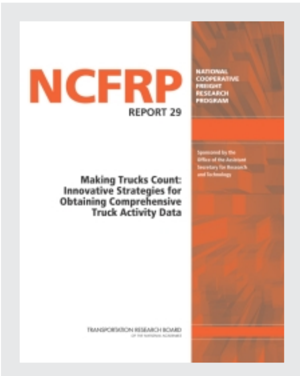

Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

NCFRP REPORT 29

Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data

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NATIONAL COOPERATIVE FREIGHT RESEARCH PROGRAM

America's freight transportation system makes critical contributions to the nation's economy, security, and quality of life. The freight transportation system in the United States is a complex, decentralized, and dynamic network of private and public entities, involving all modes of transportation—trucking, rail, waterways, air, and pipelines. In recent years, the demand for freight transportation service has been increasing fueled by growth in international trade; however, bottlenecks or congestion points in the system are exposing the inadequacies of current infrastructure and operations to meet the growing demand for freight. Strategic operational and investment decisions by governments at all levels will be necessary to maintain freight system performance, and will in turn require sound technical guidance based on research.

The National Cooperative Freight Research Program (NCFRP) is a cooperative research program sponsored by the Office of the Assistant Secretary for Research and Technology under Grant No. DTOS59-06-G-00039 and administered by the Transportation Research Board (TRB). The program was authorized in 2005 with the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). On September 6, 2006, a contract to begin work was executed between the Research and Innovative Technology Administration, which is now the Office of the Assistant Secretary for Research and Technology, and The National Academies. The NCFRP will carry out applied research on problems facing the freight industry that are not being adequately addressed by existing research programs.

Program guidance is provided by an Oversight Committee comprised of a representative cross section of freight stakeholders appointed by the National Research Council of The National Academies. The NCFRP Oversight Committee meets annually to formulate the research program by identifying the highest priority projects and defining funding levels and expected products. Research problem statements recommending research needs for consideration by the Oversight Committee are solicited annually, but may be submitted to TRB at any time. Each selected project is assigned to a panel, appointed by TRB, which provides technical guidance and counsel throughout the life of the project. Heavy emphasis is placed on including members representing the intended users of the research products.

The NCFRP will produce a series of research reports and other products such as guidebooks for practitioners. Primary emphasis will be placed on disseminating NCFRP results to the intended end-users of the research: freight shippers and carriers, service providers, suppliers, and public officials.

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The project that is the subject of this report was a part of the National Cooperative Freight Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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FOREWORD

By William C. Rogers
Staff Officer
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NCFRP Report 29: Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data develops and assesses strategies for obtaining comprehensive trucking activity data for making more informed public policy decisions at the national and regional levels. The report focuses on improving existing approaches rather than creating completely new ones, with a goal of yielding meaningful results in 5 to 7 years. Three approaches were developed in detail: (1) using GPS traces to understand trucking activities, (2) a re-conceptualized Vehicle Inventory and Use Survey (VIUS), and (3) agent-based models for freight transportation.

Implementing the Moving Ahead for Progress in the 21st Century Act (MAP-21) will require the application of performance measures and performance management for which better freight data will be critical. Although such planning and data must be multimodal, documenting trucking activity will be most important because trucks move about 70% of total tonnage and value shipped in the United States. Effective policy making will require information to answer such questions as how much freight is moved by trucks, what types of freight are moved by trucks, and how much road traffic is generated by the movement of freight. However, no public dataset with current comprehensive, longitudinal statistics on highway-truck freight activity exists.

Under NCFRP Project 39, RAND Corporation was asked to (1) briefly describe the state of the practice in the United States and other countries for obtaining and reporting truck activity data used for public policy decisions at the national and regional levels; (2) describe reliability and gaps in data availability in the United States, discuss data issues and limitations, and illustrate how improved data could be used to better inform public policy decisions; (3) investigate, develop, and assess strategies to obtain comprehensive trucking activity data; and (4) describe in detail how recommended strategies could be implemented in practice, including a thorough discussion of specific mechanisms required to collect the data as well as barriers and opportunities to successful implementation of the strategies.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Making Trucks Count: Innovative Strategies for Obtaining Comprehensive Truck Activity Data

The objective of NCFRP Project 39: Making Trucks Count is to suggest innovative approaches to obtain and make publicly available comprehensive truck-activity data. To fulfill this objective, the research team reviewed the current state of truck-activity data and assessed data issues and limitations to determine critical gaps. Based on this review, the team proposed strategies for obtaining more comprehensive truck-activity data and conducted feasibility reviews of these techniques. After feedback from the project oversight panel, the research team then provided in-depth implementation strategies for the three most promising strategies. The research methods for this study included literature reviews, dataset evaluations, and key informant interviews.

Implementing a national freight policy, as required by the Moving Ahead for Progress in the 21st Century Act (MAP-21), requires strategic planning and data. MAP-21 also focuses directly on expanding the use and application of performance measures and performance management, for which better freight data will be critical. Although such planning and data must be multimodal, documenting trucking activity will be most important: trucking comprises about 70 percent of total tonnage and value shipped in the United States, and is growing (U.S. Bureau of the Census Commodity Flow Survey, 2007). Effective policy making will require information to answer such questions as the following:

1. How much freight is moved by trucks? The answer to this question is helpful not only for planning purposes but also as a leading indicator of the economic health of the country.
2. What types of freight are moved by trucks? Vehicle type, weight, and origin and destination vary by type of freight, which also has differing impacts on the transportation system, air quality, and land use.
3. How much road traffic is generated by the movement of freight? Data on truck-vehicle miles can help analyze the relationship between the total volume of freight and the amount of vehicle traffic required to carry it, as well as how this traffic contributes to congestion and environmental degradation.

Answering these questions requires comprehensive, longitudinal statistics that are not available. Currently, there is no public dataset with comprehensive, longitudinal statistics on highway-truck freight activity. In part, this is because trucking activity is highly fragmented, with hundreds of thousands of businesses, varying enormously in size, and shipping myriad goods over innumerable routes. Yet, given its scale and complexity, it is impossible to analyze and understand highway-truck freight activity in the absence of large statistical databases.

Information Gaps

Early in the study, the team identified the data elements that were most important for freight policy and planning needs, assessed their availability and accessibility, and used this information to begin determining potential innovative strategies for ameliorating current coverage limitations. The data elements were as follows:

- **Vehicle Miles Traveled (VMT):** Measure of the extent of motor vehicle operation within a specific geographic area over a given period of time.
- **Tons/Ton-Miles:** Total weight of the entire shipment/shipment weight multiplied by the mileage traveled by the shipment.
- **Value/Value-Miles:** Market value of shipments multiplied by the mileage traveled by the shipment.
- **Origin-Destination (O/D) Flows:** The start and end points for a particular truck trip.
- **Vehicle Speed:** Velocity of a vehicle.
- **Transportation Cost:** Cost of freight movement by truck.

The research team focused not only on these specific research elements, but also on how comprehensive current sources were in covering these variables by commodity type, vehicle type, vehicle characteristics, and different levels of geography. The team's initial assessment considered the range of ways for obtaining truck-activity variables: surveys, administrative records, synthetic or amalgamated datasets, roadway operations data sources, and modeling approaches. The key findings of this assessment follow:

- Because of the patchwork nature of the truck-activity data infrastructure, users must piece together information from many sources to answer critical policy questions.
- The Commodity Flow Survey (CFS) is the basis for understanding freight in America. For data on tons and ton-miles of goods transported, all current data sources depend on the CFS. This survey is conducted only every 5 years and does not cover all shipments by truck.
- Usability is a significant issue for many current data sources, which require a great deal of technical knowledge to use and visualize the data.
- There is no method for verifying modeled truck-activity data, such as the Freight Analysis Framework (FAF) or Transearch.
- Transparency in data sources and auditing procedures is a problem for nearly all the reviewed data sources. The only source that comes close to being sufficiently transparent is CFS. All other sources have problems ranging from private access to data, to unclear or obscured processing procedures, to lack of standardized collections, auditing, and uniformity of data collection periods.
- Two ways to offer an improved, comprehensive source are (1) expanding an existing source to contain more needed measures than currently available or (2) a method, such as the FAF, for integrating and synthesizing data and yielding more of the needed measures.
- A new innovative source for comprehensive truck-activity data needs to focus not only on data elements but also on statistical rigor, quality assurance, and accessibility.

Innovative Strategies

In identifying possible new approaches, the research team focused on improving existing approaches rather than creating completely new ones. Hence, the team characterizes the strategies addressed in this study as "relative" innovations—not "disruptive" ones. Given the institutional and political climates in which such improvements must be made, this seemed to be a reasonable and realistic approach. These are approaches that could yield meaningful results in 5 to 7 years. The researchers considered innovation as a process of evolution rather than a revolution in methods for obtaining data. Such evolution offers new ways of obtaining data—either more efficiently, more effectively, or both. In the short term, the proposed strategies may provide opportunities for analyses that inspire a new perspective or for the collection of data that break down traditional institutional silos.

The team identified 11 innovative strategies that could overcome limitations of current data sources. These strategies fell into one of four categories: (1) survey approaches, (2) passively collected data, (3) administrative data, and (4) modeling approaches. The researchers assessed the feasibility of these strategies. This included assessing the ability to collect the data as well as technical, institutional, operational, geographic, and financial issues. A star rating system was used to compare approaches.

The research team identified three approaches that were most likely to be implemented successfully, and developed detailed implementation scenarios for them. These were

1. **Using GPS traces to understand trucking activities.** Trucks equipped with GPS, or drivers carrying GPS-enabled devices (e.g., smart phones), create traces for the movement of each truck. Amassing this data using cloud technologies would create an innovative dataset on origins and destinations by time of day. Appending multiple attributes such as commodity or ownership can create many additional dimensions of truck activity.
2. **Re-conceptualized Vehicle Inventory and Use Survey (VIUS).** The TIUS/VIUS (Truck Inventory and Use Survey/Vehicle Inventory and Use Survey) series, which was initiated in 1963 and conducted as part of the economic census every 5 years starting in 1967, ended in 2002 due to financial constraints. This survey was central to national and state-level measures of the scope and character of the trucking industry. This strategy would entail reestablishing the survey system and consider opportunities or requirements for modifying and expanding approach and content.
3. **Agent-based models for freight transportation.** Agent-based modeling (ABM) is a new approach in freight transportation modeling. A main characteristic of it is modeling "firms" as the decision-making units. It seeks to improve typical four-stage state-of-practice models through better representation of firm behavior and their logistics and supply chain decisions. NCFRP Project 39 research addresses innovative strategies for obtaining truck-activity data. Such strategies typically include data "collection" or "capture." This strategy deals with data "production," that is, data that are the outcome of model simulations.

The first two programs could be operational within 5 years. The third is on a longer term development schedule.

Report Organization

This report is organized as follows. Chapter 1 introduces the research need and objectives. Chapter 2 provides the results of the assessment of current primary data sources. Chapter 3 introduces the menu of innovative strategies compiled in this study and provides a feasibility assessment for each. Chapter 4 presents three implementation scenarios for the strategies considered most feasible for obtaining truck-activity data. Chapter 5 summarizes the research needs and provides conclusions.

CHAPTER 1

Introduction

CHAPTER 1 KEY TAKEAWAYS

- Significance of truck data for public and private decision-making will only continue to grow.
- The number of data sources is dwindling and many have completeness and accuracy problems.
- Data are lacking to answer key policy questions of how much freight is moved, what types of freight are moved, and how much road traffic these movements generate.
- When addressing freight data limitations, it is important to focus on both data and industry coverage issues.

Trucks play an essential role in the freight transportation system. According to the 2007 CFS, trucks carried about 85 percent of total tonnage and of total value shipped in the United States. Trucks provide enormous flexibility in the origins and destinations they can serve, the commodities they can carry, and the range of services they can provide. They also provide the key link among most other modes of freight transportation. With dependence upon just-in-time inventory practices, forward positioning of supplies and inventory, and continued growth in small-package expedited delivery and e-commerce distribution services, the significance of truck traffic will only grow.

Data on truck activity have played an essential role in public- and private-sector decision-making in recent decades. In the public sector, the U.S. Department of Transportation (DOT) has used truck-activity data for analysis of cost allocation, safety issues, proposed investments in new roads and technology, and user fees. The Environmental Protection Agency has used the data to determine per mile vehicle emission estimates, vehicle performance and fuel economy, and fuel conservation practices of the trucking industry. The Bureau of Economic Analysis has used the data as a part of the framework for the national investment and personal consumption expenditures component of the Gross Domestic Product. Beginning with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA), continuing with the Transportation Equity Act for the 21st Century (TEA-21) and with the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU, 2005), states and metropolitan planning organizations (MPOs) are required to consider freight transportation issues in state and metropolitan transportation plans.

Passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21) created a new national freight policy. The bill also calls for the creation of a National Freight Strategic Plan and the establishment of a Freight Policy Council to be involved in developing it. The national freight policy and the strategic plan are conceived as multimodal endeavors; nevertheless, trucking activity on the highways will be an important component. Strategic planning will rely on data since analysis of these data will provide the information needed to inform policy and investment decisions. As a 1992 TRB special report noted "without good data, decisions will be arbitrary, options overlooked, and solutions misguided (TRB, 1992)." MAP-21 also focuses directly on expansion of directions in performance measures and performance management, for which better freight data will be critical.

In the private sector, tire manufacturers have used data to calculate the longevity of products and to determine the usage and applications of their products. Heavy machinery manufacturers have used data to track the importance of various parts distribution and service networks. Truck manufacturers have used data to determine the impact of certain types of equipment on fuel efficiency.

Though truck-activity data are increasingly important in both the public and private sectors, the number of sources for such data has dwindled in recent decades, and many sources have completeness and accuracy problems. Truck-activity data for decision making and performance measurement are critically lacking, and specific strategies for improving the sources of such data are needed now. Gaps in travel data have been enumerated in myriad studies, in congressional testimony, and by noted leaders in transportation policy and planning (Transportation Research Board, 2011). Although gaps exist for both passenger and freight data, freight (particularly, truck activity) data have serious gaps that can only be filled by new approaches in obtaining data. Freight data gaps are more costly to fill than passenger data gaps. Reasons for this difference include the complexity of the data, the potentially proprietary nature of its source, and inaccuracies that may be prevalent but time-consuming to detect. Freight data are increasingly important, as well as increasingly incomplete or missing.

In the team's examination of this topic, the researchers focus primarily on publically available sources of data. However, the research team acknowledges that there are some very important private data sources. For example, R. L. Polk is a provider of vehicle data related to characteristics, transactions (e.g., ownership history), mileage, etc. Such information not only has value in itself but also has use in the production of public data (i.e., VIUS has used a Polk database as the sampling frame).

In addition to isolating freight data gaps, determining appropriate data architectures, or developing freight system performance measures, the researchers focus on identifying creative, cost-effective methods for obtaining comprehensive trucking activity data and providing models for their implementation. Key research questions include the following:

- What can be learned from the current state of the practice for obtaining and reporting these data in the United States and other countries to inform innovation in strategies for data gathering?
- Given the state of the practice, what data issues and limitations exist that could be overcome through innovative strategies for data gathering or reporting?
- What innovative data gathering or reporting strategies can be applied to overcome current challenges and derive a complete picture of trucking activity?
- What are the recommended innovative and improved strategies for obtaining truck-activity data, and what are the risks, barriers, lessons learned, and best practices associated with their implementation?

1.1 Data Coverage Issues

The United States has had many sources of truck-activity statistics. Yet many of these have problems, some are no longer available, and the utility for others is questionable. This research attempts to rectify the situation by identifying and evaluating innovative solutions for improving the gap in trucking data. The following key policy questions guide the need for truck-activity data:

- How much freight is moved by trucks?
- What types of freight are moved by trucks?
- How much road traffic is generated by the movement of freight?

Answering these questions requires, at a minimum, data and information such as the following:

- **Vehicle Miles Traveled (VMT):** Measure of the extent of motor vehicle operation within a specific geographic area over a given period of time. Estimates of VMT are used extensively for allocating resources, estimating vehicle emissions, computing energy consumption, and assessing traffic impact. The Highway Performance Monitoring System (HPMS) is the best current source of this information for trucks providing national, state, urbanized, small urban, and rural area coverage, often measuring truck-vehicle miles as the residual after considering passenger vehicles.
- **Tons/Ton-Miles:** Total weight of the entire shipment/shipment weight multiplied by the mileage traveled by the shipment. Ton-miles provides the best single measure of the overall demand for freight transportation services. This is also a measure of the overall level of industrial activity in the economy. A ton-mile estimate is necessary to construct other estimates of transportation system performance, such as energy efficiency and accident, injury, and fatality rates. The CFS data are the best publicly available source to construct trucking ton-miles estimates, but coverage is incomplete among industries.
- **Value/Value-Miles:** Market value of goods shipped multiplied by the mileage traveled by the shipment. The choice of transportation modes or combinations of modes depends on characteristics such as type and value of commodity, distance, and desired speed and reliability of transportation. This measure can be used for assessing economic trade-offs over distance; it captures increases in activity for goods that tend to have an inverse relationship between technological improvement and weight. Growth in demand for high-value, time-sensitive goods has driven the forecast growth of trucking activity. Value is available from the CFS but value-miles is not available from any source.
- **Origin-Destination (O/D) Flows:** The start and end points for a particular truck trip. Measuring the sizes of O/D flows is important to many network management applications such as capacity planning, traffic engineering, anomaly detection, and network reliability analysis. Two public sources provide

information on truck O/D flows—the survey-based CFS and the FAF, which is based on synthetic or modeled information from the CFS. CFS captures freight flows, although incompletely, at the national level. Private data sources provide more geographically detailed origin-destination flows for some types of trucking flows and commodity movements, but have coverage and transparency problems. As described in *NCFRP Report 26*, supplemental data collection is required to obtain local detail.

- **Vehicle Speed:** Velocity of a vehicle. Vehicle speed, together with volume, is used as a measure of congestion and as a performance metric for roadway maintenance. The availability of speed data is extremely limited and constrained by the number and geographic coverage provided by roadside traffic counters, weigh in motion (WIM) stations, aerial photographs, and limited samples of global positioning satellite (GPS)- or onboard diagnostic (OBD)-enabled truck fleets. Private-sector sources, such as INRIX and American Transportation Research Institute (ATRI), produce vehicle speed data but with access and coverage limitations.
- **Transportation Cost:** Cost of freight movement by truck. Forecasting costs and evaluating potential responses from the private sector, particularly shippers and carriers, requires access to transportation cost data. Such information is quite important for mode diversion analyses and for assessing the transportation economic productivity and impacts on the economy. The collection of transportation cost data, however, was largely discontinued after deregulation. *NCFRP Report 22: Freight Data Cost Elements* identifies the specific types of direct freight transportation cost data elements required for public investment, policy, and regulatory decision making and describes and assesses very general strategies for obtaining the needed cost data elements.

Information gaps are further exacerbated when existing data are segmented by commodity type, vehicle type, and vehicle characteristics. To be "comprehensive" and most useful for policy and planning, data should include the following:

- **Commodity type:** Products that an establishment produces, sells, or distributes. Such data, ideally, would use five-digit Standard Classification of Transported Goods (SCTG) codes.
- **Vehicle type:** Based on the vehicle gross weight rating, ranging from light duty to medium duty to heavy duty. VIUS standards use eight classes.
- **Vehicle characteristics:** Age, weight, length, fuel type, acceleration capabilities, fuel efficiency, emissions, and range of operation, among other characteristics, of vehicle.

