	0.27	0.38
Industrial				
Light	1,000 gsf	0.33	0.27	0.6
Heavy*	1,000 gsf	0.19	0.38	0.57
Heavy*	acre	11.9	8.63	20.53
Industrial Park	1,000 gsf	0.21	0.15	0.36
Truck Terminal	acre	7.34	28.47	35.81
Truck Sales & Leasing	1,000 gsf	6.95	1.79	8.74

*Results based on only two data points.

TABLE C-1E
WEEKDAY MORNING ADJACENT STREET PEAK HOUR TRUCK TRIP GENERATION RATES (Fontana, CA)

Land Use	Independent Variables	2- & 3-Axle Trucks	4- to 6-Axle Trucks	All Trucks
Warehouse				
Light	1,000 gsf	0.01	0.02	0.03
Heavy	1,000 gsf	0.01	0.01	0.02
Industrial				
Light	1,000 gsf	0.03	0.02	0.05
Heavy*	1,000 gsf	0	0.02	0.02
Heavy*	acre	0	0.03	0.03
Industrial Park	1,000 gsf	0.01	0	0.01
Truck Terminal	acre	0.39	0.92	1.31
Truck Sales & Leasing	1,000 gsf	0.64	0.11	0.75

*Results based on only two data points.

TABLE C1-F
WEEKDAY EVENING ADJACENT STREET PEAK HOUR TRUCK TRIP GENERATION RATES (Fontana, CA)

Land Use	Independent Variables	2- & 3-Axle trucks	4- to 6-Axle trucks	All Trucks
Warehouse				
Light	1,000 gsf	0.01	0.02	0.03
Heavy	1,000 gsf	0	0.01	0.01
Industrial				
Light	1,000 gsf	0.01	0	0.01
Heavy*	1,000 gsf	0.03	0.03	0.06
Heavy*	acre	0.58	0.08	0.66
Industrial Park	1,000 gsf	0.02	0.02	0.04
Truck Terminal	acre	0.36	1.66	2.02
Truck Sales & Leasing	1,000 gsf	0.52	0.08	0.6

*Results based on only two data points.

TABLE C1-G
WEEKDAY TRUCK TRIP GENERATION RATES FOR THE SITE PEAK HOUR
(Fontana, CA)

Land Use	Independent Variables	2- & 3-Axle Trucks	4- to 6-Axle Trucks	All Trucks
Warehouse				
Light	1,000 gsf	0.03	0.03	0.06
Heavy	1,000 gsf	0.01	0.03	0.04
Industrial				
Light	1,000 gsf	0.03	0.02	0.05
Heavy*	1,000 gsf	0.02	0.03	0.05
Heavy*	acre	0.08	0.08	0.16
Industrial Park	1,000 gsf	0.01	0	0.01
Truck Terminal	acre	0.67	1.73	2.4
Truck Sales & Leasing	1,000 gsf	1.22	0.25	1.47

Note: Site peak hour is based on all trips not just truck trips.
*Results based on only two data points.

SECTION C-2

TABLE C-2
SKAGIT COUNTYWIDE AIR, RAIL, WATER, AND PORT TRANSPORTATION SYSTEM STUDY

Sector	Employment	Ann. Total Tons	Ann. Ton Rate*	Ann. Loaded Truck Trips	Ann. Total Truck Trips*	Weight Factor*	Annual Trip Rate**	Daily Trip Rate**
Agriculture/Logging	2,290	744,742	672.81	37,170	74,340	20.04	65.57	0.18
Logging		796,000		37,905	75,810	21.00		
Mining	702	1,938,300	2,761.11	88,913	177,826	21.80	253.31	0.69
Construction	2,686	536,619	199.78	40,046	80,092	13.40	29.82	0.08
Food & Kindred Products	1,318	399,279	302.94	22,182	44,364	18.00	33.66	0.09
Lumber & Wood Products	746	949,448	1,272.72	52,747	105,494	18.00	141.41	0.39
Chemicals & Allied Products	124	467,814	3,772.69	23,990	47,980	19.50	386.94	1.06
Petroleum & Coal Products	753	1,472,484	1,955.49	77,499	154,998	19.00	205.84	0.56
Other Manufacturing	1,506	115,057	76.40	6,768	13,536	17.00	8.99	0.02
Rail/Water/Air	286	1,197,577	4,187.33	70,231	140,462	17.05	491.13	1.35
Wholesale Trade	1,844	1,485,525	805.60	100,373	200,746	14.80	108.86	0.30
Retail Trade	8,238	2,051,440	249.02	213,692	427,384	9.60	51.88	0.14

*Values are calculated by MJF (Michael J. Fischer).
**Trips per employee.

Quick Response Freight Manual—Final Report
September 1996
Appendix D

TRIP GENERATION SUMMARY TABLES

The following tables contain the detailed daily trip generation rates for each location, land-use type, and truck classification. The tables are grouped into the following four sections:

D-1) Trip generation rates per employee;
D-2) Trip generation rates per 1,000 square feet of office space;
D-3) Trip generation rates per acre; and
D-4) Trip generation regression formulas.

Within each of these sections, trip generation rates are summarized according to the following land use types (SIC numbers enclosed in parentheses—See Appendix C):

a) Agriculture, Mining, and Construction (1–19);
b) Manufacturing, Transportation/Communications/Utilities, and Wholesale Trade (20–51);
c) Retail Trade (52–59);
d) Offices and Services (60–88); and
e) Unclassified (89)

Note that some of the trip generation rates shown in the table, specifically those obtained from the Puget Sound Region (i.e., Washington State counties) are expressed in truckload equivalents (TLEs). Rates expressed in TLEs not only include freight transportation by trucks, but also freight moved by other modes including rail and waterways (which has been converted into "equivalent" truckloads).

TABLE D-1a
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER EMPLOYEE FOR AGRICULTURE, CONSTRUCTION & MINING INDUSTRIES (SIC 1–19)

Location	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
King County, Washington	Mining (10–14)	—	—	—	—	213.835	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Kitsap County, Washington	Mining (10–14)	—	—	—	—	108.295	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Pierce County, Washington	Mining (10–14)	—	—	—	—	306.395	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Snohomish County, Washington	Mining (10–14)	—	—	—	—	409.525	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Median	SIC (10–14)					260.115	—	TLE
Average	SIC (10–14)					259.512	—	TLE
Minimum	SIC (10–14)					108.295	—	TLE
Maximum	SIC (10–14)					409.525	—	TLE
King County, Washington	Construction (15–19)	—	—	—	—	11.770	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Kitsap County, Washington	Construction (15–19)	—	—	—	—	12.120	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Pierce County, Washington	Construction (15–19)	—	—	—	—	10.355	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Snohomish County, Washington	Construction (15–19)	—	—	—	—	11.730	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Median	SIC (15–19)					11.750	—	TLE
Average	SIC (15–19)					11.494	—	TLE
Minimum	SIC (15–19)					10.355	—	TLE
Maximum	SIC (15–19)					12.120	—	TLE

Notes: TLE = truckload equivalents; SIC = Standard Industrial Classification.