Table 1-1 illustrates these information gaps and further characterizes these gaps in terms of weaknesses of *quality* or *usability*. Comprehensive truck-activity data would be represented by 100 percent filled cells in Table 1-1 and the absence of quality or usability issues.

- Quality is defined as having "fitness for use" in terms of accuracy (i.e., when reality and what is recorded as data are in agreement), completeness (i.e., sufficient breadth and depth), coverage (i.e., how much of what is recorded is available), or reliability (i.e., consistency over time and with other major datasets).
- Usability is defined as having "fitness for use" in terms of timeliness (i.e., at temporal scale that is sufficient for purpose or monthly/quarterly, peak/off-peak, etc.) and accessibility (i.e., easily retrievable).

The information in Table 1-1 answers two questions:

1. Do data exist? If not, "missing" populates the cell.
2. If yes, is data of sufficient quality and usability? If there is a gap in either quality or usability, the gap is identified in the cell.

One conclusion from Table 1-1 is that being able to arrive at comprehensive truck-activity data requires filling in many data weaknesses. Given possible biases in determining what is most important to fill, as well as trade-offs in the perceived benefit/cost, the researchers opted for strategies that would fill the greatest number of data needs for the least incremental cost and risk. The team's feasibility review in Chapter 3 discusses how they arrived at such decisions.

1.2 Industry Coverage Issues

This project focuses on truck-activity data—information about the over-the-road transportation of cargo using motor vehicles, such as trucks and tractor-trailers. This study universe covers all trucks and tractor-trailers that move some sort of cargo, as well as those that provide services, regardless of industry as defined by the North American Industry Classification System (NAICS). We use the term "universe" as it is used in statistical sampling to denote the entire aggregation of items from which samples can be drawn.

The CFS, which is a comprehensive tool for understanding freight flows in the United States, samples from a universe of business establishments and auxiliary establishments (i.e., warehouses and managing offices) in the 50 states and the District of Columbia. Trucking activity (i.e., for-hire truck, private truck, parcel, or courier) is captured as one of several modes of transport for shipments emanating from sampled establishments. Other modes of transport captured are rail, air, water, and pipeline, all of which are outside the scope of this study. Improving the industry coverage of the CFS would entail expanding the number of sampled industries. By design, the CFS lacks coverage of establishments in forestry, fishing, utilities, construction, transportation, most retail and services

Table 1-1. Quality and usability assessment of existing truck-activity data.

Truck-Activity Measure	Segmentation Variable	Level of Geography			
		National	State	Metropolitan	Facility
VMT	**Vehicle Characteristics**[a] *Vehicle characteristics data limited; VIUS discontinued.*	Missing	Missing	Missing	Missing
	Vehicle Type	FHWA VM1 Table using HPMS data; accessibility gaps (microdata)	Exists from HPMS but not reported; accessibility gaps	Missing	Missing
	Commodity Type	Derived from CFS in FAF	Derived from CFS in FAF	Derived from CFS in FAF	Missing
Ton	**Vehicle Characteristics** *Vehicle characteristics data limited; VIUS discontinued.*	Missing	Missing	Missing	Missing
	Vehicle Type	Missing	Missing	Missing	WIM data coverage, accessibility issues
	Commodity Type	Derived from CFS in FAF	Derived from CFS in FAF	Derived from CFS in FAF	Missing
Ton-Miles	**Vehicle Characteristics** *Vehicle characteristics data limited; VIUS discontinued.*	Missing	Missing	Missing	Missing
	Vehicle Type *Ton-miles available from CFS but not by vehicle type.*	Missing	Missing	Missing	Missing
	Commodity Type	Derived from CFS in FAF	Derived from CFS in FAF	Derived from CFS in FAF	Missing
Value/Value-Miles	**Vehicle Characteristics** *Vehicle characteristics data limited; VIUS discontinued.*	Missing	Missing	Missing	Missing
	Vehicle Type	Missing	Missing	Missing	Missing
	Commodity Type *Value, but not value-miles available from CFS.*	Derived from CFS in FAF; availability issues	Derived from CFS in FAF; availability issues	Derived from CFS in FAF; availability issues	Missing
O/D Flows	**Vehicle Characteristics** *Vehicle characteristics data limited; VIUS discontinued.*	Derived from CFS in FAF	Derived from CFS in FAF	Derived from CFS in FAF and from MPO surveys; completeness, accessibility issues	Derived from TMAS, TMC; coverage, completeness, accessibility issues[b]
	Vehicle Type				
	Commodity Type *Value, but not value-miles available from CFS.*				
Vehicle Speed	**Vehicle Characteristics** *Vehicle characteristics data limited; VIUS discontinued.*	Private sources; coverage, completeness, accessibility issues	Private sources; coverage, completeness, accessibility issues	Derived from TMAS, TMC; coverage, completeness, accessibility issues	Derived from TMAS, TMC; coverage, completeness, accessibility issues
	Vehicle Type				
	Commodity Type *Value, but not value-miles available from CFS.*	Missing	Missing	Missing	Missing
Truck Transportation Costs	**Vehicle Characteristics** *Vehicle characteristics data limited; VIUS discontinued.*	Private sources; coverage, accessibility issues	Missing	Missing	Missing
	Vehicle Type	Services Annual Survey and private sources; coverage, accessibility issues	Missing	Missing	Missing
	Commodity Type *Value, but not value-miles available from CFS.*				

[a] Vehicle characteristics include age, weight, length, fuel type, acceleration capabilities, fuel efficiency, emissions, and range of operation, among other characteristics of vehicle; whereas vehicle type is based on the vehicle gross weight rating, ranging from light duty to medium duty to heavy duty.
[b] TMAS refers to the FHWA's Traffic Monitoring Analysis System. TMC refers to the regional Traffic Management Centers.

industries, farms and government-owned entities, and foreign-based business importing to the United States.

In reviewing the ways in which the trucking industry universe has been presented in prior NCFRP reports, the team identified several different universe definitions. Not all NCFRP reports describe the trucking universe. Those that did were focused on the objectives of their particular study (e.g., performance measures, freight trucks as part of freight system, association with FAF truck definition, urban truck movements, revenue generation by firm type). This led to various universe definitions, noted as follows:

- Truckload (TL), less-than-truckload (LTL), private trucking (NCFRP Project 2);
- TL, LTL, bulk, general freight (NCFRP Project 3);
- TL, LTL, specialized carriers, third-party logistics, other specialized (bulk liquid, flatbed carriers) (NCFRP Project 4);
- Interregional: TL, LTL, private trucks; intraregional shipments (i.e., parcel, delivery trucks to commercial/home); intraregional movements to support construction, utilities (i.e. telephone, contractors); fleet allocations and patrols that operate on fixed route (i.e., garbage truck, mail) (NCFRP Project 6);
- LTL; intermodal; package and courier (NCFRP Project 11);
- TL vs. LTL; single vs. combination trucks (NCFRP Project 12);
- Long-haul trucks with both O-D outside urban area; long-haul trucks with pickup/delivery in region; truck drayage—the short-haul movements of intermodal containers moving to and from railroad intermodal yards and marine container ports; local trucks moving goods among facilities on pickup and delivery runs within the region; construction vehicles (e.g. cement mixers, dump trucks, construction cranes); utility and other residential service vehicles (e.g., refuse trucks); trucks delivering freight with special requirements; package services (NCFRP Project 15);
- Private fleet truck operations; for-hire TL companies; for-hire LTL trucking companies (includes parcel, express); drayage/cartage companies; brokerage/third-party logistics companies; specialized trucking companies (NCFRP Project19);
- For-hire: TL, LTL, parcel delivery, drayage; private: long-haul, interplant, direct store delivery (NCFRP Project 27); and
- Universal vehicle classification: Classes 1-2: primarily pickups, vans, and SUVs used for personal transportation or light service and delivery purposes; Class 3: includes the largest pickups and vans ordinarily used for personal transportation and the smallest trucks routinely used to carry goods, supplies, and equipment; Classes 4-6: medium-duty trucks, step vans, flat beds, small dump trucks, and other trucks used to move freight; Classes 7-8: heavy-duty trucks, both straight trucks and tractors for use with semi-trailers, predominantly used to move freight and very heavy service vehicles, such as concrete pumpers, cranes, and drilling equipment (NCFRP Project 29).

For creating a more complete picture of truck activity, the universe must be as expansive as possible. For this reason, the team's proposed trucking classification system organizes the trucking industry into the following four types of trucking activity.

1. For-hire carrier,
2. Owner-operator,
3. Shipper-owned trucking, and
4. Construction/utility/services.

The fourth type, construction/utility/services, while important to clearly delineate the trucking industry universe, is not relevant to commodity-related trucking activity. Therefore, this category is not used further in this report. However, the other trucking activity categories are used in Chapters 3 and 4 to gauge the potential effectiveness of proposed strategies.

This report also presents two types of geography—long distance/interstate and local.

CHAPTER 2

Assessment of Primary Data Sources for Truck-Activity Data

CHAPTER 2 KEY TAKEAWAYS

- A weakness for many current data sources is difficulty of use.
- Transparency in data sources and auditing procedures is a problem across nearly all sources.
- New innovative sources would need to focus on statistical rigor, quality assurance, and accessibility. Improvements could either expand existing sources or offer a method for integrating and synthesizing data.

This chapter evaluates the current state of truck-activity data. Truck-activity data encompass many datasets and statistical reports. Ideally, such data should provide complete information on the movement of trucks on U.S. road networks, including the number of miles and the roads traveled, as well as goods and weight hauled. As this assessment of primary data sources reveals, there are many limitations to the current state of the practice.

The researchers began the study by reviewing statistical databases and reports on truck activity. They developed profiles of each, summarizing their definition of truck, data items and their source and method, responsible agency, and years covered in each source. The researcher also noted the background and purpose, coverage, sources, reliability, time series, and availability for each. The team derived nearly all information from published sources. Appendix A provides a descriptive profile of each, as well as a matrix that systematically arrays the information from each source.

The study team also examined the truck-activity data for a subset of these sources to determine what issues and limitations exist that could be overcome through innovative strategies for data gathering or reporting. Where possible, the team examined data elements to better understand the following:

- How the data was generated (e.g., traditional survey, roadside intercept survey, sensors, GPS);
- What auditing procedures were used (e.g., manual or automated review);
- How the data are maintained (e.g., single data collection project or ongoing program);
- How the data can be accessed (e.g., only with summaries on paper, microdata);
- How the data are archived (e.g., central or decentralized system, on CD only);
- Whether metadata availability exists (e.g., electronic listings, paper details); and
- What were previous uses of the data (e.g., listings of reports or analyses produced from a particular dataset).

The sources are profiled below. Appendix B contains a detailed evaluation of each of these sources in terms of its methodology, quality control, stewardship, accessibility, archival practices, and metadata availability. The text that follows presents a high-level summary of the detailed information in Appendix B.

2.1 U.S. Census Bureau Data

The quinquennial economic census is the standard used by federal statistical agencies in classifying business establishments for collecting, analyzing, and publishing statistical data economic data. Among its elements are the Commodity Flow Survey (CFS), conducted with the Bureau of Transportation Statistics, and the Vehicle Inventory and Use Survey (VIUS), conducted from 1963 to 2002.

2.1.1 Commodity Flow Survey

The CFS is the most comprehensive public tool for understanding U.S. freight flows. It has evolved continually since its introduction in 1993. In its latest iteration, the CFS provides origin-destination flows among and within state portions of major metropolitan areas and balances of states for economic census years ending in 2 and 7. While CFS data are collected from over 100,000 establishments and are based on 4.9 million shipments, the CFS has coverage limitations, such as imports and farm-based shipments, and it is not timely. The FAF is built on the CFS and uses additional data and models to fill in gaps in coverage and provide annual estimates. The FAF has less commodity detail than the CFS and does not include several CFS shipment attributes such as shipment size. Local data collection is necessary to provide greater geographic detail for either the CFS or the FAF as indicated in *NCFRP Report 26.*

2.1.2 Services Annual Survey

The U.S. Census Bureau also conducts the Services Annual Survey (SAS), a detailed high-level report of activity in selected industries, including Transportation and Warehousing, which are North American Industry Classification System (NAICS) codes 48 and 49 (Trucking and Warehousing are only two of the dozen sectors covered in the survey). SAS has its roots in the Transportation Annual Survey, which originated in 1985. These datasets provide information that is self-reported directly by firms and not directly available from any other source. NAICS coverage includes all carriers, both employer establishments and non-employers (owner-operators). The survey covers all for-hire (TL, LTL), heavy and tractor-trailer, light or delivery services identified by NAICS code—private carriage is not included. Data include motor carrier revenue by commodity classes, end of year fleet size by type, fuel expenditures, payroll, and purchased freight transportation. Although these data are excellent for understanding general features of the transportation industry, and especially for-hire trucking, its summaries can only serve as a baseline to understand trends because SAS measures revenue and expenses and not trucking activity.

Among the advances of these data are up-to-date high-level information on trucking industry operations, and the ability they offers to calibrate older data with current metrics.

2.1.3 Vehicle Inventory and Use Survey (VIUS) Discontinued

VIUS provided data on the physical and operational characteristics, such as VMT, on trucks. Conducted every 5 years as part of the economic census, the primary goal of VIUS is to produce national and state-level estimates of the total number of trucks. Its truck inventory data were used by several state and federal agencies for developing transportation plans, analyzing highway safety issues and environmental impacts of emissions, and creating studies on vehicle performance, fuel demands, and fuel conservation practices. Some have suggested restarting VIUS for monitoring data on heavy-duty trucks, which will soon have new fuel-economy standards, and for differentiating commercial and personal use of light-duty trucks. VIUS would also be the only source of data on difficult-to-locate operators of vehicle fleets (Transportation Research Board, 2011).

Strengths of the data include its detail on vehicles that could be used to understand U.S. freight movement, including configuration and commodities hauled. In addition to its discontinuation in 2002, challenges include its quinquennial collection and separate imputation processes for missing data on length, average weight, and annual mileage for trucks.

2.2 Amalgamated Datasets

Amalgamated datasets use advanced post-processing techniques on a number of different sources to depict U.S. highway freight movements. Among these are the FAF, freely available from the Federal Highway Administration (FHWA) office of Operations, and IHS Transearch data, commercially available from IHS Global Insight. Both datasets cover the U.S. highway system. Although Transearch has more granular O/D and is updated more frequently, its closed and proprietary nature makes it difficult to ascertain its quality and reliability.

2.2.1 The FAF

The FAF estimates tonnage, value, and ton-miles of all goods shipped to, from, and within the United States by origin, destination, commodity type, and mode. The FAF is based primarily on the CFS, and uses the CFS geography of state portions of major metropolitan areas and balances of states plus eight foreign regions. The FAF has less commodity detail and fewer shipment characteristics than the CFS, but has complete coverage of goods movement and includes annual updates between CFS years. In addition to origin-destination data, the FAF assigns truck tonnages to individual routes.

The FAF and CFS divide commodity movements by truck among three modal categories: truck only, multiple modes and mail, and other and unknown. For national and state totals, the CFS distinguishes types of multiple modes such as truck and rail. Estimates of truck activity based on the truck-only category miss trucking activity that can be significant in selected areas.

Neither the FAF nor CFS provides local origin-destination flows such as for pairs of counties. Several techniques exist to disaggregate FAF region-to-region flows to the county-to-county level, but the statistical reliability of these techniques is highly suspect and remains to be thoroughly tested. Most, if not all, are based to some extent on County Business Patterns that, like the FAF, is a composite estimate of economic activity rather than direct observation. As described in *NCFRP Report 26*, supplemental data collection is required to get local detail.

2.2.2 IHS Global Insight Transearch Data

This dataset originated when Reebie Associates invited trucking companies to "volunteer" their shipping data in exchange for all other data Reebie collected. IHS Global Insight later bought Reebie and integrated its transportation data with Global Insight's wealth of economic data. Many of its data elements are similar to those of the FAF. The amalgamated data is generally available at the county level rather than the broad economic regions of the FAF and CFS.

Transearch reports to have a sample size of more than 70,000 shipments. Its data, however, are limited to those firms that contribute data, and therefore may not be representative like CFS. The restriction of the data also can make it expensive—and maybe even inappropriate—for public planning. With no opportunity for oversight or verification, there could be the appearance, or potential, for biases in the analysis due to undiscovered mistakes, or purposeful targeting of projects, places, individuals, or modes.

2.3 Roadway Operations Data Sources

Roadway operations data are data that are measured directly from road or vehicle operations. There are two categories of these data: traffic count data and GPS data. Traffic count data can be subdivided into short and continuous categories, and again into weigh in motion (WIM), classification, and speed and volume data.

2.3.1 ATR Classification Count Data

There are more than 6,000 automatic traffic recorders (ATRs) in the United States; only about 2,000 can differentiate among FHWA vehicle classes. These stations provide an insight into fleet mix on all different road classifications in each state. Although the data from class count stations are not as detailed as WIM data, the greater number of stations can make the dataset very useful in understanding highway truck flows. The continuous count classification data are collected monthly from each state by the FHWA Office of Highway Policy Information as a part of their Traffic Monitoring Analysis System (TMAS). These data are be used to calibrate data obtained from the FAF, especially when FAF data may have become unreliable as a result of economic or other changes since last published. There are some challenges to their use, because they are not centrally available to the public. This, in turn, makes it difficult to determine how complete or uniform the data are, as well as to develop a nationally representative sample of the data.

2.3.2 Weigh-in-Motion (WIM) Data

WIM devices are designed to capture and record axle weights and gross vehicle weights as vehicles drive over a measurement site. Unlike static scales, WIM systems do not require the vehicle to stop.

Every state department of transportation has a WIM program responsible for the upkeep of WIM stations and archiving and analyzing the collected data. All states are required to submit their WIM data annually to FHWA, which uses it as a measure in determining Truck VMT as well as for use in creating Vehicle Travel Information System reports.

Virtual WIM stations are now being added to WIM Programs. Such stations use cameras to capture images of each passing truck and software to digitize information such as license plate numbers. This additional information can be used to link data from WIM stations to other datasets, such as truck size and weight permits, or even with WIM data from other stations. Although these data have a centralized standard, they do not have a centralized repository, which makes it difficult to conduct analyses using multiple years of data. Data quality procedures can also vary by state.

2.3.3 Highway Performance Monitoring System (HPMS)

The Highway Performance Monitoring System (HPMS) provides data on the extent, condition, performance, use, and operating characteristics of the nation's highways. It was developed in 1978 as a national highway transportation system database. It includes limited data on all public roads, more detailed data for a sample of arterial and collector functional systems, and certain statewide summary information. HPMS replaced numerous uncoordinated annual state data reports as well as biennial special studies conducted by each state. These special studies had been conducted to support a 1965 congressional requirement that a report on the condition of the nation's highway be submitted to Congress every 2 years.

HPMS supports development and evaluation of the Administration's legislative, program, and budget options. HPMS provides the rationale for Federal-Aid Highway Program funding level requests, and is used for apportioning federal-aid funds back to the states under TEA-21. HPMS includes TMAS, which has all continuous count traffic data, including class counts and WIM data, from across the country since the 1990s. It also supports Traffic Volume Trend Reports, a monthly report of vehicle miles traveled for each state as deduced from the baseline HPMS data. HPMS uses ATRs to estimate percentages of single-unit and combination trucks; these estimates, in turn, can be used to develop VMT for these types of trucks (Beagan et al., 2007).

However, HPMS is not available in its published form from a centralized database. In addition, the distribution of sensors was originally designed to estimate passenger vehicles using volume counts. Increasing the accuracy of truck counts would require using more classification count and weigh-in-motion equipment. The lack of microdata makes it difficult to assess data completeness. Quality procedures may vary by state.

2.4 Vehicle-Based Operations Data

The rapid progress of GPS and cellular technology has led to rapidly increasing use of GPS data for fleet management. Although this data is used mostly in real time for trucking industry operations, such data, if archived, could be a powerful tool for understanding truck freight behaviors. GPS data can provide speed, latitude, longitude, and heading of trucks in operation. Gathering detailed O/D information requires special data handling techniques to deal with privacy concerns. Although many users of GPS do not archive their data, truck logistics companies have many uses for it and have been collecting it for years. Companies do not share the data, though many firms are now gathering GPS data from public and private parties.

Studies conducted by the Washington State Department of Transportation using truck GPS data have included research aimed at understanding freight bottlenecks and the impact of construction on freight flows, as well as developing good quality checking tests for these data as well. Truck GPS data could provide a robust form of truck-activity data, with sufficient sample size and advances in collection and processing.

2.4.1 Freight Performance Measure Program

The Freight Performance Measure Program (FPM) is an initiative to develop freight-specific performance measures and to promote the practice of freight performance measurement to help identify needed transportation improvements and monitor their effectiveness. As part of FPM, FHWA is advancing tools and research for multimodal freight performance measurement, especially in the use of truck probe data to analyze freight performance on highways. The most recent tool FHWA provides is the newly acquired National Performance Management Research Data Set (NPMRDS) consisting of a passenger and freight average travel time probe reported every 5 minutes on the national highway system that is available for use by states and MPOs. This dataset is provided through a contract with HERE, formerly Nokia. HERE acquires the freight data from probe data collected by ATRI, the research arm of the American Trucking Associations. ATRI's ties to the trucking industry have helped it collect detailed GPS data over a number of years that other agencies have not been able to collect. Information on the quality of this data is available to users and has been assessed as part of this report.

Additionally, FHWA contracts with ATRI directly to assist FHWA with the development of tools and analysis based on the probe data they provide. Two tools have been in use to understand performance using the probe data, Freightperformance.org or FPM Web and the National Corridors Analysis and Speed Tool (N-CAST). FPM Web allows the user to submit a query, specifying a highway or group of highways, and the time interval. It returns the average speed on that highway in 3-mile segments. This data can be downloaded as a CSV file. The site also includes instructions for visualizing the data with an available corresponding ESRI shapefile for ArcMap 9.3 or later. N-CAST is a second-generation product with greater coverage of the national highway system and 1-mile segmentation. In its current state, it does not allow users to query by time and only shows the average speed for A.M., midday, and P.M. peaks without indicating when the data was gathered. Because these datasets have not been publicly assessed, the research team was not able to evaluate their quality procedures. The team also was not able to judge how complete the data are. Some information related to this data can be derived from the quality reports associated with the NPMRDS. FHWA is currently assessing these tools and determining what next-generation format would be most useful for users. Through ATRI's data and tools, FHWA is also able to analyze the probe data to understand corridor performance, aggregated origin and destination information, locations of significant freight activity, freight node performance, and incident/weather impacts.

At the time of this report, FHWA is developing a significant body of freight performance research, some of which is evaluating probe use and developing approaches and resources, as well as identifying new tools and data to consider.

2.5 Administrative Data Sources

For a truck to operate anywhere in the United States it must be registered with at least one state Department of Motor Vehicles. A truck operating in more than one state (or Canada) may register with the International Registration Plan (IRP) and report the number of miles it plans to travel in each state. Trucks hauling goods over legal size or weight limits are required to get a permit from each state to be traveled.

Each year, a massive amount of data is collected regarding trucking operations for administrative datasets, yet these are little used in planning or research. This lack of use could be attributed to the lack of access to the data, although truck registration data have been provided upon request (Lawson et al., 2002). The Federal Motor Carrier Safety Administration (FMCSA) requires companies operating commercial vehicles transporting passengers or hauling cargo in interstate commerce to obtain a U.S.DOT Number. Commercial intrastate hazardous-materials carriers who haul quantities requiring a safety permit must also register for a U.S.DOT Number that serves as a unique identifier when collecting and monitoring a company's safety information acquired during audits, compliance reviews, crash investigations, and inspections (see http://www.fmcsa.dot.gov/registration-licensing/registration-U.S.DOT.htm).

2.5.1 Federal Motor Carrier Management Information SYSTEM (MCMIS)

FMCSA manages their vast information resource on the safety and fitness of commercial motor carriers and hazardous material shippers through MCMIS (see http://mcmiscatalog.fmcsa.dot.gov/). The MCMIS system has its roots in the Motor Carrier Safety Act of 1984 and the Commercial Motor Vehicle Safety Act of 1986.

There are several types of reports available from MCMIS, as follows:

- **Crash File Extracts:** This data extract describes commercial vehicle crashes reported to FMCSA.
- **Crash Count Report:** Shows the number of federally recordable crashes by user-specified categories. A "recordable" crash is one that has a fatality, an injury requiring medical attention away from the scene of the crash, or a vehicle towed away.
- **Inspection File Extract:** The FMCSA Inspection File contains data from state and federal inspection actions involving motor carriers, shippers of hazardous materials, and transporters of hazardous materials operating in the United States. Most inspections were conducted roadside by state personnel under the Motor Carrier Safety Assistance Program.
- **Inspection Count Report:** Shows the number of inspections by user-specified categories.
- **Company Safety Profiles:** Are the most comprehensive summary of a specific carrier's national safety performance.
- **Census File Extracts:** Provide descriptive information on every active company in the MCMIS Census File. The file from which the extract is generated is updated biweekly and currently contains more than 1.5 million interstate carriers and hazardous materials shippers. It also has many broader uses for transportation planning, containing records for the roughly 1.7 million companies or entities subject to the Federal Motor Carrier Safety Regulations or Hazardous Materials Regulations. Census file extracts offer more than 130 data elements, including physical address information, the number and type or trucks owned and leased, the types of commodities hauled by the entity, the number of drivers hired, whether the entity ships less or more than 100 miles, and whether it ships by inter- or intra-state routes. It also includes annual VMT by entity. These data are mainly collected through mandatory biennial self-report forms, although safety and crash data also are aggregated for the census file and other MCMIS reports.

Many entries in the census file have incomplete fields and have not been updated recently. In addition, data quality procedures for these files are not documented or publicly available.

2.5.2 International Registration Plan (IRP) Data

The International Registration Plan was initially developed in the 1960s and early 1970s as a means of replacing the system of registration reciprocity, which then prevailed and was rapidly becoming inadequate to meet the needs of expanding interstate and international commerce. With the related International Fuel Tax Agreement, the IRP is unique in that it is an inter-jurisdictional agreement administered and managed by the states and provinces that are its members without any significant federal involvement (International Registration Plan, 2011).

All apportioned vehicles must be registered under IRP. The plan defines an apportionable vehicle as one that is, among other things, used in two or more member jurisdictions for transportation of persons for hire or of property and exceeds 26,000 pounds or has at least three axles (excepting buses and recreational vehicles). IRP has estimates of the number of miles traveled by jurisdiction for each truck registered. Unfortunately, its data are not currently available to the public for research.

2.5.3 Truck Oversize – Overweight Permitting Data

According to federal law, no truck can operate with a gross vehicle weight greater than 80,000 pounds, have a single-axle weight greater than 20,000 pounds, or have tandem axles with weight greater than 34,000 pounds. In addition to the regulations on weight, there are numerous regulations on the size of trucks that can operate on certain roads. Trucking companies may apply for permits to transport oversize loads (such as manufactured homes or transformers) that, if divided, would be unsuitable for their intended purpose or require more than 8 hours to dismantle using appropriate equipment. States may also grant permits for oversize divisible loads such as fuel, logs, milk, or trash. The resulting permit data includes details on oversize and overweight truck shipments in each state, but

Table 2-1. Data availability and elements.

Dataset	Avail-ability	VMT	Tons	Ton-Miles	Commod-ities	Speed	Weight	O/D	Volume Counts
CFS	5 years	---	X	X	X	---	---	X	---
FAF	5 years[a]	---	X	X	X	---	---	X	X
VIUS	Dis-continued	---	X	X	X	---	X	---	X
Transearch[b]	Annual	---	---	---	---	---	---	---	---
HPMS	Monthly	---	---	---	---	---	---	---	X
WIM	> Monthly	---	---	---	---	---	X	---	X
Class Counts	> Monthly	---	---	---	---	---	---	---	X
FreightPerformance.org	> Monthly	---	---	---	---	X	---	---	---
GPS	> Monthly	---	---	---	---	X	---	X	---
IRP**	Monthly	---	---	---	---	---	---	---	---
Oversize/Weight	> Monthly	---	---	---	---	---	X	X	---
SAS	Annual	X	X	---	X	---	---	---	---
MCMIS	Annual	X	X	X	X	---	---	---	---

[a] FAF availability is 5-year benchmarks and annual estimates.
[b] The researchers were not able to obtain any samples of Transearch data so they used secondary sources to write about it.

these data are not currently available for public research. Such data also are collected by each state transportation department, with availability varying by year.

Information generated in response to these questions, along with other relevant factors, was assembled into tables and graphs to help illustrate the relationships across truck-activity datasets, with an opportunity to look for patterns of strengths and weaknesses within and between datasets. This process provided additional insight into what is currently available.

Table 2-1 summarizes the datasets reviewed, including their frequency of publication and elements. It illustrates the patchwork nature of the truck-activity data infrastructure, indicating that users may need to piece together information from many sources to answer critical policy questions.

At the same time that there are critical gaps, there is also overlap among sources in the data that are available. Figure 2-1 illustrates overlapping data elements in the datasets. The researchers realize that these datasets are not really

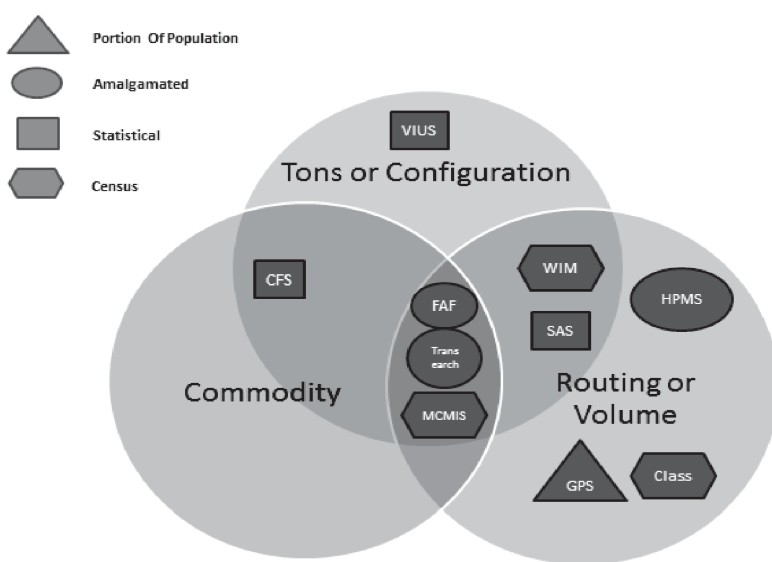


Figure 2-1. Diagram of data areas and datasets.

comparable and have different objectives, but can be used to provide an overview of the overlap. The MCMIS dataset and the two amalgamated datasets, FAF and Transearch, contain commodity, tons, and routing and volume.

MCMIS is administrative data (an updated census), while both of the other sources are amalgamated sources. The methods of the FAF are available but can only be applied to very large geographies. Transearch data integration is not known and most likely is not based on a random sample. Many statistical techniques can address bias of non-random samples, but are difficult to apply without knowing the underlying methods of Transearch data. Furthermore, Transearch provides county-level estimates, while certain types of transportation planning efforts for freight need corridor- or subcounty-level data.

Drilling down into potential quality issues, Table 2-2 summarizes the dataset according to other data quality characteristics. The quality assessments were judgments of the research team. The value definitions are presented following Table 2-2.

The datasets available to freight planners often are difficult to compare in their potential use because each one is designed to address different needs in different communities of planners

Table 2-2. Data quality characteristics.

Dataset	Centralized Data Availability	Years Available	Data Completeness	Price	Frequency of Collection	Quality Pro-cedures	Metadata Avail-ability
CFS	5	5	4	5	3	5	4
SAS	4	5	5	5	3	5	4
VIUS	5	2	5	5	0	5	5
FAF	4	5	5	5	3	4	5
Transearch	5	5	5	1	5	n/a	2
ATR	2	2	2	5	5	3	5
WIM	2	2	2	5	5	2	5
HPMS	3	3	2	5	4	3	4
Truck GPS	1	1	n/a	3	5	4	2
ATRI	5	4	n/a	5	n/a	n/a	5
MCMIS	4	4	3	4	5	3	4
IRP	2	2	4	n/a	5	n/a	1
Oversize	2	2	5	n/a	5	n/a	1

Definitions for Values

Centralized Data Availability: 1—neither summaries nor microdata publicly available; 2—microdata collected by many agencies but not uniformly available or uniformly available only as summary data; 3—data collected by many agencies and is uniformly available but not in a centralized location; 4—data collected or reported to central location but quality and format type varies due to lack of centralized procedures; 5—data collected or reported to central location, with central quality control and easily available microdata.

Years Available: Historical data is 1—not available, 2—available in some cases but not uniformly, 3—uniformly available for 10 years, 4—uniformly available for 20 years, 5—uniformly available for 30 years.

Data Completeness: 1—data unusable, 2—significant problems to use, 3—data issues occur but are documented and do not pose a significant problem, 4—data can be shown to be complete, 5—data completeness is considered in creating data and is measured.

Price: 1—more than $10,000; 2—$1,000 to $10,000; 3—$1 to $1,000; 4—free but processing fees; 5—free and publicly available.

Frequency of Collection: 1—discontinued, 2—every 10 years, 3—every 5 years, 4—annually, 5—monthly or more frequently.

Quality Procedures: 1—none; 2—limited, insufficient, or not publicly available; 3—sufficient and publicly available; 4—publicly available with data in pre- and post-processing forms; 5—specific data quality procedures uniformly applied.

Metadata: 1—not available, 2—exists but not publicly available, 3—publicly available, 4—publicly available with documentation, 5—publicly available with documentation and examples.

and engineers. Nevertheless, two characteristics of use offer some basis of comparison: completeness and timeliness. Figure 2-2 ranks each dataset by these attributes based on the scores in Table 2-2. These data are not publicly available for analysis of a number of important characteristics (e.g., auditing techniques) because they are produced by a private-sector company.

In some cases, it might be possible to correlate Transearch data with FAF and CFS data. A correlation between Transearch and CFS/FAF would identify which portions of Transearch used CFS/FAF numbers to fill in missing coverage. Providing standard practices for such correlations could be useful for cross validation. Figure 2-2 also indicates that while other datasets are scored lower on the comprehensiveness criterion, they were collected and processed much more frequently than other datasets. It may be possible to unify these more frequent datasets using a data architecture approach (such as the Freight Data Architecture program described in *NCFRP Report 9*), making it possible to increase the completeness and timeliness of publicly available datasets.

Among those datasets for which all features are known, SAS ranks highest overall on statistical characteristics, quality assurance, and stewardship, followed by VIUS and CFS. Statistical characteristics are primarily based on the use of a random sample if data are not a complete census of operations. Administrative data and that on roadway and vehicle operations could all be available as a complete census going forward. Data products produced through the economic census follow strict procedures to ensure generalizability. Quality assurance is highest for SAS and CFS. Establishing a transparent, documented set of procedures is critical for any future data to ensure all users understand data conditions. Dimensions of stewardship vary by dataset. Roadway operations, vehicle operations, and administrative data (except MCMIS) score low on centralized data availability but can be formatted well and have strong quality procedures, making it possible to produce a decentralized system with analytical value. At this time, Transearch and some GPS data have associated costs, while some "free" data are difficult to obtain due to institutional issues.

Key findings from the review of the limitations and challenges associated with current data sources follow.

- CFS is the basis for understanding freight in America. For collecting freight activity in the metrics of tons and ton-miles of goods transported, all current data sources depend on CFS. CFS is conducted only every 5 years, making it difficult to accurately model intervening years. The FAF is directly based on CFS, and Transearch is likely calibrated by it. Improving CFS by increasing its reach, granularity, and frequency would lead to downstream improvements for all other datasets.
- MCMIS provides tons and ton-miles in their administrative data program. Its continual updating provides an opportunity (as well as a challenge) for analysis.
- A large issue for many current data sources is *usability*. Many require a great deal of technical knowledge to use and visualize the data. For example, operations data (e.g., roadway and vehicle based) contain a great deal more

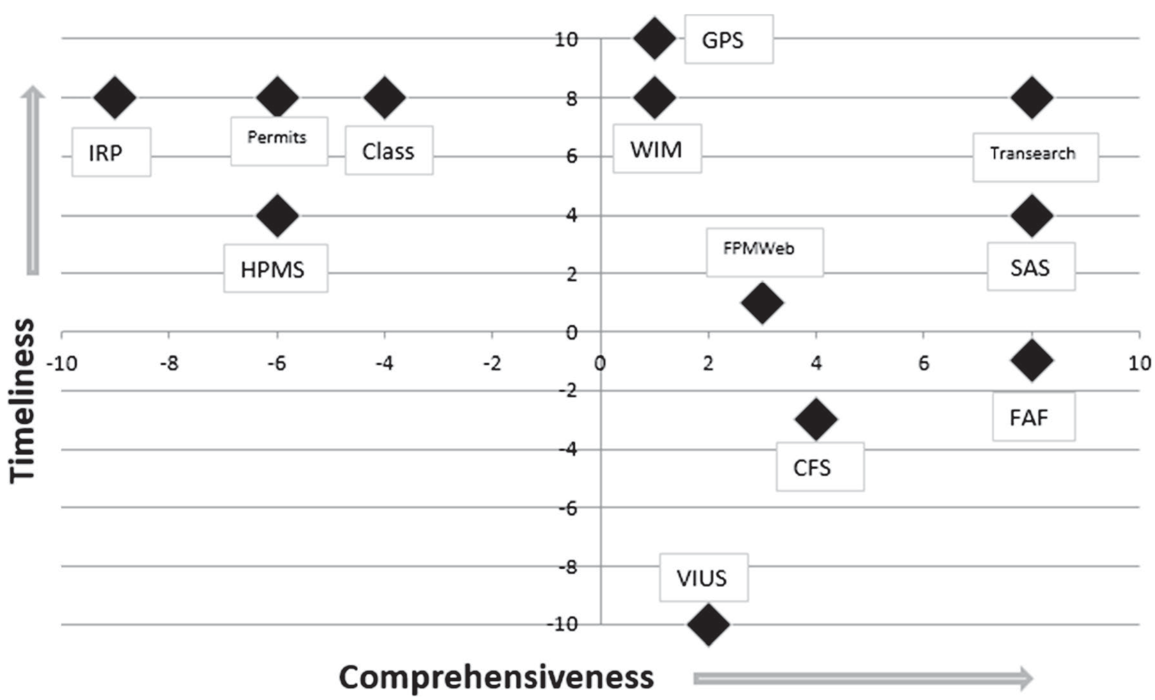


Figure 2-2. Timeliness and comprehensiveness of data sources.

information than are currently "harvested" and used for statistical estimation. There is a great opportunity to help planners at all levels by creating tools that could make using these data more intuitive.