TABLE D-1b
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER EMPLOYEE FOR MANUFACTURING, TRANSPORTATION/COMMUNICATIONS/UTILITIES, AND WHOLESALE TRADE (SIC 20–51)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Phoenix, Arizona (1.7 million)	Manufacturing (20–39)	0.641	0.100	0.050	0.150	0.790	1992	See notes 2 and 5.
Knoxville, Tennessee (450,000)	Truck Transportation (42)	0.050	0.160	0.465	0.625	0.675	1979	—
Modesto, California (216,000)	Truck Transportation (42)	0.060	0.193	0.562	0.755	0.815	1979	—
Rochester, New York (1,040,000)	Truck Transportation (42)	—	—	—	—	0.575	1979	—
Saginaw, Michigan (235,000)	Truck Transportation (42)	—	—	—	—	0.955	1979	—
Phoenix, Arizona (1.7 million)	Transportation, Communication, and Utilities (40–49)	0.763	0.106	0.075	0.181	0.944	1992	See notes 2 and 5.
Knoxville, Tennessee (450,000)	Wholesale Operations (50–51)	—	—	—	—	0.195	1979	—
Modesto, California (216,000)	Wholesale Operations (50–51)	0.075	0.136	0.129	0.265	0.340	1979	—
Rochester, New York (1,040,000)	Wholesale Operations (50–51)	0.048	0.088	0.084	0.172	0.220	1979	—
Saginaw, Michigan (235,000)	Wholesale Operations (50–51)	0.031	0.056	0.053	0.109	0.140	1979	—
Median	SIC (20–51)	0.060	0.106	0.084	0.181	0.625	—	Truck Trips
Average	SIC (20–51)	0.238	0.120	0.203	0.322	0.565	—	Truck Trips
Minimum	SIC (20–51)	0.031	0.056	0.050	0.109	0.140	—	Truck Trips
Maximum	SIC (20–51)	0.763	0.193	0.562	0.755	0.955	—	Truck Trips
King County, Washington	Manufacturing (20–39)	—	—	—	—	5.580	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Kitsap County, Washington	Manufacturing (20–39)	—	—	—	—	3.525	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)

Notes: TLE = truckload equivalents; SIC = Standard Industrial Classification.

TABLE D-1c
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER EMPLOYEE FOR RETAIL TRADE (SIC 52–59)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Knoxville, Tennessee (450,000)	Retail—Downtown (52–59)	0.075	0.032	0.009	0.040	0.115	1979	—
Modesto, California (216,000)	Retail Trade (52–59)	0.214	0.091	0.025	0.116	0.330	1979	—
Phoenix, Arizona (1.7 million)	Retail—Downtown (52–59)	0.591	0.133	0.037	0.169	0.760	1992	See notes 2 and 5.
Rochester, New York (1,040,000)	Retail—Downtown (52–59)	0.039	0.016	0.004	0.021	0.060	1979	—
Saginaw, Michigan (235,000)	Retail—Downtown (52–59)	—	—	—	—	0.150	1979	—
Median	SIC (52–59)	0.145	0.061	0.017	0.078	0.150	—	Truck Trips
Average	SIC (52–59)	0.230	0.068	0.019	0.087	0.283	—	Truck Trips
Minimum	SIC (52–59)	0.039	0.016	0.004	0.021	0.060	—	Truck Trips
Maximum	SIC (52–59)	0.591	0.133	0.037	0.169	0.760	—	Truck Trips
King County, Washington	Retail Trade (52–59)	—	—	—	—	14.540	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Kitsap County, Washington	Retail Trade (52–59)	—	—	—	—	17.690	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Pierce County, Washington	Retail Trade (52–59)	—	—	—	—	17.040	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Snohomish County, Washington	Retail Trade (52–59)	—	—	—	—	17.770	1994	See note 4. Rates are TLEs and include all modes (truck, rail, air, etc.)
Median	SIC (52–59)					17.365	—	TLEs
Average	SIC (52–59)					16.760	—	TLE's
Minimum	SIC (52–59)					14.540	—	TLE's

Notes: TLE = truckload equivalents; SIC = Standard Industrial Classification.

TABLE D-1d
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER EMPLOYEE FOR OFFICES AND SERVICES (SIC 60–88)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Phoenix, Arizona (1.7 million)	Office and Services (60–87)	0.309	0.021	0.003	0.024	0.334	1992	See notes 2 and 5.
Phoenix, Arizona (1.7 million)	Medical & Government (80)	—	0.006	0.024	0.030	0.325	1992	See notes 2 and 5.
Median	SIC (60–88)	0.309	0.014	0.014	0.027	0.329	—	Truck Trips
Average	SIC (60–88)	0.309	0.014	0.014	0.027	0.329	—	Truck Trips
Minimum	SIC (60–88)	0.309	0.006	0.003	0.024	0.325	—	Truck Trips
Maximum	SIC (60–88)	0.309	0.021	0.024	0.030	0.334	—	Truck Trips

TABLE D-1e
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER EMPLOYEE FOR OTHER LAND USE TYPES (UNCLASSIFIED—SIC 89)

Location/ (Population)	Land Use Type	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Phoenix, Arizona (1.7 million)	Group Quarter Households	—	7.523	—	7.523	7.523	1992	See notes 2 and 5.
Phoenix, Arizona (1.7 million)	Resident Households	0.040	—	0.003	0.003	0.043	1992	See notes 2 and 5. Rates per unit household.
Phoenix, Arizona (1.7 million)	Residential—Total Households	—	—	—	—	0.236	1992	See notes 2 and 5. Rates per unit household.
Washington D.C. (3.5 million)	Government Warehouse and Garage	0.074	0.072	0.084	0.155	0.229	1977	See note 1. Washington D.C. government warehouse and garages averaged to get trip generation rates.
Washington D.C. (3.5 million)	Government Office	—	—	—	—	0.006	1977	See note 1. Washington D.C. government offices averaged to get trip generation rates.