- A widespread weakness is that there is no method for verifying modeled truck-activity data, such as the FAF or Transearch. A method or tool that could be used to verify these data would be of great value to users. It also might be possible to use the MCMIS on some specific factors as a source for verification and validation.
- Transparency in data sources and auditing procedures is a problem across nearly all the reviewed data sources.

This review of current primary data sources for truck-activity data provided direction to the research team in terms of the types of new innovative strategies to consider. An improved, comprehensive source would either be (1) an expansion to an existing source so that it would contain more of the needed measures than are currently available or (2) a method for integrating and synthesizing data, such as the FAF, that provides more of the needed measures. A new innovative source would need to focus not only on critical data gaps, but also on data elements for addressing the important areas of statistical rigor, quality assurance, and accessibility.

CHAPTER 3

Feasibility Review of Innovative Strategies

CHAPTER 3 KEY TAKEAWAYS

- The researchers assessed the feasibility of 10 proposed strategies for obtaining truck activity data with minimum uncertainty in their outcomes.
- Rather than proposing disruptive strategies, the team evaluated the feasibility of evolutionary improvements in obtaining truck activity data.
- The team identified three strategies for further consideration: a new VIUS-like survey, a national freight GPS framework, and an agent-based modeling approach.

This research is about innovation that could be used to implement or guide how truck-activity data might be obtained. The research team relied on our experience and expertise as well as project panel input to identify possible strategies for doing so. This chapter introduces these strategies and presents initial feasibility reviews of them.

In identifying possible new approaches, the researchers focused on improving existing approaches rather than creating new ones. Given current institutional and political climates, this seemed to be a reasonable and realistic approach. These are approaches from which the freight data community could see implementation and results within 5 to 7 years. The team addressed innovation as following a process of evolution rather than a revolution in methods for obtaining truck-activity data.

Innovation is risky, especially as it applies to the public sector. Every new undertaking involves some risk, but not all risk is created equal. Knight (1921) identified two types of risk: "risk proper" and uncertainty. Risk proper is real; it cannot be eliminated but, because its probability can be accounted for with reasonable accuracy, it can be managed and hedged against. Uncertainty occurs when the probability of risk proper is unknown; its costs and benefits also may be unknown or change over time depending on the actions of others.

To inform the costs and benefits of hedging against the unknown, the research team conducted feasibility reviews of 10 proposed innovative strategies for obtaining truck-activity data. The team defined a "feasibility review" as an initial assessment of whether the data gathering strategy can be executed for the intended purpose. The team's feasibility assessments of each strategy fall into the following five categories:

1. Technical: Capability to meet the technical requirements of implementing proposed strategy. This includes an assessment of industry and data coverage issues.
2. Institutional: Laws and formal provisions that define roles and responsibilities of all the organizations involved in implementing the strategy.
3. Operational: If the strategy is developed, will it be used? Operational issues include internal issues, such as labor objections, manager resistance, organizational conflicts and policies. External issues include social acceptability, legal aspects, and government regulations.
4. Geographic scalability: Level of geographies for which the strategy can be implemented.
5. Financial: Rough estimates of cost to see if they match general expectations or would have an acceptable return on investment.

For quick reference, the researchers used a star rating system (1 star is low and 5 stars is very high). These reviews and ratings are based on our teams' knowledge, expertise, and experience, literature reviews, and expert interviews. The researchers gave star ratings to technical feasibility, institutional feasibility, operational feasibility, geographic scalability, and financial feasibility of each alternative considered. The star ratings were summed to calculate a total feasibility score for each strategy. Hence, the total star scores could range from 5 to 25 stars. Total scores are provided after each strategy along with the research team's general recommendations regarding feasibility and next steps. Each feasibility review begins with a general description of the strategy. Also identified are the reasons that the strategy would be useful for addressing coverage of the trucking industry universe and in filling gaps in data coverage.

The team classified strategies as being based on surveys (census-based and other surveys), operations data (traditional and new sources), or administrative records or modeling techniques. The strategies for which the team conducted feasibility reviews are as follows:

- Census-Based Surveys
  1. Expansion of the CFS
  2. Expansion of the Trucking and Warehousing (T&W) Survey
- Other Surveys
  3. A New VIUS-Like Survey
  4. A New Industry-Based Supply-Chain Survey
- Traditional Operations-Type Data
  5. Operations Data Analysis Platform
- New Sources of Operations Data
  6. National Freight GPS Framework
  7. Investigate License Plate Tracking
- Administrative Data
  8. Analysis of Federal MCMIS Records
  9. Analysis of R. L. Polk Data
- Modeling Approaches
  10. Agent-Based Modeling Identify Truck Movements on Network

3.1 Expanded Commodity Flow Survey

The expansion of the Commodity Flow Survey entails multiple strategies. The CFS warrants these because it provides the most comprehensive primary data on truck activity. Most agree that it is the basis for understanding freight in America. The CFS provides detailed O/D data by detailed commodity for freight movements by all modes.

The researchers explored the following five options for expanding the CFS:

1. Continuous survey approach to reduce costs and accelerate reporting,
2. Additional observations to deepen the geographic detail of the survey,
3. Expansions of industries sampled to broaden reporting representativeness,
4. Extending transportation questions to economic census, and
5. Reestablished import/export survey addendum.

Of these, the team did not consider the following for feasibility review:

- Continuous survey approach, because experience to date with the continuous American Community Survey (ACS) indicates this strategy would have very limited reward regarding costs or reporting.
- Additional observations, because at current sample size levels the CFS is manageable and provides extensive coverage. Were greater observations to be considered, the issues of disclosure and cost would be critical. It may be worth considering in future research but holds limited potential in the short term. Of particular value could be a sampling plan that expanded sampling for establishments with very large sets of shipment destinations (a one-to-many versus a one-to-few production/distribution structure), thus responding to potential disclosure constraints.

Three strategic paths may hold promise for expanding industry coverage. These are

- A joint research effort at shared cost with the U.S. Department of Agriculture (USDA) on developing O/D data for farm to assembly points that would expand industries represented in the CFS.
- A research assessment of the industries covered by the economic census (and not covered in the CFS) in which introduction of limited questions (e.g., odometer readings, cost data, or expanded vehicle characteristics) can provide high-value transportation information. It is recognized that most of the industries not covered in the CFS generate little in the way of major transportation shipments, either in volume, value, or distances shipped. The ultimate rationale would be completeness.
- Assessment with Customs and Border Protection (CPB) of a prospective joint import/export survey, which, for a shared cost, would expand coverage to shipments originating outside the United States.

Table 3-1 summarizes what data an expanded CFS could provide by geography and trucking activity type. Similar tables later summarize potential for industry and data coverage of the other innovations examined by the research team.

3.1.1 Technical Feasibility ★★★

Though the three strategies discussed below do not have any inherent design complexity, they would still all be complex undertakings because of the multiple stakeholders involved.

Table 3-1. Expanded CFS: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	County and Sub-County
For-hire carrier	O/D flows, ton-miles, transportation costs	O/D flows
Owner-operator	O/D flows, ton-miles, transportation costs	---
Shipper-owned trucking	O/D flows, ton-miles, transportation costs	---

3.1.1.1 Developing O/D Data for Farm to Assembly Points

Farm shipments to assembly points are not included in the CFS at present. Stockyards and grain storage facilities are included. An opportunity exists through the Census of Agriculture to establish a survey procedure to fill this "farm to first assembler" gap. It would require design and resource considerations as well as a benefit/cost assessment. Of the industries that are not included in the current CFS, agriculture is the only one the researchers would call a shipping industry; the others are more readily defined as receiver industries.

As noted, expanding CFS to cover O/D data for farm to assembly points would require data from the Census of Agriculture. The Census of Agriculture is conducted every 5 years by the USDA's National Agricultural Statistics Service (NASS). It provides the only source of agricultural data for every U.S. county. Current questionnaires are tailored to seven geographic growing regions. As a general condition, the questionnaire establishes the number of cars and trucks held on the farm as of December 31 of the survey year. A current question in some questionnaires asks percentage of sales to local, regional, national, and international markets.

The USDA just completed its fieldwork for its most recent iteration, which, like the economic census, is conducted in years ending in "2" and "7." Transportation-related questions on this census could establish modes of transportation of farm products and destination types and ranges for farm products.

3.1.1.2 Expanded Transportation Questions for Economic Census

The economic census provides a detailed portrait of business activity for a calendar years ending in "2" and "7" from the national to the local level. For 2007, census forms were mailed to more than 4.7 million companies with one or more paid employees. All large- and medium-sized businesses receive a census form, but only a sample of small-employer businesses receives one. For 2007, there were more than 500 versions of the census form, each customized to particular industries. By collecting separate information for each establishment, the economic census can include detailed data for each industry and area.

Expanding transportation questions to the economic census would be a technically feasible adjunct to the CFS. This approach would require a comprehensive assessment of the elements of the economic census to establish which industries would be most important to access and what questions would yield the highest payoff. Questions that may be considered include own-account transportation for certain industries or fleet size and expenditures to yield important linkages in the national accounts and input/output (I/O) structure.

3.1.1.3 Import/Export Survey

A weakness of the CFS is its inability to capture imports and exports. The CFS does not report imports and has only a limited sample of exports. Nevertheless, the Department of Transportation surveyed inland movements of goods in foreign trade several decades ago. It drew a sample of import and export declarations and used them to trace shipments to the shipper/receiver and to establish the sources or destinations of the flows and modes employed. It was a very straightforward and relatively low-cost undertaking with many benefits, which would be even more valuable now. The technical challenge for a new survey would be sampling electronic, rather than paper, records. This undertaking may be potentially complex. There are multiple federal agencies involved in promoting and managing exports. Imports are under the control of the County Business Patterns (CBP).

3.1.2 Institutional Feasibility ★★

All of the three prospective activities are elements of existing federal operations that have long histories of continuing operations. All have legal, mandated reporting requirements. The Bureau of Transportation Statistics (BTS) may have the legal authority to conduct such operations. The interactions with other federal statistical agencies, the necessity for competent statistical design and logistical handling of these multifold efforts, and the multimodal character of the undertakings would make BTS the only feasible entity for these prospective programs. The strategies would require negotiating institutional responsibilities and cost coverage, which could require considerable time and resources and lower the institutional feasibility rating.

3.1.3 Operational Feasibility ★★

Operationally, there are some challenges. First, in general, response rates are declining for surveys and the proposed strategies would involve increased response burden. Although respondent burden can be eased by electronic reporting, the lack of standard formats for shipping records across all industries could create an enormous data processing burden on Census with financial costs. Second, given the quinquennial structure of two of the surveys (Census of Agriculture and Economic Census), timing for testing and preparation may be an issue. These two surveys are complex given their number of specialized sub-questionnaires involved. Selecting the right starting place for each CFS expansion activity would be key to success.

An inland origins and destinations survey would have to account for the long-term plans of the customs service to establish a complete tracing capability, particularly for imports. An O/D would need to support, and not conflict with, a CBP reporting system. That said, duplication of some elements may be necessary, particularly those CBP is precluded from divulging or unwilling to divulge.

3.1.4 Geographic Scalability ★

As all of the strategies are essentially expanding the industry coverage and not the geographic specificity, there would be no perceived gains in geographic coverage such as county-to-county flows.

3.1.5 Financial Feasibility ★

These three efforts were specifically selected for their relatively low cost. There is design and institutional complexity in all of them so that internal staff resources might become an issue at some stage, though likely not in the preliminary stages of development in which scale and scope are defined. For the linkages to the Census of Agriculture and Economic Census, incremental costs of additional questions appended to existing surveys are typically not an expensive undertaking. Nevertheless, given survey expenses, competition for space on forms may be great, and the impact of additional items on overall response rates would be of concern, as might potential costs. The follow-on survey of imports and exports would be a new survey (although using existing administrative records as the sample frame) and would entail greater financial risks than the other two activities. The greatest financial burden would be in preparing shipment information to generate estimates. To retain a similar level of data quality with an expanded sample of shipments would be quite an undertaking. Tripling the number of records might require a substantial increase in the budget. With an expanded sample, respondent attrition becomes a more serious issue as well.

Total Feasibility Score: 9. These three options were considered because they are relatively low-cost expansions to the CFS. Addressing the quality issues associated with expanded CFS sample might dilute the potential low-cost expansion. The potential for improved industry and data coverage is not great. Next steps might include discussions with USDA, Economic Census, and CBP to gauge their receptivity to an add-on activity. Such discussions would need to be prefaced by a review of the industries covered and current questions asked for two of the surveys; the third discussion with CBP would be more general. Given the uncertainty of the receptivity of these federal agencies, the team did not proceed with a detailed implementation scenario.

3.2 Expansion of the Trucking and Warehousing Survey

The Trucking and Warehousing Survey, for industries in Truck Transportation (NAICS 484), is a part of the Services Annual Survey (SAS). The existing dataset goes back at least to 1998. The NAICS 484 coverage includes all carriers, both employer establishments and non-employers (owner-operators). The survey covers all for-hire (TL, LTL), heavy and tractor-trailer, light or delivery services identified by NAICS code; private carriage is not included. Thus, not only does it cover a significant portion of the trucking industry universe, but also it has significant potential, as shown in Table 3-2, to relate to other modes of freight transport with the same collection methods and definitions. The Trucking and Warehousing Survey represents the most comprehensive set of transportation industries available, with reporting on an annual and quarterly basis. Its weakness is that it does not encompass shipper-owned vehicle fleets engaged in own-account haulage.

The survey at present covers several data elements of interest.

- Motor Carrier Revenue by commodity classes,
- End-of-year fleet size by type,
- Fuel expenditures,
- Payroll, and
- Purchased freight transportation.

Table 3-2. NAICS industries included in the Services Annual Survey.

NAICS Code	NAICS Category	No. of Sub-Categories	No. Freight-Related	No. Truck-Related
481	Air Transportation	4	2	n/a
482	Not Used	0	0	n/a
483	Water Transportation	6	3	n/a
484	Truck Transportation	6	6	6
485	Transit	11	0	n/a
486	Pipeline Transportation	4	4	n/a
487	Scenic and Sightseeing	3	0	n/a
488	Towing and Other Support	12	4	4
49	Courier and Express Delivery	6	6	6
All		52	25	16

Note: Excludes NAICS 482 Rail and 491 Postal Service.

The main focus of the survey is revenues; thus, it has the potential to gather important information on value-miles by commodity and vehicle type. It is also a potential source of derived information on VMT and ton-miles (see Table 3-3). Relating the revenue items collected to discrete transportation values such as VMT and tonnage would provide valuable current information, conceivably even quarterly, to the extent not already employed in FAF and other estimates.

The research team proposes the following three potential approaches for obtaining data:

- Derivation: The data can be tested and analyzed as a potential source of modeled information on broad VMT, tonnage, and value for carriers and owner-operators. Other opportunities include fuel costs linkages to VMT. To the extent feasible, where data were derived from revenue data, quarterly estimates would be possible. Present quarterly reporting provides only broad total revenue values for employer and non-employer firms.
- Add-ons: There should be opportunities for question add-ons that do not impede response rates. There is precedent for such supplemental questions in the SAS series. Conceivable add-ons such as fleet VMT, tonnages moved, or broad commodity classification could be tested.
- Survey sample expansion: A third area of opportunity would be expanding the survey samples to assure state-level coverage. There would be considerable cost implications of doing so. This strategy should not be considered in the short term.

3.2.1 Technical Feasibility ★★

The surveys are ongoing activities of the Census Bureau. These data are now on a substantially sound footing for the future and represent a valuable potential resource about the trucking industry and its activities. Absent extreme fiscal conditions, they appear to be steady over time. The modeling activities to derive the additional data elements (VMT, ton-miles, value-miles) are technically feasible if time and

Table 3-3. Expanded Trucking and Warehouse Survey: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	VMT, Ton-Miles, Value-Miles	--
Owner-operator	VMT, Ton-Miles, Value-Miles	---
Shipper-owned trucking	---	---

resource intensive. Technically, changes can be made in the survey design. For example, in 2009 the SAS was expanded to cover a greater share of gross domestic product (GDP). Adding questions to gather additional data items would not incur substantial added expense, and would appear to be feasible, to the extent that such items do not reduce response rates.

3.2.2 Institutional Feasibility ★★★

There would be no legal constraints on deriving modeled information. Some constraints may arise should the need to work with individual records surface. In this case, sworn status for researchers or other procedures, such as anonymizing the data, could be necessary.

Another possible legal issue would revolve around asking supplemental questions (which likely would not have the force of required response) in a survey that is required by law.

None of these present insurmountable legal questions.

The natural entity for such an undertaking would be BTS. It would have the skills and perhaps the human resources for undertaking such an effort.

3.2.3 Operational Feasibility ★★★★

Operationally, there are likely few challenges because the surveys are ongoing activities of the Census Bureau. Given the annual structure of the surveys, timing for testing and preparation would not be as onerous as in a quinquennial survey. Data collection might also take place in alternating years or over another period.

3.2.4 Geographic Scalability ★★

This survey currently has a national scale, but cost would be the only limit in expanding it to the state level. Establishments in the list have addresses identified and therefore, conceivably, could be analyzed by corridor or region.

3.2.5 Financial Feasibility ★★

The modeling or derivation activities would require a focus of human resources that may pose some opportunity costs for DOT. This activity might be better housed at a university transportation research center. Beyond that, supplemental questions should require few additional financial resources. An early strategy would be to start with a limited question set for a small number of industries. This might include, for example, one question for the long-distance truck freight component (NAICS 484121) or long-distance specialized freight (484230). Although adding questions might not pose a financial burden, expanding the sample to provide state or regional detail could entail substantial expense.

Total Feasibility Score: 13. None of the three activities were pursued in detailed implementation scenarios. The proposed strategies might have great use in deriving data but they could not provide timely sub-annual data. The team's final report states that university-based or other researchers may consider the challenge of modeling or derivation work. The notion of expanding such work to state or regional detail may be considered a long-term research opportunity.

3.3 New VIUS-Like Survey

The loss of VIUS was a problem for road-based freight statistics. It provided crucial vehicle characteristics and differentiation of vehicle activity by range, products carried, miles traveled, industry, and type of operator at the state level. The survey was cancelled due to financial problems, hence, reinstating or expanding it would likely raise financial issues.

A new program modeled on VIUS could again become the baseline for truck freight activity, differentiating business from personal use of light trucks, providing coverage of all categories of trucking operations, and establishing the universe characteristics of the truck fleet: for hire, public, private, owner-operator, off-road, rental, and others.

It would likely be straightforward to incorporate all vehicles into the survey and obtain a national framework picture of the entire motor vehicle fleet's characteristics and activity. This was at one time a valued endeavor, but expansion of TIUS to VIUS only got as far as the name change in 1997.

The strategy would entail possible expansion in three areas.

- Appling the new Canadian Vehicle Use Survey (CVUS) and developing a parallel U.S. prototype.
- Working with R. L. Polk to obtain commercial vehicle-registration or MCMIS records to obtain motor carrier information for sampling purposes.
- Expanding the sample frame to include private vehicles, government, and motor carriers of passengers to obtain a comprehensive picture of over-the-road vehicle movements.

All of these are feasible either as simultaneous or separate activities.

VIUS represents a critical area of development of road transportation statistics. It recognizes and uses vehicle registrations unique to road transportation rather than establishments as its universe for trucking activity statistics.

In addition, VIUS can obtain VMT for all industries for which vehicles are sampled and ton-miles for industries not covered by the CFS. VIUS obtained VMT for the vehicle types covered irrespective of industry, largely getting around CFS coverage issues. Ton-miles could be estimated from

Table 3-4. New VIUS-like survey: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	VMT, Ton, Ton-Miles,	VMT, Ton, Ton-Miles,
Owner-operator	VMT, Ton, Ton-Miles	VMT, Ton, Ton-Miles
Shipper-owned trucking	VMT, Ton, Ton-Miles	VMT, Ton, Ton-Miles

payloads and VMT, and truck VMT could be estimated from VIUS payloads times FAF tonnages (see Table 3-4).

3.3.1 Technical Feasibility ★★★

VIUS was conducted by the Census Bureau within the last 10 years and can be readily reinstated in its previous form without any delay caused by technical concerns. However, applying the CVUS design to the U.S. context could provide opportunities for potential improvements in survey efficiency and data quality.

The CVUS now underway requires that a sample of vehicles monitor total daily trip making with onboard equipment requiring some driver input (e.g., trip purpose, occupancy). The technical design elements of this comprehensive vehicle survey (i.e., passenger and commercial vehicles) have been worked out for the Canadian application. This would make the technical feasibility higher for U.S. implementation. FHWA is considering moving forward with a pilot demonstration of the CVUS technology in the United States. A potential future activity might be a harmonized, cross-border survey in which the questions would be the same so the data could be made useful for either country. However, each country would be responsible for in-country deployment.

The technical feasibility of this strategy cannot ignore the challenges associated with data collection through an in-vehicle device rather than a traditional survey questionnaire. There is precedent for the use of such technology to collect travel information from the use of GPS devices in the conduct of regional household travel surveys. Much research has investigated issues related to non-response and response bias. Privacy issues have not been given as much attention in the household travel survey literature. One of the core challenges is an agreed framework for data management. Data management, in this sense, entails policies and "best" practices that relate to data collection, storage, and analysis. It addresses data governance, transparency, value distribution, data ownership, and data privacy.

The previous VIUS used the vehicle registrations supplied by the Polk Company as the sampling frame. This same sampling frame could be used in a CVUS-like application. Polk has maintained those records for decades. As an alternative, the MCMIS could be employed as a sampling frame. If Polk were used, a sampling frame could be purchased in the format desired. If MCMIS were used, significant data processing would be needed to obtain a usable frame. Polk allows for multiple types of vehicle databases, covering (1) automobiles and light-duty trucks and (2) heavy-duty trucks and other vehicles, which would be useful for expanding the survey population. Regardless of the frame itself, the CVUS approach requires a sample be drawn throughout the year to reflect seasonal variation in driving, whereas the old VIUS asked for year-end totals in a single sample. The rolling sample would allow multiple uses of CVUS hardware (i.e., send it back, download data and clean, use in next sample wave).

3.3.2 Institutional Feasibility ★★★

BTS would likely lead any new VIUS-like efforts. There do not appear to be any legal barriers to BTS observing the CVUS or participating in the ongoing North American Transportation Statistics interchange.

It is not necessary for the Census Bureau to have a role in VIUS-like activity. If a direct Polk relationship is considered, then publication of some findings might be an issue regarding proprietary materials. More specialized and detailed access would require negotiation with Polk regarding its interests and protection of its arrangements with states and attendant costs.

A relationship with FMCSA for use of MCMIS may help accomplish a new VIUS without proprietary or other cost concerns. A purely internal DOT effort built around the MCMIS also could be evaluated.

3.3.3 Operational Feasibility ★★

Operational feasibility would be influenced by the same issues relating to survey participation, response bias, and data management (e.g., privacy, governance, etc.)—that were raised under technical feasibility. These issues would need to be addressed through future research or in conjunction with a pilot study.

Other operational issues include the following:

- There may need to be operational changes at the Census Bureau were the survey conducted under the their auspices.
- Minor operational changes might be required regarding sampling and supporting any prospective data mining operation. A similar observation would apply to the Canadian relationship.

3.3.4 Geographic Scalability ★★★★

Like the Trucking and Warehousing Survey, the fundamental structure of VIUS is national, but the sample could expand to yield state estimates. The VIUS sample was drawn from the state vehicle-registration files managed by R. L. Polk. This made the resulting national survey similar to 51 state surveys done with the same questionnaire at the same time.

3.3.5 Financial Feasibility ★

Designing and implementing a VIUS-like full vehicle survey would be a significant undertaking. An analysis conducted for FHWA's Office of Freight Management and Operations in 2010 estimated program costs for the expanded survey at about $12 million per survey cycle (ORNL, 2010). This was a maximum; costs, depending on design, could be as low as $9 million.

In addition, the application of a CVUS approach would entail further costs in the short run, but perhaps lowering costs in the long run. For example, current estimates of the CVUS hardware costs are approximately $800 per unit, although costs are expected to decrease with technological evolution and a bulk purchase (as has been the case with using GPS equipment in household travel surveys). Financial resources will be central to this effort, which led the research team to giving financial feasibility a 1-star rating.

Total Feasibility Score: 13. Based on the outcomes of the feasibility analysis, the research team produced a detailed implementation scenario (see Chapter 4) to evaluate: (1) establishing a relationship with Statistics Canada to apply CVUS methodology and implementation, and (2) holding preliminary discussions about a public-private approach permitting development and use/sale of data, in which BTS could develop the data and the contracted company would act as the marketing entity, or, if that is not feasible, researching other funding sources to establish a new VIUS-like survey.

3.4 New Industry-Based Supply-Chain Survey

As *TRB Circular E-C169* highlighted, supply-chain data are critical for transportation planning and policy making. *TRB Special Report 304: How We Travel: A Sustainable National Program for Travel Data* also identified supply-chain data as a major gap in freight transportation data. There is currently no data program responsible for capturing, analyzing, and delivering supply-chain information. A new survey would capture intercity data on freight shipments from origin to intermediate handling and warehousing locations, and to final destination. This new survey would provide information on intermodal freight (i.e., movements of freight from origin to destination using two more end-on modes) that is not currently captured by the CFS. It also could provide more detailed O/D information than the CFS. CFS survey respondents typically do not know how their products reach their final destinations; they can only report the mode by which products leave their establishment. This new survey would provide information necessary to understand where goods originate, where they are ultimately consumed, and the modes of travel between the two. Focusing on supply chains as the sampling unit would expand coverage of the trucking industry to activities not currently included in the CFS, such as agriculture, retail, construction, and even imports. Trucking industry coverage would be extended to all for-hire and private fleets as well as parcel deliveries. Such a survey could conceivably help fill data gaps on VMT, tons/ton-miles, value/value-miles, O/D flow, and truck transportation costs for specific supply chains (see Table 3-5).

3.4.1 Technical Feasibility ★

Supply-chain surveys require a design that collects information from shippers, receivers, and intermediaries. This is such a technically challenging endeavor that the practicality of such a survey is questionable. A 2004 French shipper survey remains the only attempt to conduct such a survey on a national scale (Rizet, 2008). The French experience identified a number of problems with achieving good response rates, and with higher costs per successful response than with traditional shipper surveys, such as the CFS. In particular, the probability of getting a complete description of the complex supply chain and its elements for sampling proved to be low.

One reason for this is the diversity of supply chains (which we address in terms of the need for developing a typology of supply chains below). The supply chain for a local restaurant that buys ingredients from the local farmers market serviced by local farmers is less complicated than the supply chain for a chain of car dealers that obtain cars from several manufacturers who supply cars from multiple factories that obtain

Table 3-5. New industry-based supply-chain survey: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	VMT, Ton/Ton-Miles, Value/Value-Miles, O/D, Transportation Costs	VMT, Ton/Ton-Miles, Value/Value-Miles, O/D, Transportation Costs
Owner-operator	VMT, Ton/Ton-Miles, Value/Value-Miles, O/D, Transportation Costs	VMT, Ton/Ton-Miles, Value/Value-Miles, O/D, Transportation Costs
Shipper-owned trucking	VMT, Ton/Ton-Miles, Value/Value-Miles, O/D, Transportation Costs	VMT, Ton/Ton-Miles, Value/Value-Miles, O/D, Transportation Costs

components from many suppliers who use materials from many sources who, in turn, get raw materials from multiple origins. The remainder of this section discusses some of the contingent issues.

Freight transport across industry sectors is commonly measured and described (loosely) using two terms: commodity flows (CFs), and vehicle flows (VFs) (Blanquart et al., 2012). CFs are represented by an O/D matrix focused on the type and quantity of goods moved through VFs represented by traffic flows in different modes, where the focus is on the vehicle and its operation. VFs are the result of logistics decisions made by carriers. A supply-chain view connects these, focusing on the commodity, the value, the volume, the origin, and the ultimate destination, and on intermediate routing of products from production to consumption to recycling. This view focuses on senders, receivers, and intermediaries as well as the operational (VF) activities of transporters. The total supply chain and range of processes that need to be included are numerous and varied, making them difficult to sample and challenging to analyze. In addition, collecting the required data from companies can be a very involved and complicated task. Researchers would need to consider the willingness of companies to provide information, data confidentiality issues, and data terminology issues (which can vary between sectors and also between companies in the same sector).

The complexity of a supply-chain survey design could be simplified by developing typologies of supply chains. However, the researcher team's literature search uncovered no useful typologies that could be used for survey sampling. The typologies in existence relate to supply-chain management, not supply-chain logistics. Examples of supply-chain management typologies include (1) procurement, production, distribution, and sales or (2) number of stages and forms of integration. These typologies are not useful for a survey trying to design efficient and explanatory sampling approaches or generating a unit of analysis from which generalizations can be made to a larger population.

The development of typology that would be useful for sampling supply chains would entail a large R&D activity. Researchers from North Dakota State University are researching the use of FAF-CFS databases to determine a typology or systematic classification of supply chains and their relationships to commodity flows.

One could simplify the technical requirements of a supply-chain survey by focusing on supply chains for a few or single commodities. Many prior survey efforts have done just this. Studies have worked backward from a commodity (such as strawberry yogurt) to the origins of its components (e.g., strawberries, yogurt culture, and sugar beets) (Browne and Allen, 2004). Alternatively, one could take a category of products like organic vegetables and trace their delivery; chains also could be prioritized by the volume in a corridor, region, or nation. The benefit-cost ratio of such an exercise, however, may be low, given its low inferential power.

Supply chains also are dynamic. Decisions are made in real time and are typically short term in nature. Hence, policymakers need to consider the long-term value of tracking one or a few commodities through their chain. Perhaps, a more fruitful approach would be to conduct more qualitative research on how shippers decide about modes and routes. This would be very useful basic research but much less immediately applicable to the objectives of NCFRP Project 39.

Finally, although NCFRP Report 29 focuses on trucking activity, a supply chain is multimodal and intermodal. Hence, while a supply-chain survey would yield much rich data, it would not focus wholly on truck movements.

3.4.2 Institutional Feasibility ★

Much of the supply-chain data is privately held and shippers and carriers consider their supply chains to be a strategic advantage. While supply-chain managers do share information on challenges and risks in annual surveys by organizations such as PriceWaterhouseCoopers (PwC), McKinsey, CSC, UPS, and

Deloitte, such data are highly aggregate and are more attitudinal than behavioral. The sponsor of a supply chain survey obtaining relevant information for transportation policy and planning would need to be a government agency (e.g., sub-unit of the Department of Transportation, Department of Agriculture, Department of Commerce, or Census Bureau). Collecting private sector supply-chain data for public purposes while protecting private interests could be challenging. This would be even more difficult if focusing on one supply chain or one corridor.

3.4.3 Operational Feasibility ★★

The complexity and variability of supply chains require more sophisticated approaches to data collection, integration, and fusion that would capture end-to-end flows, modes, interchange points, and routes. Even if one were to focus on administrative or sensor data (i.e., RFID), the complexity of multi-level data collection points is substantial. Establishing these approaches would require a substantial research and development effort.

3.4.4 Geographic Scalability ★★

Boundary issues are a challenge. Supply chains cross jurisdictions, regions, states, and even countries. For example, most processed food supply chains involve numerous transformations of an input being transformed into something else in order to supply consumers with a final product. Examples include making flour out of grain or transforming olives into oil. Depending on the complexity of the product being studied, this can result in the study of the entire system, and involve enormous numbers of other products and the processes involved in their production and supply.

3.4.5 Financial Feasibility ★

The lack of precedence for comprehensive supply-chain surveys indicates that the development of a new supply-chain survey would require much research and development. The complexity of such a survey in sampling, levels of analysis, and post-processing of data indicates that this survey is likely to be double or triple the current cost of CFS.

Total Feasibility Score: 7. The research team did not examine a detailed implementation scenario. The cost-benefit ratio makes it a risky investment of public funds in this resource-constrained environment. The team suggests two research activities that could lead to needed insights for supply-chain research: (1) exploratory research on developing a typology of supply chains for the purpose of designing an efficient and effective sampling approach, and (2) qualitative research on how shippers choose among modes and routes.

3.5 Operations Data Analysis Platform

Operations data is one of the richest sources of timely and detailed data about trucks traveling on public infrastructure. These data represent private, for-hire (TL, LTL), heavy and tractor-trailer, and light or delivery services trucks. They represent many industries not currently covered by the CFS. Although extensively collected by states and reported to FHWA, the currently generated reports do not include VMT and do not use weigh-in-motion (WIM) data to look at freight flows. This program would create tools to estimate truck VMT based on operations data as well as freight flows based on Classification Counts and WIM data. This strategy acknowledges that the current sample size for WIM equipment is too small to measure truck weights on individual routes or on functional classes of routes in each state. That is why the strategy focuses on developing a platform for accessing and visualizing the data in conjunction with data from other sources.

3.5.1 Technical Feasibility ★★★

Roadway operations data are collected by sensors installed by state departments of transportation in America's roadway network. There are more than 6,000 installed in America's roads, continually collecting data. Although a vast majority of these sensors only collect volume data, some are able to differentiate the types of vehicles that are on the roads, allowing for analysis of fleet mix and a comprehensive understanding of truck volumes. About 800 devices collect WIM data, which captures the total weight, axle weights, and even axle spacing of trucks passing through these stations.

Because operations data are collected continually, they can be used to analyze the underlying traffic patterns. This same data is used in conjunction with HPMS data to project general traffic VMT and could be used with additional analysis to calculate truck VMT and to understand regional truck flows and ton-miles (see Table 3-6).

3.5.2 Institutional Feasibility ★★★★★

Currently, all states must report these data to FHWA, which collects the data in the Traffic Monitoring Analysis System (TMAS) (Tang, 2010). This system could provide an excellent institutional platform for continued analysis of operations data to fill gaps in available truck data. FHWA, however, focuses on national-level data collection and may not have incentives to calculate local truck data. At the same time, state-level traffic monitoring and count programs are constantly striving to derive regional and local values from the count programs. Both the national and state-level institutional approaches are valid, and would provide valuable inputs, with different but overlapping interests.

Table 3-6. Operations data analysis platform: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	VMT, Ton-Miles	---
Owner-operator	VMT, Ton-Miles	---
Shipper-owned trucking	VMT, Ton-Miles	---

3.5.3 Operational Feasibility ★★★★★

Analysis tools could be constructed easily to produce accurate truck VMT counts using operations data available from publically available HPMS reports. Such data, used in conjunction with operations data from a states-count program or the TMAS database, could help in understanding the amount of freight that flows in monitored corridors by truck.

Since TMAS is already a funded program and every state has a mandated count program managed by the state DOT, there are few extra responsibilities or expenses incurred in creating these new datasets. This project also could be designed as a TMAS module with fixed inputs and outputs that would not require additional funding beyond the cost of creation.

3.5.4 Geographic Scalability ★★

Operations data by its very nature creates excellent national- and state-level aggregate data but becomes less reliable below the state level. As more WIM and count sites come online, however, more reliable detail is available in local areas. This program allows states to decide how to use funding for their count programs.

3.5.5 Financial Feasibility ★★★★★

This strategy focuses on development of a module to extract truck VMT, ton/ton-miles, and vehicle speed from existing data. It does not consider expansion of the current WIM or sensor systems. Costs would cover creating the data processing and analysis tools based on currently available operations data. The project could be accomplished and made available to FHWA with a budget around $500,000.

Total Feasibility Score: 20. The development of a module to extract truck VMT, ton/ton-miles and vehicle speed from existing data would be helpful.

3.6 National Freight GPS Framework

The rapid uptake of GPS technology in the last 10 years is the most notable example of recent technological innovation in transportation. GPS data has the potential to fill important gaps in truck-activity data. Requiring all trucks, or a statistically valid sample of trucks, to report GPS data for all trips would create a near perfect dataset for understanding truck movements in the United States. Such a dataset could produce VMT with unprecedented accuracy. Adding commodity and cargo weight records to the data requirements would create leading economic indicators with a high level of spatial and temporal resolution (see Table 3-7).

3.6.1 Technical Feasibility ★★★★★

This strategy relies heavily on the recent rapid proliferation of inexpensive and reliable GPS devices. The trucking

Table 3-7. National freight GPS framework: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	VMT, Ton-Miles, Value-Miles	VMT, Ton-Miles, Value-Miles
Owner-operator	VMT, Ton-Miles, Value-Miles	VMT, Ton-Miles, Value-Miles
Shipper-owned trucking	VMT, Ton-Miles, Value-Miles	VMT, Ton-Miles, Value-Miles

industry has already largely adopted the technology to provide data for fleet management, greatly reducing the barriers for adoption of GPS devices for this strategy.

Nevertheless, relying on this strategy would require resolving several other technological issues. One primary challenge is incentivizing truck operator willingness to share truck trace data from in-vehicle tracking devices. Chapter 4 presents a strategy (My Trip Matters, or MTM) that would rely on information and services exchange to overcome this challenge. Other challenges have to do with the sheer size of the data being collected. For example, the amount of data generated by this project would require significant amounts of infrastructure for storage. New tools would need to be developed to analyze the data, both in real-time and off line. Recent research into the development and implementation of algorithms to compress and query GPS trace data, such as SQUISH, offer near-term solutions for both storage and analyses (Muckell et al., 2009; 2013).

At the same time, FHWA has been "harvesting" GPS data from trucks and developing travel time information (see http://ops.fhwa.dot.gov/freight/time.htm). Thus, the data collection and analysis requirements of this project are well within the scope of currently available technology.

Creating a valid sampling frame from which to generalize observations to the broader population of trucks would be the greatest technical challenge for this strategy. CVUS provides an excellent model for how this might be implemented. Although there are several possible sources that could be used to develop a sampling frame, such as state vehicle registration from R. L. Polk and MCMIS, they may not suffice for a valid sampling frame and would require further investigation.

3.6.2 Institutional Feasibility ★

Collecting and analyzing GPS data from trucks has historically been difficult for transportation planners and researchers. Although several studies have collected truck GPS data from private sources, these have recognized roadblocks to broad-based GPS collection. Many fleets currently produce GPS data, but their prime use for these data is to facilitate "real-time" tracking and fleet management. There are limited examples of using these data for histories analyses, such as applications to facilitate backhauls (Muckell et al., 2009). As a result, there are only very limited systems in place for data extraction and manipulation. It has been easier in some cases for researchers to buy the data from the cellular providers who facilitate the collection of data for truck fleet management.

As previously mentioned, FHWA sponsored a project with ATRI to assemble a large, broad-based collection of truck GPS data from a number of fleets across America. Privacy and proprietary information concerns, however, limited the number of variables collected.