TABLE D-2b
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER 1,000 SQUARE FEET (TSF) OF BUILDING SPACE FOR MANUFACTURING, TRANSPORTATION/COMMUNICATIONS/UTILITIES, AND WHOLESALE TRADE (SIC 20–51)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	Single Unit	Combination Unit	All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
Australia	Manufacturing (20–39)	0.092	0.046	0.090	0.136	0.228	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Australia	Warehouse (20–39)	0.047	0.090	0.090	0.180	0.227	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Boston, Massachusetts (4.6 million)	Manufacturing (20–39)	—	—	—	0.350	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Warehouse (20–39)	—	—	—	0.440	—	1992	Summed various trucks to get total truck trips/TSF.
Fontana, California (>100,000)	Industrial—Heavy (20–39)	—	—	0.190	—	0.280	1994	See note 8.
Fontana, California (>100,000)	Industrial—Light (20–39)	—	—	0.135	—	0.300	1994	See note 8.
Fontana, California (>100,000)	Industrial Park (20–39)	—	—	0.075	—	0.180	1994	See note 8.
Fontana, California (>100,000)	Warehouse—Heavy (20–39)	—	—	0.135	—	0.185	1994	See note 8.
Fontana, California (>100,000)	Warehouse—Light (20–39)	—	—	0.105	—	0.185	1994	See note 8.
Median	SIC (20–39)	0.070	0.068	0.105	0.265	0.227	—	Truck Trips
Average	SIC (20–39)	0.070	0.068	0.117	0.276	0.226	—	Truck Trips
Minimum	SIC (20–39)	0.047	0.046	0.075	0.136	0.180	—	Truck Trips
Maximum	SIC (20–39)	0.092	0.090	0.190	0.440	0.300	—	Truck Trips
Australia	Truck Transportation (42)	0.920	0.700	1.800	2.500	3.420	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Fontana, California (>100,000)	Truck Transportation (42)	—	—	0.895	—	4.370	1994	See note 8.
Knoxville, Tennessee (450,000)	Truck Transportation (42)	0.118	0.573	1.669	2.242	2.360	1979	—
Modesto, California (216,000)	Truck Transportation (42)	0.054	0.264	0.767	1.031	1.085	1979	—
Rochester, New York (1,040,000)	Truck Transportation (42)	0.052	0.255	0.742	0.998	1.050	1979	—
Saginaw, Michigan (235,000)	Truck Transportation (42)	0.135	0.655	1.905	2.560	2.695	1979	—
Median	SIC (42)	0.118	0.573	1.282	2.242	2.528	—	Truck Trips
Average	SIC (42)	0.256	0.489	1.296	1.866	2.497	—	Truck Trips
Minimum	SIC (42)	0.052	0.255	0.742	0.998	1.050	—	Truck Trips
Maximum	SIC (42)	0.920	0.700	1.905	2.560	4.370	—	Truck Trips
Knoxville, Tennessee (450,000)	Wholesale Trade (50–51)	0.032	0.058	0.055	0.113	0.145	1979	—
Modesto, California (216,000)	Wholesale Trade (50–51)	0.106	0.192	0.182	0.374	0.480	1979	—
Rochester, New York (1,040,000)	Wholesale Trade (50–51)	0.044	0.080	0.076	0.156	0.200	1979	—
Saginaw, Michigan (235,000)	Wholesale Trade (50–51)	0.015	0.028	0.027	0.055	0.070	1979	—
Median	SIC (50–51)	0.038	0.069	0.066	0.135	0.172	—	Truck Trips
Average	SIC (50–51)	0.049	0.090	0.085	0.175	0.224	—	Truck Trips
Minimum	SIC (50–51)	0.015	0.028	0.027	0.055	0.070	—	Truck Trips
Maximum	SIC (50–51)	0.106	0.192	0.182	0.374	0.480	—	Truck Trips

Notes: TLE = truckload equivalents; SIC = Standard Industrial Classification.

TABLE D-2c
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER 1,000 SQUARE FEET (TSF) OF BUILDING SPACE FOR RETAIL TRADE (52–59)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	Single Unit	Combination Unit	All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
Australia	Retail Trade—Other (52–59)	0.830	0.190	0.000	0.190	1.020	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Australia	Retailing—Regional Center (52–59)	0.650	0.280	0.460	0.740	1.390	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Baltimore, Maryland—Suburban Area	Retail Trade—Soft (52–59)	—	—	—	—	2.000	1987	See note 5.
Boston, Massachusetts (4.6 million)	Retail—Major (52–59)	0.005	—	—	0.075	0.080	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Boston, Massachusetts (4.6 million)	Retail—Major (52–59)	—	—	—	0.300	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Retail—Storefront (52–59)	0.282	—	—	0.114	0.396	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Boston, Massachusetts (4.6 million)	Retail—Storefront (52–59)	—	—	—	0.170	—	1992	Summed various trucks to get total truck trips/TSF.
Knoxville, Tennessee (450,000)	Retail—Downtown (52–59)	0.062	0.026	0.007	0.033	0.095	1979	—
Modesto, California (216,000)	Retail—Downtown (52–59)	0.413	0.175	0.048	0.222	0.635	1979	—
Rochester, New York (1,040,000)	Retail—Downtown (52–59)	0.065	0.028	0.008	0.035	0.100	1979	—
Saginaw, Michigan (235,000)	Retail—Downtown (52–59)	0.078	0.033	0.009	0.042	0.120	1979	—
Boston, Massachusetts (4.6 million)	Retail—Convenience (53,59)	—	—	—	0.440	—	1992	Summed various trucks to get total truck trips/TSF.
Australia	Retail—Local Supermarket (54)	0.506	0.230	0.090	0.320	0.826	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Australia	Retail—Major Supermarket (54)	0.280	0.190	0.090	0.280	0.560	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Baltimore, Maryland—Suburban Area	Foods—Prepared (54)	—	—	—	—	3.900	1987	See note 5. Converted from one way (trip ends) to total trips.
Australia	Retail Trade—Department Store (56)	0.320	0.460	0.046	0.506	0.826	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Boston, Massachusetts (4.6 million)	Food—Fast (58)	—	—	—	0.770	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Restaurant/Club (58)	—	—	—	0.770	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Restaurants (58)	0.714	—	—	0.494	1.209	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Baltimore, Maryland—Suburban Area	Variety/Pharmacy (59)	—	—	—	—	0.600	1987	See note 5.
Median	SIC (52–59)	0.301	0.190	0.046	0.280	0.635	—	Truck Trips
Average	SIC (52–59)	0.350	0.179	0.084	0.324	0.917	—	Truck Trips
Minimum	SIC (52–59)	0.005	0.026	0.000	0.033	0.080	—	Truck Trips
Maximum	SIC (52–59)	0.830	0.460	0.460	0.770	3.900	—	Truck Trips

TABLE D-2d
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER 1,000 SQUARE FEET (TSF) OF BUILDING SPACE FOR OFFICE AND SERVICES (SIC 60–88)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	Single Unit	Combination Unit	All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
Baltimore, Maryland—Suburban Area	Office Buildings (60–67)	—	—	—	—	0.200	1987	See note 5.
Boston, Massachusetts (4.6 million)	Office (60–67)	0.022	—	—	0.037	0.059	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Boston, Massachusetts (4.6 million)	Office (60–67)	—	—	—	0.110	—	1992	Summed various trucks to get total truck trips/TSF. Converted from one way (arrivals) to two way (total trips).
Boston, Massachusetts (4.6 million)	Hotel (70)	0.012	—	—	0.022	0.034	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Boston, Massachusetts (4.6 million)	Hotel (70)	—	—	—	0.040	—	1992	Summed various trucks to get total truck trips/TSF.
Baltimore, Maryland—Suburban Area	Personal Services (72)	—	—	—	—	2.300	1987	See note 5.
Boston, Massachusetts (4.6 million)	Theater (78)	—	—	—	0.006	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Recreation—Outdoor (79)	—	—	—	0.006	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Office—Medical (80)	—	—	—	0.110	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Hospital (80)	0.005	—	—	0.004	0.009	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Boston, Massachusetts (4.6 million)	Hospital (80)	—	—	—	0.014	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Laboratory (80)	—	—	—	0.110	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	School (82)	—	—	—	0.018	0.018	1992	Summed various trucks to get total truck trips/TSF. See note 7.
Boston, Massachusetts (4.6 million)	School—Public (82)	—	—	—	0.010	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	School—College (82)	—	—	—	0.015	—	1992	Summed various trucks to get total truck trips/TSF.
Boston, Massachusetts (4.6 million)	Library (82)	—	—	—	0.050	—	1992	Summed various trucks to get total truck trips/TSF.
Median	SIC (60–88)		0.012		0.020	0.046	—	Truck Trips
Average	SIC (60–88)		0.013		0.039	0.437	—	Truck Trips
Minimum	SIC (60–88)		0.005		0.004	0.009	—	Truck Trips
Maximum	SIC (60–88)		0.022		0.110	2.300	—	Truck Trips

Note: SIC = Standard Industrial Classification.

TABLE D-2e
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER 1,000 SQUARE FEET (TSF) OF BUILDING SPACE FOR OTHER LAND USES (UNCLASSIFIED—SIC 89)

Location/ (Population)	Land Use Type	4-Tire Commercial Vehicles	Single Unit	Combination Unit	All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
Washington D.C. (3.5 million)	Government Warehouse and Garage	0.022	0.021	0.025	0.047	0.069	1977	See note 1. Washington D.C. government warehouses and garages averaged to get trip generation rate.
Australia	Industry (Light)/High Tech	1.210	0.230	0.046	0.276	1.486	1989	Summed various trucks to get total truck trips/TSF. See note 6.
Boston, Massachusetts (4.6 million)	Residential	—	—	—	0.011	—	1992	Summed various trucks to get total truck trips/TSF.
Washington D.C. (3.5 million)	Government Office	0.011	0.008	0.003	0.011	0.022	1977	See note 1. Washington D.C. government offices averaged to get trip generation rates.

TABLE D-3a
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER ACRE FOR AGRICULTURE, MINING, AND CONSTRUCTION (SIC 1–19)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Columbus, Ohio (810,000)	Agriculture and Vacant (1,2,7)	0.005	—	0.000	0.000	0.005	1964	Summed various trucks to get total truck trips/acre. See note 9.
Racine, Wisconsin (136,952)	Agriculture and Related (1–9)	0.005	—	0.000	0.000	0.005	1972	Summed various trucks to get total truck trips/acre. See note 10.
Kenosha, Wisconsin (99,664)	Agriculture and Related (1–9)	0.010	—	0.000	0.000	0.010	1972	Summed various trucks to get total truck trips/acre. See note 10.
Columbus, Ohio (810,000)	Mining (10–14)	—	0.005	—	—	0.005	1964	Summed various trucks to get total truck trips/acre. See note 9.
Median	SIC (1–14)	0.005	0.005	0.000	0.000	0.005	—	Truck Trips
Average	SIC (1–14)	0.007	0.005	0.000	0.000	0.006	—	Truck Trips
Minimum	SIC (1–14)	0.005	0.005	0.000	0.000	0.005	—	Truck Trips
Maximum	SIC (1–14)	0.010	0.005	0.000	0.000	0.010	—	Truck Trips

Note: SIC = Standard Industrial Classification.

TABLE D-3b
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER ACRE FOR MANUFACTURING, TRANSPORTATION/COMMUNICATIONS/UTILITIES, AND WHOLESALE TRADE (SIC 20–51)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Chicago, Illinois (8 million)	Manufacturing (20–39)	—	—	—	—	3.600	1979	—
Richmond, Virginia	Manufacturing (20–39)	—	—	—	—	2.800	1979	—
Baton Rouge, Louisiana	Manufacturing (20–39)	—	—	—	—	1.300	1979	—
Columbia, South Carolina	Manufacturing (20–39)	—	—	—	—	1.500	1979	—
Monroe, Louisiana	Manufacturing (20–39)	—	—	—	—	5.900	1979	—
Little Rock, Arkansas	Manufacturing (20–39)	—	—	—	—	0.400	—	—
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Manufacturing (20–39)	—	—	—	—	1.805	1981	—
Flint, Michigan (470,000)	Manufacturing (20–39)	5.185	1.030	1.080	2.110	7.295	1966	Summed various trucks to get total truck trips/acre.

Note: SIC = Standard Industrial Classification.