Although some form of mandated reporting from selected trucks would be ideal for this strategy, its implementation would be a tremendous institutional undertaking that would likely be met by strong resistance from the transportation industry. Mandated reporting is a worthy long-term goal, so other options may be considered to demonstrate the viability of collecting GPS data from trucks as a source of analytical data. For example, a pilot program could leverage existing GPS data from ATRI data, foster the collection of new GPS data on a voluntary basis, or use a data-sharing agreement for an existing GPS truck data program.

3.6.3 Operational Feasibility ★★★★

A national freight GPS framework could give an unprecedented level of access to data on freight moving by truck. It has the potential to generate high-quality data for truck VMT, truck speed, and freight performance measure data. In addition, it would be feasible to append information to the GPS trace data. For example, adding waybill data to the GPS format would allow for the collection of commodity flow data at better spatial and temporal resolution than is currently available in CFS.

The first approach to this project is to conduct a pilot study with a small number of trucks providing GPS trace data and to build the project infrastructure while looking for a long-term solution for valid national, regional, and local sampling frames. By restricting the initial study to volunteer organizations, purchased data, or to a state geography where the state-level government is interested in collecting such detailed data, this project can immediately begin operations.

3.6.4 Geographic Scalability ★★★★★

The nature of this project allows it to scale to all geographic levels, or even to be deployed in single instances, given geographic restrictions. The long-term goal of the project would be to cover the entire country with sufficient samples to support analysis at the state, regional, and local levels. Examples of state-level existing programs include Oregon's weight-mile data collection using smartphone GPS (Bell and Figliozzi, 2013) and Washington State's GPS-based truck freight performance measure platform (McCormack et al., 2010).

An example of a multi-geographic platform for truck analysis is being deployed through the Ministry of Transportation Ontario. Their iCorridor project is supported through the "harvest" and visualization of GPS data from trucks in Canada and the United States and provides information to many different geographic users (see http://www.gbnrtc.org/files/9813/2769/5483/Tardif.pdf).

3.6.5 Financial Feasibility ★★★

The largest financial barrier to implementing a national freight GPS framework would be the collection of data. There are a number of options for collecting GPS data from the nation's private trucking fleets that would reduce cost barriers.

The first would provide devices for each vehicle to be tracked. According to truckinfo.net, there are 15.5 million trucks in the United States, of which 2 million are tractor-trailers. Market research shows a number of GPS tracking devices priced around $50 a unit. To cover all trucks would cost $775 million or $100 million to cover only tractor-trailers, while a 1 percent sample would cost $7.5 million for all trucks and $1 million for tractor-trailers.

Because a large number of fleets already use GPS data in their operations, it may be possible to offer incentives for these companies to provide their existing data. This would be a much more cost-effective option than providing specific physical devices, allowing the market and fleets to decide which devices serve their needs best, while producing the valuable GPS data for analysis. Also, the FHWA system discussed above could be leveraged for financial benefits.

The last option to consider would be to purchase the data from third parties that are currently supplying data services to trucking fleets.

In addition to the data collection costs, this project would need to account for data storage and processing costs as well as the development of the software to analyze the data and create reports or visualizations. The cost of hosting and bandwidth may be as high as $50,000 per year. The project would need to be maintained by a team of three to five workers, whose salary and overhead costs may be between $300,000 and $500,000 per year.

Another strategy for storage would be to use a secure data storage center, such as the Secure Transportation Data Center (STDC) (see http://www.nrel.gov/vehiclesandfuels/secure_transportation_data.html). STDC provides secure storage for household travel survey GPS data and allows access to these data for research and analysis through procedures similar to those used with the Census Bureau for access to microdata. Data users are not required to be on-site at the center to use the GPS data but can access the trace data with secure logins.

Total Feasibility Score: 20. Based on the outcomes of the feasibility analysis, the research team produced a detailed implementation scenario (see Chapter 4) that investigated the requirements for starting a limited pilot program allowing for immediate returns in freight data availability and capable of growing into an essential data program.

3.7 Data from License Plate Recognition (LPR) Systems

LPR is an image-processing technology used to identify vehicles by their license plates. LPR systems use cameras, computer hardware, and software to capture an image of a license plate, recognize its characters by converting them into readable text, and check the license plate against designated databases for identification. Use of LPR among law enforcement agencies across the country has been increasing rapidly in recent years. In addition, LPR is used for toll collection and traffic management on major arteries. A subset of the data from such systems—specifically, large volumes of observations of different commercial vehicles at different locations and points in time—could be analyzed to develop information about truck travel patterns. This capability could lead to the development of more detailed O/D flow data particularly in urban areas (see Table 3-8).

3.7.1 Technical Feasibility ★

The use of LPR to capture data for characterizing goods movement activity is conceptually attractive; it could be largely automated following initial integration efforts, and the deployment of LPR cameras—both fixed and mobile—for law enforcement or other purposes (such as tolling) is rapidly increasing across the country (Lum et al., 2010). There are, however, a number of difficult technical challenges that would need to be overcome in order for this strategy to succeed.

Table 3-8. LPR systems: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	---	O/D
Owner-operator	---	O/D
Shipper-owned trucking	---	O/D

The first challenge relates to accessing data on a national basis. LPR systems are typically acquired and operated by individual jurisdictions, or perhaps by several neighboring jurisdictions. Some of these systems maintain databases of historical LPR observations for a period of time that might range from a few days to a few years. Such databases could, in theory, provide access to the large volumes of historical observations that would be needed to analyze travel patterns of commercial vehicles. Currently, mainly because of privacy considerations, LPR data are used for real-time purposes and are not typically archived—regardless of application. Accessing archived data, however, would require a significant amount of systems integration work. Because different systems are used by different jurisdictions, the systems integration work would need to be repeated for many different jurisdictions.

More work has been done in terms of data sharing across systems in the law enforcement sector than in the transportation sector. For example, Nlets, the International Justice and Public Safety Network (www.nlets.org), is currently developing a national portal for sharing LPR data across jurisdictions. Such a portal could collect LPR data for commercial vehicles at a national scale. The design of the Nlets portal, however, is intended to facilitate checks on specific vehicles. For example, the portal might be used to determine whether a vehicle owned by a fugitive suspect in a robbery in one city has been observed by LPR in any other cities across the country. The system is not designed for automated collection of large volumes of LPR records from multiple jurisdictions across the country. That is, it is not set up to allow for the type of data mining that would be necessary to evaluate commercial vehicle flows and trips. For the foreseeable future, collection of data at a national scale would require system integration on a jurisdiction-by-jurisdiction basis.

The second issue is that the location of cameras—either at fixed locations or mounted on police cruisers—is determined by agency needs, which may not overlap particularly well with the most helpful points for observing goods movement flows. For example, police cruisers are more likely to circulate through high-crime areas than around trucking hubs (assuming the two do not overlap). Open-road tolling operations are only on select facilities in a region. Also, for the foreseeable future, much of the forecast market for additional LPR technology acquisition will be in law enforcement, even though other end uses include access control, travel time measurement, parking time management, and tollways (IHS IMS Research, 2012).

A third challenge relates to the difficulty of inferring origins and destinations assuming that the network of LPR readers is relatively sparse. Imagine that a commercial vehicle is observed at Point A and then again, after some time has passed, at Point B. It would be impossible to discern whether, during the period between the two observations, the vehicle stopped to make a pickup or a drop-off, or perhaps simply stopped for a lunch break. Unless cameras were spread ubiquitously throughout a region—unlikely in the near term at least—this challenge would be difficult to overcome. Additionally, it would be impossible to determine whether a vehicle observed by LPR is carrying a load or deadheading, further complicating the difficulty of inferring O-D information from a series of LPR records.

A final challenge relates to license plates for commercial vehicles. First, depending on ownership and logistics arrangements, the license plate on the cab of a tractor-trailer configuration may differ from the plate on the trailer. Second, some vehicles may have multiple license plates for the different states in which they travel, and many LPR systems are not currently capable of reading multiple license plates for a given vehicle. Both of these issues may compound the challenges of accurately identifying certain commercial vehicles.

3.7.2 Institutional Feasibility ★

Beyond the technical obstacles discussed, there are three institutional barriers to using LPR systems for goods movement data. First, many law enforcement and other agencies are contending with privacy-related concerns associated with their use of LPR technology (Lum et al., 2010). To avoid compounding those concerns, many agencies and jurisdictions may be unwilling to share their historical LPR data for any purposes other than legitimate law enforcement activities. Second, there are legal questions yet to be resolved regarding appropriate constraints on use and storage of LPR data. Lum et al. (2010) consider a spectrum of possible uses that ranges from quickly identifying vehicles of interest (e.g., a stolen vehicle, vehicle that should pay a toll) in real time to archiving the data over much longer periods to facilitate more complex historical analyses (e.g., to perhaps construct a suspect's travel patterns in the days leading up to a crime in some future investigation or to analyze the travel patterns of toll road users). Although past legal precedent suggests that use of LPR at the simpler end of the spectrum appears to be acceptable, there is much greater uncertainty regarding the collection and long-term storage and analytic uses of LPR data (Lum et al., 2010). Until this issue is resolved in the courts, it remains uncertain whether long-term storage of historical LPR data will be viewed as constitutional. This could have a significant effect on the viability of collecting such data for goods movement analysis. Third, vehicles travel freely among different jurisdictions, so it is important that LPR systems can share data among agencies in order to assure coverage. Because LPR systems are, for the most part, owned and operated by individual agencies, sharing data requires added effort beyond normal operation. As with any technology, different vendors use varying data formats and transfer protocols that make sharing difficult. As technologies mature, markets typically converge toward standardized formats, easing interoperability. For now, it is possible to share data only with agencies using the same brand of LPR system.

3.7.3 Operational Feasibility ★★★★★

Assuming the necessary systems integration work and the development of suitable algorithms for evaluating LPR were completed, this approach to collecting goods movement data would be largely automated. Ongoing operational requirements are likely to be modest, and there should be no burden on users or respondents.

3.7.4 Geographic Scalability ★★★

Much of the geographic coverage for LPR systems is designed to serve specific agency needs and is likely to be concentrated at certain spots on the network. LPR data may therefore be most useful for examining origins and destinations for goods movement at the metropolitan scale. If augmented with additional observations—for example, from weigh-in-motion stations—along major highways, the data might support analysis of origins and designations for regional or interstate travel as well.

3.7.5 Financial Feasibility ★★

Assuming the need to integrate with many disparate LPR systems across the country as discussed earlier, the initial expense for this strategy is likely to be cost prohibitive. If such an investment were made, however, ongoing operating costs could be quite modest.

Total Feasibility Score: 12. This strategy, while intriguing, faces a daunting array of technical, institutional, and legal challenges or concerns. Further pursuit of this strategy in the near term does not appear promising, although it would be worthwhile to monitor the deployment and integration of LPR systems for ongoing developments that could make it more feasible in future years.

3.8 Analysis of the MCMIS for Use as Sampling Frame

MCMIS is an establishment-based source of truck-activity data. It contains more than 1 million trucking company records with information about size, how they operate, what commodities they carry, and how many miles their trucks travel. A detailed analysis of these data with the objective of assessing their suitability as a sampling frame could enable an alternative establishment-based sampling frame outside of the Census Bureau. The frame could be used for a new VIUS-like survey or to build the truck GPS framework.

3.8.1 Technical Feasibility ★★★★

It would be technically feasible to obtain and use the MCMIS file as a sampling frame. There are many different reports available from MCMIS, but the Census File Extract is the file of interest here. This file contains a record for every company or entity that operates a vehicle subject to the Federal Motor Carrier Safety Regulations (FMCSR) or Hazardous Materials Regulations (HMR). That includes any company, from owner-operators to large companies that operate commercial trucks in the United States. The census file for this research was from July 7, 2012, and contains records for 1,627,638 entities registered with FMCSA. There are more than 130 data elements for each entry including physical address information, the number and type of trucks owned and leased, the types of commodities hauled by the entity, whether the commodity was hauled less or more than 100 miles, and whether it was hauled across or within states. The data also includes total VMT for the year for the entire company. Through the analysis of these data, particularly VMT and commodity information, an efficient, stratified sampling approach for VIUS (or other surveys) could be designed. The team’s review indicated that most of the data is complete and current, although stringent quality controls would be needed to guard against misreporting of information by respondents.

Because MCMIS is being reviewed for its appropriateness as a sampling frame, a table indicating coverage in terms of data elements and trucking activity types is not presented. Such a table is not relevant.

3.8.2 Institutional Feasibility ★★★★

These data belong to FMCSA, a DOT administration. Thus, it is unlikely that institutional issues would arise if an internal DOT effort is built upon MCMIS.

3.8.3 Operational Feasibility ★★★★

There are no significant operational conflicts to evaluating MCMIS data for use as a sampling frame. The largest data source for the census file, Form MCS-150, must be updated biennially. The long-term availability of the data is secure. Metadata and documentation are free and publically available on the MCMIS website, making identification of the required data items relatively easy.

3.8.4 Geographic Scalability ★★★

This could be applied at any geographic level. One has the exact address of the firms and would be able to geocode the stratified sample desired and determine its geographic reach.

3.8.5 Financial Feasibility ★★★★

The cost to obtain the data is inexpensive. Any financial outlay would be to cover the work required to process and output data upon request.

Total Feasibility Score: 16. In Chapter 4, the research team evaluates MCMIS (relative to R. L. Polk) as a potential sampling frame for a VIUS-like survey or truck GPS framework.

3.9 Analysis of the R. L. Polk Data

R. L. Polk and Company provides the opportunity for a vehicle-based sampling frame for a new VIUS-like survey, truck GPS framework, or for data mining of truck-related characteristics. Polk compiles Department of Motor Vehicle registration information from the 50 states and the District of Columbia. In 2010, Polk launched the National Vehicle Population Profile (NVPP) that provides a near-census of Class 1-8 vehicles in the United States and Canada. In 2013, Polk released an enhanced version of its data that is VIN-based and updated in near real time. Without purchasing the data, it is not possible to access its file structures.

3.9.1 Technical Feasibility ★★★★

VIUS (formerly Truck Inventory and Use Survey), as well as other surveys, have used a Polk database as the sampling frame. Using the vehicle-based frame allows for stratification that could achieve greater coverage of the trucking industry than an establishment-based survey. A shortcoming is that registration data contains no descriptive information beyond what Polk derives from the VIN. The data would include truck-activity data; registration information (i.e., the data that Polk could provide) would include registration date, vehicle identification number, make, model year, fuel type, body type, wheelbase, and gross vehicle weight. One can use these data to determine the vehicle-based truck universe is (i.e., what is on the roads), but not what these trucks are doing.

Prior experience with VIUS indicates that it would be technically feasible to use the Polk database as a sampling frame. As in the past, it would be necessary to select a single date for which to obtain the files of truck registrations. For instance, the sampling frame for the 2002 VIUS was constructed from files of truck registrations identified as being active as of July 1, 2002. Information in the files can then be used to stratify the frame by geography and truck characteristics. The 50 states and the District of Columbia comprise the 51 geographic strata. Body type and gross vehicle weight (GVW) determined the following five truck strata:

1) Pickups;
2) Minivans, other light vans, and sport utilities;
3) Light single-unit trucks (GVW $< 26{,}000$ lb);
4) Heavy single-unit trucks (GVW $\geq 26{,}000$ lb); and
5) Truck-tractors.

Polk-based percentage data were then applied to state supplied total registered vehicle data to obtain final counts of each of the five vehicle segments. For trend purposes, a similar sampling approach could be envisioned for future, reinstated VIUS-like surveys.

Polk handles all processing of registration data and little information is available about the accuracy of the data. One purchases the processed files directly from Polk.

As with the MCMIS data, the research team presents a table indicating data element and trucking activity type coverage.

3.9.2 Institutional Feasibility ★★★★

If Polk data were used it would have to be purchased by the agency that owns and operates a new VIUS-like survey. In previous VIUS iterations, this purchaser would have been the Bureau of the Census. This does not preclude DOT from holding the institutional responsibility. There is precedent for FHWA purchasing Polk data, which is currently used to calibrate truck information reported in the HPMS. This has been done through a sole-source contract with Polk. Also the National Highway Traffic Safety Administration (NHTSA) already makes extensive use of the files.

3.9.3 Operational Feasibility ★★★

Polk is a privately held consumer marketing and information company, which started motor vehicle statistics operations in 1922. Since then, Polk has maintained comprehensive vehicle databases for sale. Given its long-standing legacy as a data and information supplier, there could be future operational issues that would prevent obtaining the required commercial database, and this may be an issue. Polk has been acquired by IHS, which may affect future business operations.

3.9.4 Geographic Scalability

Geographic scalability does not apply.

3.9.5 Financial Feasibility ★★

The cost of Polk data varies by the amount and type of information purchased. There do not appear to be published price schedules, and cost proposals are produced on a customer-by-customer basis. The government, however, may be able to negotiate the price.

Total Feasibility Score: 13. In Chapter 4, the research team further evaluates R. L. Polk data as a potential sampling frame for a VIUS-like survey and as a source of other data to support such a survey activity, but it received a lower feasibility score than did MCMIS.

3.10 Agent-Based Modeling to Identify Truck Movements on Network

This strategy attempts to improve upon the current methods through the use of more powerful simulation-based modeling techniques. Such techniques are the primary analysis tool for designing or understanding complex systems, such as truck movements on a network. When linked with optimization techniques, agent-based modeling (ABM) techniques have been effectively used for representing such systems. With a sufficiently complex simulation model, the strategy has the potential to represent a large part of the trucking industry universe, both interregional as well as intraregional truck movements. There is also the possibility of filling gaps in VMT and O/D flow data. The researchers tested the feasibility of using agent-based modeling (see Table 3-9).

The current best model of applying powerful modeling techniques to produce freight information is the FAF. The FAF has two basic products: an O/D matrix of tons by mode and a highway network loaded with truck payloads as a surrogate for trucks. The approach used to identify actual truck movements is an approximation. Current methods rely on transforming tons carried by truck-only into truck payloads based on payload-per-vehicle estimates from the VIUS and weigh-in-motion data. O/D flows are then disaggregated to sub-regional geography and off-the-shelf network assignment methods are used to fit the flows to the network using time and other impedance factors, adjusting the flows so that payloads per year divided by 365 do not exceed average annual daily traffic (AADT) from HPMS. This method requires several assumptions, including that (1) truck O/D and truck tonnage O/D geography are the same, (2) errors in disaggregation of regional flows to the county level balance out, and (3) there is no way of assigning intra-zonal traffic. Since the FAF is largely based on CFS, it is subject to the same limitations of CFS; namely, limits in commodities covered, timeliness of data, and local coverage.

This strategy evaluates whether ABM could produce improved network assignment models.

3.10.1 Technical Feasibility ★★★

The ABM approach is technically feasible. An agent-based model represents individual decisionmakers whose interactions form a system. Experimenting on this system by changing agent parameters or performing optimizations can provide insight into the study objectives. Agent-based simulations have been used to analyze patterns of pedestrian behavior, urban traffic, and emergency evacuations.

Basic components of an agent-based model are agents and an environment in which these agents interact. The model has to define behavior rules and attributes for agents so that their interaction with each other and the environment can be simulated. Developing a model for truck movements and exploring model results by changing parameters such as the number of trucks, speeds, times of departure, and route selection rules can yield insights into truck traffic patterns.

The first step to develop an agent-based model is to define *agent.* An agent-based approach to truck traffic can take the perspective of individual drivers and their decisions on travel times, route selection, and speed to observe emerging patterns of traffic flow in the region of interest. Truck drivers follow instructions from their companies on destination and route selection, although they may have more initiative when they select local roads depending on the traffic situation. Another option is to define carrier companies as agents. Carriers

Table 3-9. Agent-based modeling: potential for industry and data coverage.