TABLE D-3c
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER ACRE FOR RETAIL TRADE (SIC 52–59)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Flint, Michigan (470,000)	Retail (52–59)	5.925	2.800	0.565	3.365	9.290	1966	Summed various trucks to get total truck trips/acre.
Median	SIC (52–59)	5.925	2.800	0.565	3.365	9.290	—	Truck Trips
Average	SIC (52–59)	5.925	2.800	0.565	3.365	9.290	—	Truck Trips
Minimum	SIC (52–59)	5.925	2.800	0.565	3.365	9.290	—	Truck Trips
Maximum	SIC (52–59)	5.925	2.800	0.565	3.365	9.290	—	Truck Trips

Note: SIC = Standard Industrial Classification.

TABLE D-3d
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER ACRE FOR OFFICE AND SERVICES (SIC 60–88)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Flint, Michigan (470,000)	Services (70–89)	2.464	0.595	0.090	0.685	3.149	1966	Summed various trucks to get total truck trips/acre.
Flint, Michigan (470,000)	Cultural, Recreation, Entertainment (79)	0.155	0.050	0.005	0.055	0.210	—	—
Racine, Wisconsin (136,952)	Recreation (79)	0.015	—	—	0.010	0.025	1972	Summed various trucks to get total truck trips/acre. See note 10.
Kenosha, Wisconsin (99,664)	Recreation (79)	—	—	—	—	0.005	1972	Summed various trucks to get total truck trips/acre. See note 10.
Columbus, Ohio (810,000)	Recreation, Open Space (79)	0.015	0.150	0.115	0.265	0.280	1964	Summed various trucks to get total truck trips/acre. See note 9.
Richmond, Virginia	Services—Schools, Government (82)	—	—	—	—	4.000	1979	—
Baton Rouge, Louisiana	Services—Schools, Government (82)	—	—	—	—	2.600	1979	—
Columbia, South Carolina	Services—Schools, Government (82)	—	—	—	—	2.300	1979	—

Note: SIC = Standard Industrial Classification.

TABLE D-3e
TRIP GENERATION SUMMARY—DAILY COMMERCIAL VEHICLE TRIPS PER ACRE FOR OTHER LAND USES (UNCLASSIFIED—SIC 89 OR COMBINATION OF VARIOUS SICS)

Location/ (Population)	Land Use Type (SIC)	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	Date	Notes/Comments
			Single Unit	Combination Unit				
Kenosha, Wisconsin (99,664)	Commercial Wholesale and Storage	0.970	0.500	0.020	1.520	2.490	1972	Summed various trucks to get total truck trips/acre. See note 10.
Racine, Wisconsin (136,952)	Commercial Wholesale and Storage	1.345	1.695	0.065	1.760	3.105	1972	Summed various trucks to get total truck trips/acre. See note 10.
Richmond, Virginia	Retail—Wholesale (50–59)	—	—	—	—	10.300	1979	—
Baton Rouge, Louisiana	Retail—Wholesale (50–59)	—	—	—	—	33.600	1979	—
Little Rock, Arkansas	Retail—Wholesale (50–59)	—	—	—	—	16.000	1979	—
Columbia, South Carolina	Retail—Wholesale (50–59)	—	—	—	—	20.300	1979	—
Monroe, Louisiana	Retail—Wholesale (50–59)	—	—	—	—	35.000	1979	—
Chicago, Illinois (8 million)	Commercial	—	—	—	—	14.250	1975	See note 5.

TABLE D-4a
TRIP GENERATION SUMMARY—REGRESSION FORMULAS FOR DAILY COMMERCIAL VEHICLE TRIPS FOR AGRICULTURE, MINING, AND CONSTRUCTION (1–19)

Location	Land Use Type (SIC)	Date	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	R^2	Notes/Comments
				Single Unit	Combination Unit				
Leake and Gan (unknown), London?	Road Haul Contractors (17)	1973	—	—	—	—	$1.69 + (1.73 * N) - (.02 * N^2)$	0.58	N = Total non-office floor area in 1,000 sq. ft. See note 4.

Note: SIC = Standard Industrial Classification.

TABLE D-4b
TRIP GENERATION SUMMARY—REGRESSION FORMULAS FOR DAILY COMMERCIAL VEHICLE TRIPS FOR MANUFACTURING, TRANSPORTATION/ COMMUNICATIONS/ UTILITIES, AND WHOLESALE TRADE (20–51)

Location/ (Population)	Land Use Type (SIC)	Date	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	R^2	Notes/Comments
				Single Unit	Combination Unit				
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Manufacturing (20–39)	1981	163.4 + (95.16*MANL)	933.5 + (31.01*MANL)	255.8 + (28.2*MANL)	—	$1.69 + (1.73*N) - (0.02*N^2)$	0.07 to 0.48	MANL = Manufacturing land in the district. See note 5.
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Manufacturing (20–39)	1981	253.8 + (2.1*MANEMP)	257.6 + (5.11*MANEMP)	271.6 + (2.3*MANEMP)	529.2 + (7.41*MANEMP)	730.6 + (9.7*MANEMP)	0.25 to 0.58	MANEMP = Employment at manufacturing sites. See note 5.
Starkie, London–Industrial Suburb	Manufacturing and Engineering (20–39)	1967	—	—	—	—	26.96 + (0.0377*E)	0.24	E = Employment. See note 4.
Starkie, London–Industrial Suburb	Manufacturing and Engineering (20–39)	1967	—	—	—	—	19.44 + (0.0003*FA)	0.36	FA = Floor area. See note 4.
Fontana, California (>100,000)	Industrial—Heavy (20–39)	1994	—	—	78 – (0.652*TSF)	—	127.3 – (1.09*TSF)	—	TSF = Building area in thousands of gross sq. ft. See note 8.
Fontana, California (>100,000)	Industrial–Light (20–39)	1994	—	—	3.39 + (0.0877*TSF)	—	13.94 + (0.148*TSF)	0.98	TSF = Building area in thousands of gross sq. ft. See note 8.
Fontana, California (>100,000)	Industrial Park (20–39)	1994	—	—	–0.93 + (0.16*TSF)	—	24.87 + (0.208*TSF)	0.3	TSF = Building area in thousands of gross sq. ft. See note 8.
Fontana, California (>100,000)	Warehouse—Heavy (20–39)	1994	—	—	37.75 + (0.2249*TSF)	—	57.653 + (0.2891*TSF)	—	TSF = Building area in thousands of gross sq. ft. See note 8.
Fontana, California (>100,000)	Warehouse—Light (20–39)	1994	—	—	11.43 + (0.1406*TSF)	—	30.44 + (0.1785*TSF)	0.6	TSF = Building area in thousands of gross sq. ft. See note 8.
Leake and Gan (unknown), London?	Industrial (Other) Materials and Mach. (20–39)	1973	—	—	—	—	$5.29 + (22.9*S) - (2.4*S^2)$	0.32	S = Site area in acres. See note 4.
Columbus, Ohio (1.1 million)	Industry-Oriented (35)	1980	—	—	—	—	16.2 + (0.28*INE) + (0.18*CTUE)	0.26	INE = Industrial non–manufacturing employment; CTUE = Communication, transportation, and utility employment. See note 5.
Flint, Michigan (593,000)	Industry-Oriented (35)	1980	—	—	—	—	37.6 + (0.2*OE) + (0.13*ME)	0.73	OE = Other employment; ME = Manufacturing employment. See note 5.
Saginaw, Michigan (236,000)	Industry-Oriented (35)	1980	—	—	—	—	6.12 + (0.36*TCE) + (0.09*TE)	0.64	TCE = Transportation and communications empl. TE = Total empl. See note 5.

TABLE D-4b *(Continued)*

Location/ (Population)	Land Use Type (SIC)	Date	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	R^2	Notes/Comments
				Single Unit	Combination Unit				
Fontana, California (>100,000)	Truck Sales and Leasing (37)	1994	—	—	–2.8 + (1.89*TSF)	—	–189.4 – (1.53*TSF)	0.21	TSF = Building area in thousands of gross sq. ft. See note 8.
NE Illinois/NW Indiana—Eight Counties (>8 million)	Transportation, Communications, Utilities (40–49)	1981	279.3 + (7.77*TCUEMP)	—	390.4 + (10.5*TCUEMP)	—	1384.1 + (10.3*TCUEMP)	0.21 to 0.65	TCUEMP = Employment at transportation, communications, utilities. See note 5.
NE Illinois/NW Indiana—Eight Counties (>8 million)	Transportation, Communications, Utilities (40–49)	1981	—	540.6 + (11.51*TCUL)	—	—	—	0.16	TCUL = Transportation, communications, utilities land in the district. See note 5.
Fontana, California (>100,000)	Truck Transportation (42)	1994	—	—	–72 + (38.2*TSF)	—	–108 + (50.6*TSF)	0.1	TSF = Building area in thousands of gross sq. ft. See note 8.
Nashville, Tennessee (770,000)	Truck Transportation (42)	1990	—	—	—	—	(2.0552*TE) – 3.4407	0.726	TE = Number of terminal employees.
Leake and Gan (unknown), London?	Wholesale Distribution–Food, Drink (51)	1973	—	—	—	—	–1.88 + (1.75*N)	0.81	N = Total non-office floor area in 1,000 sq. ft. See note 4.

TABLE D-4c
TRIP GENERATION SUMMARY—REGRESSION FORMULAS FOR DAILY COMMERCIAL VEHICLE TRIPS FOR RETAIL TRADE (SIC 52–59)

Location/ (Population)	Land Use Type (SIC)	Date	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	R^2	Notes/Comments
				Single Unit	Combination Unit				
Leake and Gan (unknown), London?	Builders and Agriculture Supplies (52)	1973	—	—	—	—	1.69 + (1.73**N*) – (0.02*N^2)	0.83	*F* = Total floor area in 1,000 sq. ft. See note 4.
Gastonia, North Carolina (166,000)	Goods (52–59)	1980	—	—	—	—	50.1 + (1.1*RE) + (0.33*LIDU)	0.37	RE = Retail employment; LIDU = Low-income dwelling units. See note 5.

TABLE D-4d
TRIP GENERATION SUMMARY—REGRESSION FORMULAS FOR DAILY COMMERCIAL VEHICLE TRIPS FOR OFFICE AND SERVICES (SIC 60–88)

Location/ (Population)	Land Use Type (SIC)	Date	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	R^2	Notes/Comments
				Single Unit	Combination Unit				
Gastonia, North Carolina (166,000)	Service (70–89)	1980	—	—	—	—	$1.69 + (1.73*N) - (0.02*N^2)$	0.27	HE = Highway employment; TE = Total employment. See note 5.

TABLE D–4e
TRIP GENERATION SUMMARY—REGRESSION FORMULAS FOR DAILY COMMERCIAL VEHICLE TRIPS FOR OTHER LAND USES (UNCLASSIFIED—SIC 89)

Location/ (Population)	Land Use Type (SIC)	Date	4-Tire Commercial Vehicles	6+ Tire Commercial Vehicles		All 6+ Tire Commercial Vehicles	All Commercial Vehicles	R^2	Notes/Comments
				Single Unit	Combination Unit				
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Commercial	1981	—	—	515.7 + (18.9*COML)	—	1.69 + (1.73*N) – (0.02*N^2)	0.17 to 0.22	COML = Commercial land in the district. See note 5.
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Commercial	1981	1,112.2 + (9.76*COMEMP)	2,492.1 + (3.6*COMEMP)	305.7 + (2.2*COMEMP)	—	2,252.7 + (23.7*COMEMP)	0.18 to 0.50	COMEMP = Employment at commercial sites. See note 5.
Columbus, Ohio (1.1 million)	Commercial Oriented	1980	—	—	—	—	54.6 + (0.51*INE) + (0.18*CGE)	0.35	INE = Industrial non–manufacturing employment; CGE = Commercial and government employment. See note 5.
Flint, Michigan (593,000)	Commercial Oriented	1980	—	—	—	—	73.3 + (0.59*CE) + (0.36*TDU)	0.47	CE = Commercial employment; TDU = Total dwelling units. See note 5.
Saginaw, Michigan (236,000)	Commercial Oriented	1980	—	—	—	—	11.9 + (0.38*TDU) + (0.37*TE)	0.65	TDU = Total dwelling units; CE = Commercial employment. See note 5.
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Residential (88)	1981	762.7 + (5.43*DU)	—	—	—	416.7 + (16*DU)	0.21 to 0.37	DU = Dwelling units. See note 5.
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Residential (88)	1981	–188.8 + (35.38*RESL) + (2.86*DU)	—	—	—	1078.6 + (56.5*RESL) + (11.7*DU)	0.54 to 0.55	RESL = Residential land in the district; DU = Dwelling units. See note 5.
NE Illinois/ NW Indiana—Eight Counties (>8 million)	Public Buildings	1981	196.5 + (20.92*PB)	—	—	—	112.6 + (73.6*PB)	0.17 to 0.43	PB = Public buildings in the district. See note 5.