Trucking Activity Types	Geographic Detail	
	State and Multi-County Regions	State and Multi-County Regions
For-hire carrier	VMT, O/D	VMT, O/D
Owner-operator	VMT, O/D	VMT, O/D
Shipper-owned trucking	VMT, O/D	VMT, O/D

schedule trips and routes for their trucks, based on an internal decision rule and orders from shippers. Since the question is about the number of trucks and their route assignment, a higher resolution model that includes truck driver decisions might not bring additional benefits and unnecessarily increase the modeling burden. So, a carrier-based model would be preferred.

The second step is to define a decision rule for the agents, which is the primary challenge in an ABM effort. The difficulty in modeling carrier-company behavior is to estimate how detailed decision rules are. Some carriers might use optimization algorithms and others might follow simple rules, with a primary and secondary choice for each of their destinations. The supply-chain academic, consultancy, and third-party logistics communities already have a good handle on the private-sector decision calculus and "micro" drivers of mode shifts that can be used to estimate the necessary decision rules.

The third component of the model is the network on which carrier companies operate. The network in the model can represent the highway system with nodes and links between them. The capacity and the speed on different parts of these links must be included in the model, because it influences how carrier companies operate.

Assuming an adequate representation of the carriers is complete, the agent-based model must go through a verification and validation process. Verification ensures that the model is working as intended and that its calculations yield proper results. Validation determines if the agent is representing the reality accurately enough for the purposes of the model. Note that an agent-based model should not try to emulate reality with 100 percent accuracy. After the simulation is set up, the number of carriers and their trucks that enter the road network from the origin locations can be adjusted to real-world levels (much like the FAF does now), and the ensuing traffic flows can be observed. The validation stage can include comparison of simulated traffic flow data with truck counts from different locations to calibrate model parameters.

Although not plentiful, there are examples of ongoing research using agent-based models. One is "A Conceptual Framework for Agent-Based Modeling of Logistics Services" by the University of Toronto (Roorda et al., 2010). The effort is at a conceptual stage, with data requirements currently under investigation. Another example is work being performed for the Chicago Metropolitan Agency for Planning (CMAP). More examples of current research are presented in Chapter 4.

3.10.2 Institutional Feasibility ★★★★

The institutional feasibility of this strategy is high, given that the FAF and augments to it have been administered and financed by FHWA.

3.10.3 Operational Feasibility ★★

The operational feasibility of this strategy is questionable due to data inadequacies. GPS data from trucks could be one component of developing a carrier-company decision-making model. GPS data on trucks potentially includes truck identification number, coordinates, speed, travel heading at a given time, and stops. Data on change in coordinates and time stamps can determine if a truck had stopped or just slowed down in traffic. Stops may be classified as intended (e.g., loading or unloading) or unintended (e.g., congestion, traffic lights, or intersections).

These data do not give information on activity at a stop location; it is still unknown if the truck unloaded goods or received new cargo before continuing to a new zone or if it perhaps simply stopped for a lunch break. Combining land-use data with GPS data on stop locations can only be a limited improvement, as there are many types of establishments in the same type of land-use area. Moreover, GPS data do not necessarily include truck type, owner, cargo, or depots.

Another difficulty with GPS data is that carriers' decision rules might not be observable from truck locations. Carriers' routing choices might depend on availability of their personnel, their own priorities for different clients, maximum amount of hours a driver is allowed to drive before resting, etc. GPS data must be combined with other sources of data to derive a carrier decision-making model. Even after a decision-making model for carriers is complete, simulating this behavior to obtain truck count data between origin and destination locations will rest on the assumption that the model is accurately capturing many different decision rules of various carriers. This assumption is not easy to justify.

The main difficulty in using an agent-based model is that it is unclear what types of data sources are necessary to model carrier behavior. Identifying the relevant quantitative and qualitative data sources, obtaining them, and validating the model require a significant amount of effort. Truck GPS data alone is not enough to build such a model.

3.10.4 Geographic Scalability ★★★★

Assuming that the necessary data were available and that an agent-based simulation model could be developed, the information obtained would be at all levels of geography—national, state, and regional.

3.10.5 Financial Feasibility ★★

Without an existing, necessary data platform, the initial expense for this strategy would likely be cost prohibitive. If such an investment were made, the model development costs could be quite modest.

Total Feasibility Score: 15. In Chapter 4, the research team investigates the state of the practice in freight-related ABM activities and research further to determine whether this could be a potential source of missing information in the near future. In addition, *NCFRP Report 26* presents the findings of a study on developing commodity flow data at the state and local levels. An ABM approach may be useful for pulling together the different types of data into the FAF for a richer dataset.

Total feasibility scores indicated the levels of risk (low score) and the chances of success (high scores) for the 10 data gathering strategies. The researchers developed detailed implementation plans for three strategies with high scores: a new VIUS-like survey, national freight GPS framework, and ABM approach. A fourth strategy, operations data analysis platform, scored high on feasibility.

CHAPTER 4

Detailed Implementation Strategies

CHAPTER 4 KEY TAKEAWAYS

- Of three implementation scenarios for a national freight GPS framework, one pertaining to a new app, My Trip Matters, could produce detailed O/D and VMT data at multiple levels of geography within 5 years.
- A new VIUS-like survey would likely follow the model of the Canadian Vehicle Use Survey (CVUS) as a wholly internal U.S. DOT program.
- Agent-based modeling is largely an academic exercise at this time, and continued FHWA and TRB support would continue on a long-term development path.

This chapter provides detailed implementation plans for the three strategies that fared best in the feasibility reviews illustrated in the previous chapter. These plans can be considered guides for further developing the program.

4.1 Using GPS Traces to Understand Trucking Activities

Trucks equipped with GPS, or drivers carrying GPS-enabled devices (e.g., smartphones), create traces of the movement of each truck. Amassing these data using cloud technologies creates an innovative dataset that can provide origins and destinations by time of day. Appended with multiple attributes (e.g., commodity, ownership), many additional dimensions of truck activities can be created.

4.1.1 Current State of the Opportunity

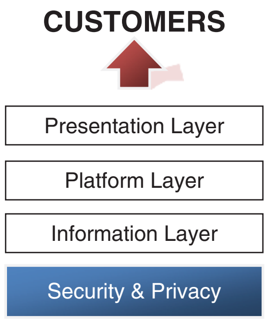
4.1.1.1 Identification of Present Conditions

The recent use of GPS trace data for truck-activity data patterns (e.g., Lioa, 2009; Greaves and Figliozzi, 2008; Zhao et al., 2011; Tardif and Li, 2011; Sharman and Roorda, 2010; Holguín-Veras et al., 2011a), the use of smartphones for GPS truck traces (Bell and Figliozzi, 2012), and GPS truck traces for backhaul analysis (Muckell et al., 2009), have provided ample evidence that this method of collecting data is viable. McCormack et al. (2011) demonstrated that GPS truck traces could be used to identify bottlenecks. In addition, GPS truck trace data can be used for performance measures (McCormack et al., 2010).

The Freight Performance Measures Program funded by FHWA used third-party ownership of GPS truck trace data through an agreement with ATRI. The data were used primarily to assign average speeds to the national road network. Because of the third-party ownership arrangement, a small number of exploratory studies were conducted with these data. In addition, neither the characteristics of the trucks or firms were made available. The data feeds were opportunistic rather than generated from a randomly sampled set of trucks, making generalization impossible. FHWA is beginning a new program for data it will collect and own. As part of this new effort, there are plans to collect GPS truck traces from trucks that have been randomly sampled. To date, the FHWA approach has not been used to produce aggregate statistics other than average speed. A Transport Canada (2013) pilot study, however, demonstrated the capability of capturing enhanced GPS trace data suitable for creating aggregate statistics.

4.1.1.2 Data Sources and/or Analytical Methods

With access to the original raw GPS truck trace data, it is possible to identify the origins and destinations by geocoding



Source: Digital Government (White House press release, 2013b)

Figure 4-1. Layers of digital services.

the latitude and longitude variables. Merging these data with geographic information systems (GIS), or Internet mapping services (e.g., Google Maps, Open Street Maps), makes it possible to identify the parcel where the trace began or ended, and to infer the type of load hauled from the attributes in the GIS data.

A recent executive order by the Obama Administration describes details for this conceptual model (White House Press Release, 2013a). Figure 4-1 illustrates how cloud-based technologies can accomplish the goals of the executive order. The same strategy could be used to amass GPS truck trace data. The raw data would be assembled digitally in the Information Layer, made "mobile" through the Platform Layer, and then visualized in the Presentation Layer (White House Press Release, 2013b). General Transit Feed Specifications (GTFS and GTFS-R) is a good example of this concept where the Information Layer contains the transit scheduling and real-time transit GPS trace data assembled in a standardized format, moved to Google Maps for the Platform Layer, and visualized as bus routes in the Presentation Layer. The executive order addresses the need for protecting the privacy, confidentially, and security of the data throughout each of layers. Any GPS truck trace data used in this strategy would receive review and full protection from disclosure, while still being made useful for statistics and other planning uses. For example, assembling the raw traces and storing them in a secure data center protects the privacy of the data, while only displaying aggregate de-identified visualizations mitigates any risk of the disclosure of protected information.

As indicated in Table 4-1, GPS truck traces generate origins and destinations by route, time of day, and speed. At the corridor level, direct metrics can be extracted from the traces. At larger geographies, cloud-based technologies can be used to "amass" the traces, yielding metro-area, multi-state, and national metrics. As mentioned, the data currently available have been gathered from cooperating, rather than randomly sampled, firms. As a result, it is not possible to generalize from the data using traditional statistical methods. The amassing process is not a statistical method and only provides the characteristics of the traces contained in the total volume of data. The raw GPS traces also provide VMT by route, time of day, and speed for each vehicle instrumented (see Table 4-2). A GPS trace accompanied by information on the type of vehicle, commodity being hauled, and whether truck is loaded or empty, as gathered by traditional surveys or electronically, can result in a multi-attributed trace with a large amount of useful data.

Table 4-3 displays how origin and destination for all of parameters (except calculated averages) can be obtained directly. The direct metrics can be amassed for larger geographies. Table 4-4 illustrates the gain in information for VMT by vehicle type, commodity type, load type, route used, time of day, and speed that is possible should multi-attributed GPS data be available.

4.1.1.3 Key Challenges

Although some firms have been willing to provide GPS truck trace data through a third-party provider, others have been willing to share their data directly using a non-disclosure

Table 4-1. Current GPS data for O/D.

Geography	Type of GPS Data							
	Vehicle Type	Commodity Type	Load Type	Average Load	Route Used	Time of Day	Speed	Average Speed
Truck Stop	NA	I	NA	NA	D	D	D	C
Corridor	NA	I	NA	NA	D	D	D	E
Metro Area	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)
State	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)
Multi-State Region	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)
National	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)

Legend: D = Direct, E = Estimated, C = Calculated, I = Inferred, NA = Not Available, A = Amassed

Table 4-2. Current GPS data for VMT.

Geography	Type of GPS Data							
	Vehicle Type	Commodity Type	Load Type	Average Load	Route Used	Time of Day	Speed	Average Speed
Truck Stop	NA	I	NA	NA	D	D	D	C
Corridor	NA	I	NA	NA	D	D	D	E
Metro Area	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)
State	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)
Multi-State Region	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)
National	NA	I(A)	NA	NA	D(A)	E(A)	E(A)	E(A)

Legend: D = Direct, E = Estimated, C = Calculated, I = Inferred, NA = Not Available, A = Amassed

Table 4-3. Multi-attributed GPS data for O/D.

Geography	Type of GPS Data							
	Vehicle Type	Commodity Type	Load Type	Average Load	Route Used	Time of Day	Speed	Average Speed
Truck Stop	D	D	D	C	D	D	D	C
Corridor	D	D	D	E	D	D	D	C
Metro Area	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	D(A)	C(A)
State	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	D(A)	C(A)
Multi-State Region	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	D(A)	C(A)
National	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	D(A)	C(A)

Legend: D = Direct, E = Estimated, C = Calculated, I = Inferred, NA = Not Available, A = Amassed

Table 4-4. Multi-attributed GPS data for VMT.

Geography	Type of GPS Data							
	Vehicle Type	Commodity Type	Load Type	Average Load	Route Used	Time of Day	Speed	Average Speed
Truck Stop	D	D	D	C	D	D	D	C
Corridor	D	D	D	E	D	D	D	C
Metro Area	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	E(A)	C(A)
State	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	E(A)	C(A)
Multi-State Region	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	E(A)	C(A)
National	D(A)	D(A)	D(A)	C(A)	D(A)	D(A)	E(A)	C(A)

Legend: D = Direct, E = Estimated, C = Calculated, I = Inferred, NA = Not Available, A = Amassed

agreement (NDA). For those not willing to share their data, more education may be needed on the value to their business of good data for freight planning. Lawson et al. (2002) were able to achieve a 60 percent response rate from private trucking firms when asking them about problems they faced while using the road network in Oregon. This traditional phone survey collected rich descriptive information on infrastructure and operations-related problems (e.g., congestion, dangerous curves) at specific locations. Having a mechanism for capturing and reporting problems facing the trucking industry and making this information available for planning purposes has benefits for the freight community.

These same infrastructure and operations issues can be identified using GPS and GIS. The raw GPS trace data can be kept confidential through the use of a secure data center (e.g., the Transportation Secure Data Center; see http://www.nrel.gov/vehiclesandfuels/secure_transportation_data.html). In a secure data center, algorithms capable of compressing and querying the GPS trace data can be used to identify infrastructure and operations problems. The dual use of the GPS trace data to provide VMT and O/D metrics increases the value of the traces. The trucking industry would be contributing to the betterment of the road network they rely upon through sharing privacy-protected data.

4.1.1.4 Key Opportunities

The concept of collecting GPS trace data for trucks has been demonstrated in the Canadian Vehicle Use Study (see http://www.tc.gc.ca/eng/policy/aca-cvus-menu-2294.htm for documentation on methods, instrumentation, and questions). The CVUS equips vehicles with GPS data loggers and an interface that allows for the capture of trip purpose and location, configuration and body style, cargo weight on board, and commodity description. It used a nested stratified sample survey to target owners of multiple vehicles. The pilot test used a random sample of 500 heavy vehicles, with one-third participating in the test. The study concluded that recruitment was difficult and driver's cooperation with entering data by hand was challenging.

One of the recognized opportunities for GPS trace data is the very large generation of location data. To achieve the highest quality of data, collection intervals need to be very small to provide the greatest granularity (e.g., every second, every 5 seconds). The resulting massive dataset (BIG DATA) can be managed using new algorithms designed specifically for use with GPS. Amassing techniques include the use of single trace compression algorithms (Muckell et al., 2013) or multiple trace compression (Birnbaum et al., 2013).

Although it is possible to grow the sample by deploying and redeploying data loggers, Bell and Figliozzi (2012) demonstrated the ease of using smartphones in the Truck Road Use Electronics (TRUE) data collection system. The State of Oregon currently collects a weight-mile tax (WMT) from all commercial trucks operating within the state. The TRUE data has advantages over previous GPS truck trace data due to its level of disaggregation and ability to report vehicle and commodity types. Smartphones have internal GPS and can be transformed into data collection instruments through the use of apps. The GPS data that is created can be incorporated into an Information Layer, managed in a Platform Layer, and visualized in a Presentation Layer.

More than 92 percent of members in the Owner-Operator Independent Drivers Association have cell phones, with 33 percent owning a smartphone/iPhone/Blackberry, 8 percent owning a tablet, and 3 percent owning an e-reader. Although the number using these technologies has been growing, more than half of those who could download apps are reluctant to do so—perhaps because the average age of the membership is 55. Although cross-tabulations of mobile device ownership by age of members is not available, perhaps more will use smart devices as younger drivers enter the trucking industry. Drivers also may use such devices more as their price drops. At the same time, as the business advantages of using a smart device increase, firms will have a greater incentive to outfit their fleets with appropriate technologies to capture these benefits.

4.1.1.5 Expected Results

Two key issues with respect to the use of GPS trace data are determining what the most cost-effective device is and getting cooperation from a fleet manager for GPS-enabled onboard equipment or driver cooperation with mobile devices. The cost of data loggers has decreased over the years and the size of the equipment has diminished. Most importantly, in the last 2 years, the capability of smart devices to provide high-quality GPS trace data means a dedicated GPS data logger is no longer required. Because GPS trace data can be generated from any number of devices and is formatted the same way, there is no need to purchase or install dedicated equipment on a truck. If the truck already has GPS-enabled devices on board, they can be used, as can any GPS mobile device the driver carries. The resulting data will be the same. The use of a smart device app makes the data transmission from the device easy. The cost of using the app depends on the mobile plan used with the device. Other means are more expensive (e.g., a dedicated transmission system from a GPS device). Alternatively, the data can just be stored in a data logger, although only storing data will not allow for real-time transmissions. One advantage of using GPS on smart devices is the capacity of sending less costly periodic transmissions.

The second issue is getting cooperation from a fleet manager for GPS-enabled onboard equipment or driver cooperation with mobile devices. If the fleet manager or third-party provider can charge for the GPS trace data feeds, they will see it as a profit center. A driver needs to receive some compensation or benefits for providing data. This concept of "service value data harvesting" uses the original methodology of a "passive harvest" (e.g., traditional GPS data collection) and returns valuable information to the data provider in real time (e.g., apps that provide users instantaneous context data based on their current location or routes chosen). Drivers would receive information regarding events or circumstances related to their location (e.g., weather conditions, traffic conditions, alerts). These locational services already exist in the private sector.

Many apps ask the mobile device owner for permission to extract location information from the device on a regular basis. Resistance to providing location information is reduced when the mobile device user receives benefits in return. Trucking companies perceiving data benefits would be willing to participate in an innovative data collection program, privacy protected and secured, capable of generating necessary truck data metrics.

4.1.2 Implementation Scenarios

Three potential implementation scenarios are identified in this section. These can best be distinguished as a voluntary program, a mandatory program, and a voluntary program that would be differentiated by the provision of information in exchange for the capture of GPS data. The research team suggests that the third scenario be researched further by FHWA, perhaps as some sort of public-private partnership.

4.1.2.1 Voluntary GPS Collection

Trucking companies use GPS equipment of their choice (e.g., fleet management system) and archive and transmit the GPS traces from each of their trucks using their U.S.DOT vehicle number. The administrative data associated with the U.S.DOT number would be appended to the GPS trace and post-processed into the standardized format used for truck metrics. The raw data could be transmitted to a private, secure center and post-processed or transmitted to FHWA for post-processing. In all cases, the data would be privacy protected and kept secure while in the Platform Layer. It would only be made available to other users in the Presentation Layer, where there is no risk of disclosure. Data processing services could be offered by secure third-party providers, trucking associations, and ATRI, or similar entities. Using a standardized post-processing methodology makes data from any source part of the collection and analysis effort.

4.1.2.2 Required GPS Collection for Hazmat Trucks

Trucks hauling hazardous material (hazmat) loads would be required to transmit GPS trace data for safety and security of their load. The GPS traces would be associated with truck-specific and load information and post-processed for truck metrics. Trucks involved in any accidents or incidents would be subject to very high fines if not current in their transmittals. Trucks hauling any type of load could receive a subsidy on their insurance costs if they participate in the GPS trace transmission data program. Additional incentives could be introduced for streamlining licensing and permitting and ensuring the availability of truck parking services.