NOTES (Trip Generation Summary Tables)
1. Commercial vehicles distributed accordingly:
   – Auto/pickup/truck/van = 4-tire commercial vehicles.
   – Single-unit truck = 6+ tire single unit.
   – Semi-trailer = 6+ tire combination unit.
2. Commercial vehicles distributed accordingly:
   – 0–8,000 lb commercial vehicles = 4-tire commercial vehicles.
   – 8,000–28,000 lb commercial vehicles = 6+ tire single unit.
   – 28,000+ lb commercial vehicle = 6+ tire combination unit.
3. Commercial vehicles distributed accordingly:
   – 2-axle commercial vehicle = 4-tire commercial vehicles.
   – 3-axle commercial vehicle = 6+ tire single-unit truck.
   – 4+ axle commercial vehicle = 6+ tire combination unit.
4. Assuming trip rate includes all commercial vehicles.
5. No time period indicated; assumed daily.
6. Commercial vehicles distributed accordingly:
   – Courier vans plus light rigid trucks = 4-tire commercial vehicles.
   – Heavy rigid trucks = 6+ tire single-unit truck.
   – Articulated trucks = 6+ tire combination unit.
7. Light commercial vehicles (4-wheeled trucks and vans) = 4-tire commercial vehicles.
8. 4+ axle trucks = 6+ tire combination unit.
9. Commercial vehicles distributed accordingly:
   – Light trucks (panel and pickup) = 4-tire commercial vehicles.
   – Medium trucks (all other commercial trucks except combination) = 6+ tire single-unit truck.
10. Light [under 8,000 lb except farm (under 10,000 lb)] = 4-tire commercial vehicles.

SECTION C-4 DEVELOPMENT OF URBAN COMMERCIAL VEHICLE TRAVEL MODEL AND HEAVY-DUTY VEHICLE EMISSIONS MODEL FOR ATLANTA REGION

Sub-Model	Industrial Employment	Retail Employment	Office Employment	Population
Light Truck	0.4823	0.6426	0.2315	0.0559
Heavy Truck	0.1439	0.2463	0.0829	0.0147

Note: International model trip rates (per employee or per person).

Model	Constant	Population (xT^x)	Government Employment (xT^x)	Industrial Employment (xT^x)	Retail Employment (xT^x)	R^2
Light w/constant	7.27	0.081	0.146	0.342	—	0.14
Final		0.088	1.039	0.596	—	NA
Heavy w/constant	15.14	0.0002	0.0126	0.0487	0.0439	0.36
Final		0.0013	0.057	0.057	0.0461	NA

Notes: External truck trip regression equations.
NA = not available.
Light truck time exponent is –1.15.
Heavy truck time exponent is –0.35.

SECTION C-5 MAG (PHOENIX AREA)

	GVWR (lb)				
Independent variable*	0–8,000	8–28,000	28–64,000	64,000+	28,000+
Total households	0.15433	0.06859	0.00671	0.0059	0.0126
Retail employment	0.59091	0.13253	0.03075	0.00609	0.03685
Industrial employment	0.64087	0.09972	0.0321	0.01781	0.04991
Public employment	0.29491	0.00596	0.01349	0.01049	0.02398
Office employment	0.30925	0.02119	0.00225	0.00095	0.0032
Other employment	0.76348	0.10567	0.04026	0.035	0.07527
Resident households	0.04004		0.00288		0.00288
Group quarter households		7.52348			
Total area (acres *100)				0.00365	0.00365
Vehicles				0.00062	0.00062

Notes: MAG = Maricopa Association of Governments; GVWR = Gross vehicle weight rating.
*Household trip rates are per household; all other trip rates are trips per employee.

SECTION C-6 ALAMEDA

	Trips per 1,000 employees		
	2-axle trucks	3-axle trucks	4+ axle trucks
Internal Garage-Based Productions			
Manufacturing	11	2	4
Retail	14	—	—
Business Service	1	—	—
Other Employment	5	4	8
Internal Garage-Based Attractions			
Other Employment	—	5	14
Total Employment	23	—	—
Internal Linked Productions & Attractions			
Total Employment	32	4	7
Internal–External Productions			
Manufacturing	—	2	22
Other Employment	—	1	9
Total Employment	4	—	—

SECTION C-7 SCAG—INTERNAL TRIP RATES*

	Outbound				Inbound			
	LH	MH	HH	Subtotal	LH	MH	HH	Subtotal
Households	0.0390	0.0087	0.0023	0.0500	0.0390	0.0087	0.0023	0.0500
Agric./Mining/ Construction	0.0513	0.0836	0.0569	0.1919	0.0513	0.0836	0.0569	0.1919
Retail	0.0605	0.0962	0.0359	0.1925	0.0605	0.0962	0.0359	0.1925
Government	0.0080	0.0022	0.0430	0.0533	0.0080	0.0022	0.0430	0.0533
Manufacturing	0.0353	0.0575	0.0391	0.1319	0.0353	0.0575	0.0391	0.1319
Transportation	0.2043	0.0457	0.1578	0.4078	0.2043	0.0457	0.1578	0.4078
Wholesale	0.0393	0.0650	0.0633	0.1677	0.0393	0.0650	0.0633	0.1677
Service	0.0091	0.0141	0.0030	0.0262	0.0091	0.0141	0.0030	0.0262

Notes: SCAG = Southern California Association of Governments. LH = light-heavy (8,501–14,000 lb GVW); MH = medium-heavy (14,001–33,000 lb GVW); HH = heavy-heavy (>33,000 lb GVW).
*Household trip rates are trips per household; all other trip rates are trips per employee.

SECTION C-8 BUFFALO

Land Use at Trip Ends	Trip Rates (per person/employee)
HH (population)	0.00188
Manufacturing	0.07187
Retail	0.15091
Wholesale	0.08731
Other	0.00514
Parcel pickup and delivery	
Households	0.00665
Businesses	0.02762

SECTION C-9 WEST VIRGINIA

Land Use	SEV	Average Weekday Rates	Valid Results?	Weekday Traffic Project Range	Weekday Regression Results	Weekday K (%)	Trucks (%)
Light Industrial Parks	Acres	12.67	N	±2032	Poor	13	8
Poultry-Related	Employees	2.08	Y	—	Good	14	12.8
Facilities	1,000 SF GFA	8.94	Y	±597	Good	14	12.8
Timber	Employees	4.39	Y	—	NRU	12	12.2
Processing							
Facilities	1,000 SF GFA	2.03	Y	—	NRU	12	12.2

Notes: NRU = not recommended for use; N = no; Y = yes; — = not determined; SEV = socioeconomic variable.

SECTION C-10 VANCOUVER

	Sub-Area Light Truck Rates			
Variable	Area 0	Area 1	Area 2	Area 3
POP	0.0077		0.0037	0.0216
PRIM	0.0964		0.0130	0.1403
MANU	0.0688		0.0199	0.0863
CONS	0.0609		0.0075	0.1503
TCU	0.0709		0.0280	0.4944
WHOL	0.2292		0.0746	0.1725
RET	0.1425		0.0782	0.1287
FIRE+BUS	0.0429		0.0225	0.0200
EH&S	0.0210		0.0236	0.0260
AF&O	0.0450		0.0296	0.0732
TOTEMP		0.0378		

Light Truck Sub-Areas
Area 0 All zones not in Area 1, Area 2, or Area 3.
Area 1 Vancouver CBD.
Area 2 North Vancouver, Valley North, Valley South.
Area 3 West Vancouver, rest of Vancouver, Pitt Meadows/Maple Ridge.

Note: Population trip rates are per person; all other trip rates are trips per employee.

	Sub-Area Heavy Truck Rates			
Variable	Area 0	Area 1	Area 2	Area 3
POP	0.0006		0.0006	0.0016
PRIM	0.2023		0.0333	0.0840
MANU	0.0758		0.0342	0.0901
CONS	0.0421		0.0757	0.0436
TCU	0.0409		0.0376	0.1591
WHOL	0.0740		0.0612	0.1512
RET	0.0305		0.0257	0.0331
FIRE+BUS	0.0013		0.0014	0.0022
EH&S	0.0030		0.0041	0.0081
AF&O	0.0212		0.0095	0.0311
TOTEMP		0.0059		

Heavy Truck Sub-Areas
Area 0 All zones not in Area 1, Area 2, or Area 3.
Area 1 Vancouver CBD.
Area 2 Rest of Vancouver, Burnaby/New Westminster.
Area 3 Northeast Sector, South Delta, Pitt Meadows/Maple Ridge, Langleys.

Notes: POP = population; PRIM = primary industry (agriculture, forestry, mining); MANU = manufacturing; CONS = construction; TCU = transportation, communications, and utilities; WHOL = wholesale trades; RET = retail trade; FIRE + BUS = finance, insurance, and real estate + business services; EH&S = education, health, and social services; AF&O = accommodations, food, and other services; TOTEMP = total employment.

SECTION C-11 LANCASTER ENGINEERING

Sites	AM Peak Trip Rates	PM Peak Trip Rates	Daily Trip Rates
Fort James	0.038	0.028	0.574
Columbia Sportswear	0.049	0.036	1.151
Nike Distribution	0.100	0.098	2.009
Average rate	0.062	0.054	1.245
Trip Manual rate	0.450	0.510	4.960

Note: Trips per 1,000 square feet.

SECTION C-12 DESHAZO TANG & ASSOCIATES

Condition		Trip Generation Rate per 1,000 sq. ft. of Gross Floor Area	Inbound (% of total)	Trucks (%)	Outbound (% of Total)	Trucks (%)
AM Peak–Hour of Adjacent Street (6:30–7:30)	Alliance	0.233	73	51	27	56
	Railhead	0.4083	77	27	23	37
	Average	0.3208	75	39	25	46
	ITE—Industrial Park	0.89	82	NA	18	NA
	ITE—Light Industrial	0.92	88	NA	12	NA
Midday Site–Related Peak Hour (12:00–1:00)	Alliance	0.1645	51	61	49	55
	Railhead	0.5978	49	26	51	35
	Average	0.3811	50	43	50	45
	ITE—Industrial Park	0.82	86	NA	14	NA
	ITE—Light Industrial	NA	NA	NA	NA	NA
Afternoon Site–Related Peak Hour (3:30–4:30)	Alliance	0.2732	34	63	66	50
	Railhead	0.3701	39	24	61	37
	Average	0.3216	37	43	63	43
	ITE—Industrial Park	0.86	21	NA	79	NA
	ITE—Light Industrial	NA	NA	NA	NA	NA
PM Peak–Hour of Adjacent Street Traffic (5:00–6:00)	Alliance	0.1411	33	63	67	51
	Railroad	0.4711	40	28	60	60
	Average	0.3061	36	46	64	56
	ITE—Industrial Park	0.92	21	NA	79	NA
	ITE—Light Industrial	0.98	12	NA	88	NA

Notes: ITE = Institute of Transportation Engineers; NA = not available.

SECTION C-13 FLORIDA DOT FREIGHT TONNAGE GENERATION EQUATIONS

Production Equations

	Code Name/ Commodity Groups	Coefficient	Variable
1	Agricultural	89.420	SIC07
2	Nonmetallic Minerals	5193.245	SUM(SIC10-14)
3	Coal		
4	Food	412.200	SIC20
5	Non-Durable Mfg.	28.227	SUM(SIC21,22,23,25,27)
6	Lumber	381.813	SIC24
7	Chemicals	1031.52	SIC28
8	Paper	247.62	SIC26
9	Petroleum Products	1485.754	SIC29
10	Other Durable Mfg.	23.771	SUM(SIC30,31,33–39)
11	Clay, Concrete, Glass	2659.828	SIC32
12	Waste	0.164	TOTEMP
13	Misc. Freight	0.047	TOTEMP
14	Warehousing	184.297	SIC50&51

Attraction Equations

	Code Name/ Commodity Groups	Coefficient 1	Variable	Coefficient 2	Variable
1	Agricultural	40.328	SIC20		
2	Nonmetallic Minerals	2052.751	SIC28		
3	Coal	246.607	SIC49		
4	Food	136.983	SIC51		
5	Non-Durable Mfg.	30.257	SIC51		
6	Lumber	258.344	SIC25	0.469	Pop
7	Chemicals	102.57	SIC51		
8	Paper	29.56	SIC51		
9	Petroleum Products	0.248	Pop		
10	Other Durable Mfg.	57.888	SIC50		
11	Clay, Concrete, Glass	3.191	Pop		
12	Waste	115.988	SIC33		
13	Misc. Freight	1.478	SUM(SIC42,44,45)		
14	Warehousing	3.118	Pop		