4.1.2.3 GPS Collection in Exchange for New Information Service: "My Trip Matters"

An app (e.g., My Trip Matters [MTM]) would be developed to provide operators with valued services and information in exchange for information on their truck movements. This business model is one that has been successful in the app world, relating data emanating from location-based systems (Herrera et al., 2009; Hann et al., 2002; Cruickshanks and Waterson, 2012). In this proposed strategy, the app would have three service levels that could be offered to truck operators, each with progressively more detailed information exchange requirements and capabilities. The first level (e.g., basic) would prompt the user with the statement *My Trip Matters would like to use your current location. Don't allow/OK.* If the user indicates OK, then the GPS data from the device will be transmitted to a secure data center to be amassed in an Information Layer that compresses the trace data. The Platform Layer would query the GPS compressed traces for route, time of day, and speed, using a standardized format (e.g., similar to GTFS) with industry acceptable buffers regarding exact locations (e.g., block, census tract, county) for the origin and the destination of the trace. The trace data also would be processed using a series of queries to produce performance measures and to detect problems experienced on the infrastructure or in operation. The Presentation Layer would display a variety of visualizations regarding all processed metrics, using any browser on a base map desired by the end user. The Presentation Layer could be accessed through password-protected portals, or be viewed in a stylized manner that protects against disclosure or unintended locational information at levels deemed unacceptable by the data provider.

The second service level (e.g., premium) also would prompt the user with the statement *My Trip Matters would like to use your current location. Don't allow/OK.* When indicating OK, the user would complete a one-time short demographic survey screen asking if the driver is a for-hire carrier or an owner-operator and whether the truck being driven is a shipper-owned truck or a service truck (construction, utility, or other services). These demographic details would be transmitted with the GPS trace data and compressed in a similar manner as the Basic MTM. At the Presentation Layer, this service level would also illustrate metrics for route, time of day, speed, O/D, VMT, and problems on the infrastructure by type of driver and type of truck.

The third level (e.g., platinum), would include the functionality of the second level, but would have an additional pop-up to query the driver for information on the commodity hauled, the registered and actual weight of the truck, and the load status (empty or loaded). This pop-up could be motion and time sensitive and could appear after a specific length of time or lack of motion to ask the driver if the information is still correct. The driver also could use voice-recognition technologies to complete the device's survey. When these platinum-level data are transmitted, the entire set of variables would accompany the GPS trace and be compressed. The Presentation Layer would be able to display any combination of the available variables for analysis. There would be metrics for route, time of day, speed, O/D, VMT, and problems on the infrastructure by type of driver and type of truck, commodity, weight of the truck, actual weight, and load status.

An available national sampling frame (e.g., MCMIS filtered for a stratified sampling of firms) could be used to recruit truck operators into the app-enabled data collection system. E-mail addresses are available in the set of attributes in the MCMIS census file. A traditional survey recruitment strategy could be used to contact firms and offer a random sample the use of the MTM app. To encourage participation in the use of MTM apps, the apps could have users compete for points, score points for a lottery, or "keep score" on their own statistics for best performance, longest trip, etc. Users could also receive feedback on the benefits their data have made to the planning process, particularly with respect to future planning for extreme weather events. Another potential incentive that the app offers is a better safety score as a result of submitting data.

The resulting data would be weighted at a future date in the Platform Layer with Travel Monitoring Analysis System (TMAS) continuous count data and weigh-in-motion (WIM) data. The weighted data would be visualized in the Presentation Layer and illustrated in a manner to alert the user that the visualizations are estimations based on a random sampling strategy rather than on original trace data. An additional data stream could be appended using Commercial Vehicle Information Systems and Networks (CVISN) (see www.fmcsa.dot.gove/facts-research/cvisn/index.htm) information and could provide validation for some of the desired data fields.

4.1.3 Potential 5-Year Progress for MTM

The entire MTM data program could be up and running in 5 years. Freight planners and researchers would be able to generate statistics and identify and monitor problems on the infrastructure system. Any additional third-party GPS or FHWA Performance Measures GPS trace data could be appended in the Platform Layer and visualized in the Presentation Layer, in addition to any other GIS shapefile features or attributes. With sufficient volumes of data, regions would be able to visualize more disaggregated data. This would be similar to strategies used in the American Community Survey (ACS) by which 5-year aggregates increase the level of detail provided without violating disclosure rules.

An added feature that could be included within a five-year period would be integrating 511 system feeds. Currently, states produce 511-information and transmit alerts and warnings in a variety of ways (e.g., Washington State DOT sends emails for incidents on its freight system). Within 5 years, MTM could consolidate all transmissions from each state into the Platform Layer and provide MTM users with customized feeds (e.g., user-defined information) in their Presentation Layer in a timeframe chosen by the user. This location service would provide the MTM user with all relevant information across states and on any route, particularly current weather conditions and any forecast window the user chooses. Members of the International Reciprocity Program (IRP) who travel in more than one state would benefit the most from a harmonized 511 system.

All of the spatially-relevant information could be assembled and appended to the GPS traces, regardless of the user display choices, and made available for safety and behavioral analyses conducted at the secure data center and only released in aggregate or visualized in the Presentation Layer with appropriate disclosure rules (e.g., minimum number of traces to prevent exposure). The Platform Layer would archive all weather-related data for the traveled portions of the network, making it available for asset management and safety analysis. This aspect of the MTM system illustrates the "capture data once, use it many times" strategy. New sets of metrics could be generated on all the previously described factors by characteristics (e.g., VMT by vehicle type) and with all the newly appended conditions and situations data (e.g., VMT by vehicle type by extreme weather condition).

The MTM user can find information on the most efficient routing. (Fleet management and GPS services already have this capability, but not in a consolidated manner with the ability for users to give feedback or confirmations of the information.) This feature would allow MTM users to query the best route from their origin to their next destination and receive information that is most relevant to freight community members. This service could include "off-hour" delivery information in large urban areas.

4.1.4 Rationale for Recommendation of MTM

4.1.4.1 Technical Feasibility

The technology required to develop a location service app is well developed. The GPS processing techniques will require some experimental research to refine existing algorithms or develop new algorithms to report the VMT, O/D, and speed parameters. These techniques are already known and can be made into Open Source processes. The more advanced metrics would require algorithm development. The compression techniques for single and multiple GPS traces are available in Open Source, but further research will be needed to compress appended attributes to the trace. The data could remain in its original form, but would require extension storage capacity—available as cloud storage. Although the use of these techniques is new to the freight community, they are already in use by private industry and app developers.

4.1.4.2 Institutional Feasibility

FHWA has been successful in obtaining GPS trace data from a third-party vendor, although the use of the data was constrained. The current contract that FHWA is completing will allow it ownership of the GPS data and the ability to share the data (assuming non-disclosure agreements) with state DOTs and MPOs. Using an app to capture and transmit the GPS trace data to a secure location is supported by a presidential executive order, which also provides a strategy to manage Open Data and provides protections for privacy and security. The Transportation Secure Data Center (TSDC) has been safeguarding GPS trace data that derive from travel surveys for several years and has a mature program to make the data available for research purposes without disclosing it. The provisions of the Open Data Policy provide for the protection of privacy and confidentially.

The ability to garner cooperation in providing GPS data remains a challenge at the federal level. Precedence for mandating the collection of freight in federal legislation can be found in SAFETEA-LU.

4.1.4.3 Operational Feasibility

The current abilities of data management systems and platform processing with cloud-based services are now well established. There are very few risks involved with retrieving GPS trace data from a smart device, processing it on a Platform Layer, and visualizing it on a Presentation Layer. Although these services are limited in freight transportation, they have been demonstrated to provide services similar to the ones required. With a standardized data format and Open Data post-processing program, any number of options could be used to transmit data.

An alternative to a central repository would be the web-accessible archiving process being used for the transit industry—the GTFS data exchange that allows the Platform Layer to act as a cloud aggregator (see http://www.gtfs-data-exchange.com/). The organization of data sources could remain flexible and adaptable regarding the data collector's preference and still be completely accessible for a Presentation Layer. This greatly reduces resource commitments. Alternatively, all post-processed data could be housed in an FHWA cloud environment.

4.1.4.4 Geographic Scalability

There are no known constraints with respect to geographic scalability with the transmission and processing of data, given the recent availability of cloud-based technologies. There could be variations in participation by regions of the United States (e.g., truck drivers on the West Coast being more tech-ready than those in the Midwest). Using a random sampling frame would make it possible to generate the spatial resolution desired for varying purposes (e.g., over-sampling at the local level for small geographies).

If the data program is federally mandated, then concerns regarding sufficient coverage would be overcome with nearly complete participation by the freight community.

4.1.4.5 Financial Feasibility

An Open Data system that relies on existing mobile devices, inexpensive cloud-based flexible data storage contracts, and cost-effective development of algorithms to extract the various metrics would have no large operational costs. Although there are no large operational costs anticipated when using an app-based data collection, storage, and visualization strategy for creating innovative truck-activity data, there would be costs associated with the development of the Web-based infrastructure. For example, a decision would need to be made regarding which devices would be used for data collection. Costs for the development of "native" apps capable of generating GPS data could cost approximately $50,000 per operating system type. The data generated by the MTM app would need to be stored, and although storage is much cheaper with cloud-based third-party facilities, a general overall cost of $60,000 per year for the data program (including storage, maintenance, and preliminary data processing) would be sufficient for very large volumes of data. To easily view, analyze, and use the generated data for reporting out statistics and planning purposes, the development of a visualization app may be of benefit. The cost of developing a visualization tool would be approximately $150,000. Thus, the MTM data program, with two data collection operating systems, a storage program, and a visualization/data analytics app would cost, in total, $310,000 in the first year, and $60,000 (or less) to operate in future years.

Another important cost consideration is the need for computer services and personnel to maintain the platform services and keep current with browser capacities for presentation services. Staff and third-party providers would be needed to maintain the code and move seamlessly across platforms and through upgrades in the various "working parts" of the system. These costs are present in all cloud-based technology deployments and not specifically due to the needs of the freight community. Further, technology-oriented solutions have the added advantage of fostering innovation and attracting private-sector participation in the development and implementation process.

4.2 A New VIUS-Like Survey

The TIUS/VIUS series, which had been initiated in 1963 and conducted as part of the economic census, ended in 2002 due to financial constraints. This survey was central to providing national- and state-level measures of the scope and character of the trucking industry. A new survey would establish a system with consideration of opportunities and requirements for modifications and expansions of the approach and content of the old VIUS.

4.2.1 Current State of the Opportunity

4.2.1.1 Identification of Present Conditions

Loss of the VIUS affected road-based freight statistics. VIUS provided vehicle characteristics and differentiation of vehicle activity by range, products carried, miles traveled, industry, and type of operator, all at the state level. The end of the VIUS program has created a gap in national and state understanding of fundamental trucking activities and fleet attributes. One gap is the ability to differentiate personal and business uses of pickups and sport-utility vehicles. No new statistical approach has arisen to replace the VIUS capabilities.

4.2.1.2 Data Sources and Analytical Methods

The new survey would follow the same analytical methods as the historic VIUS. That survey was conducted as part of the economic census every 5 years, with a sample purchased by the Bureau of the Census from the R.L. Polk Company, a provider of state vehicle-registration information. The survey was mailed to owners of more than 100,000 selected vehicles in each year of the survey. It was managed by Census as a standard procedure mail-out/mail-back survey of the economic census. The sample was stratified by geography and truck characteristics. The geographic strata were the 50 states and the District of Columbia. The five truck characteristics strata were

- Pickups;
- Minivans, other light vans and sport utilities;
- Light single-unit trucks (GVW 26,000 lbs. or less);
- Heavy single-unit trucks (GVW 26,00 lbs. or more); and
- Truck-tractors.

Individual state summary reports, as well as a national summary report, were produced.

4.2.1.3 Key Challenges

The VIUS survey was cancelled due to financial issues. Therefore, establishing a comparable or expanded survey would be a financial issue. Such a survey could again become the baseline for truck freight activity, establishing the universe characteristics of the truck fleet. It also could serve as an effective basic guide to design and survey planning for other truck surveys and statistical analyses.

The researchers are unaware of challenges in the survey design or process that would threaten a new survey program. In each quinquennial undertaking, additions and deletions were made to keep the survey current and relevant to both private and public users.

Like other similar surveys, the VIUS suffered from decreasing response rates, from 90 percent in 1992 to less than 80 percent in 2002, even with mandatory reporting (ORNL, 2010).

4.2.1.4 Key Opportunities

One opportunity would be to reinstate the survey as it would have been done in 2009 when it was defunded. While this has the benefit of clarity of purpose and execution, other options to the traditional approach are possible. Justifying reinstatement requires not only demonstrating the value of the data but also evaluating prospective methods in light of past experience and present opportunities.

Several opportunities are drawn from the previous analyses undertaken in this research effort. These opportunities can be stratified into three major groups.

1. Consideration of a new, and perhaps expanded, sample frame employing the traditional Polk procedure or the MCMIS as the source of the frame. Such consideration could include private vehicles, government, and motor carriers of passengers employing the state registration files via Polk. Such consideration would have to recognize that the MCMIS could not address personal passenger vehicles.
2. Analysis of state vehicle-registration records working with R.L. Polk and of federal records maintained by MCMIS for their ability to provide supplemental data supporting any vehicle-based data collection effort.
3. Monitoring CVUS and consideration of a parallel U.S. prototype. At the time of this publication, FHWA is progressing with a pilot demonstration of the CVUS technology in the United States.

These are shown in Figure 4-2 and described further below.

4.2.1.5 Sample Frame Opportunities

A VIUS-like survey could assist road transportation statistics. It would recognize and use a third statistical universe unique to road transportation, vehicle-registration files, in addition to the traditional household and establishment universes.

One possible weakness of the past VIUS approach is that its sampling of registrations were not fully used. Particularly, the VIUS excluded vehicles owned by governments, ambulances, buses, motor homes, and automobiles. Such consideration is beyond the scope of this work; however such an expansion could be a potential information resource in areas where no effective information sources now exist.

Another sampling consideration is that, although drawn from publicly owned state registration files, the Polk resources

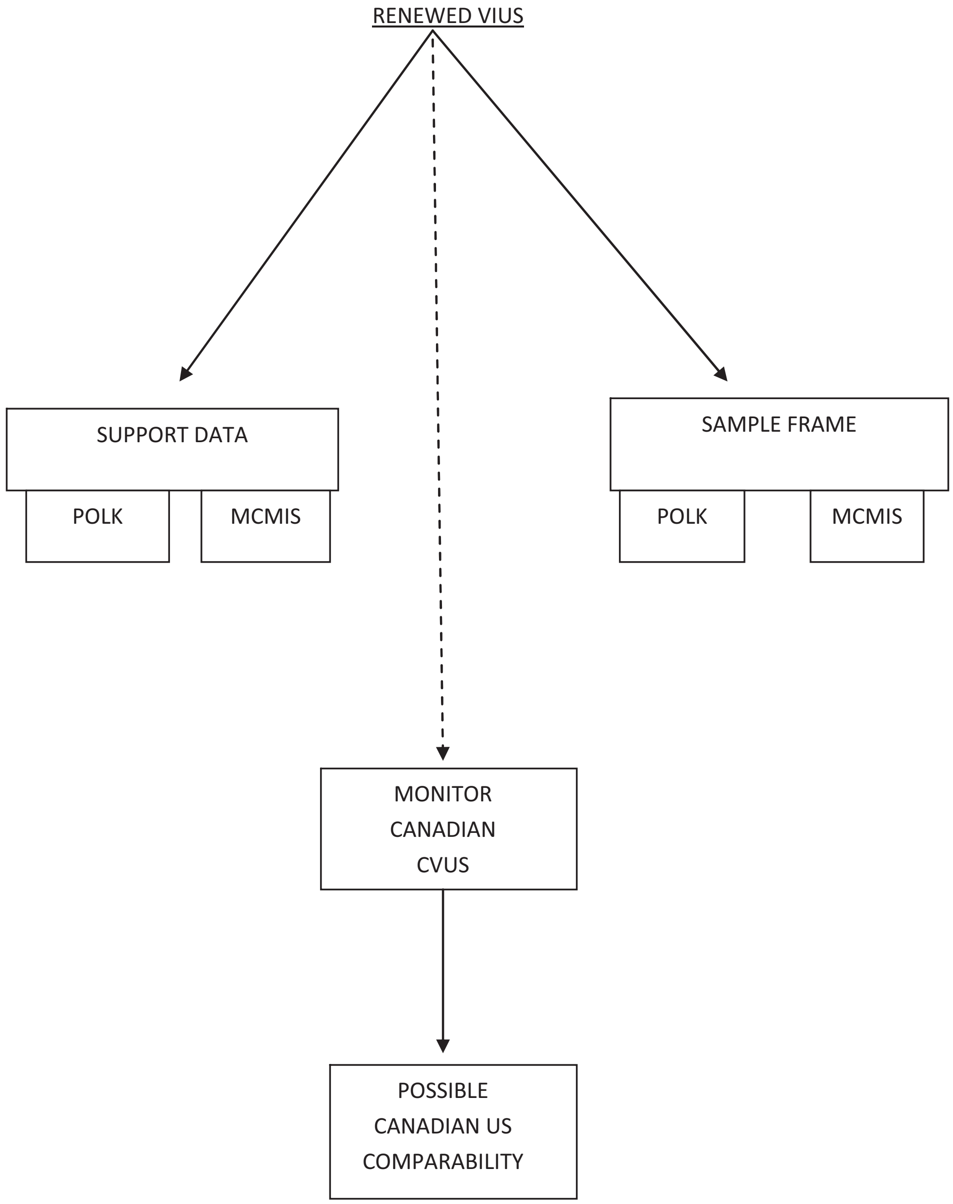


Figure 4-2. Key approaches to establish a new VIUS-like survey.

are the product of a private vendor. This would require government purchases of private products, with the expense and complexities regarding uses and disclosure that entails. Proper survey design would require investigation of alternatives.

One alternative would be for U.S.DOT to contract directly with Polk rather than through the intermediation of the Census Bureau. Thus, the U.S.DOT would own, fund, and manage the survey directly as a central part of its statistical programs. One potential conflict would be the use of legally supported mandatory reporting. The Census Bureau employs such reporting in this survey under Title 13. Conceivably, U.S.DOT could employ it under Title 49, subject to legal review.

Another potential option would be to use MCMIS. This system provides extensive detail on establishments that own motor carrier vehicles of passengers or freight. Evaluation of the basic file establishes that there is extensive detail about the owning establishments, such as the nature of their industry, whether their transport structure is interstate or intrastate in nature, general characteristics of approximately 30 commodity types carried, a general vehicle classification, and a count of vehicles and drivers by range of operations. Safety characteristics and hazmat characteristics are also a component of the dataset.

The MCMIS data may be a potential in-house data resource for U.S.DOT. One possible constraint of the data is a sample frame based on establishments and their characteristics without detailed identification and characteristics of individual vehicles. Therefore, the VIUS approach would have to sample establishments and then, in a second phase, have those establishments sample their own vehicles, given instructions from the surveying agency. A caveat is having establishments draw their owns samples may introduce bias and create editing work for those doing the processing. This would be much like the sampling strategy of the CFS but would need to be considered and pretested with necessary control mechanisms. It may only be able to be used as a sample frame for highly targeted approaches, but might be able to offer advantages of cost and control in using MCMIS.

4.2.1.6 Supplemental Data Support to the VIUS Approach

Both R.L. Polk and MCMIS prospectively provide opportunities to develop data about the truck fleet and its activities.

R.L. Polk maintains a Web-based dataset as a public service and as a guide and advertisement for its more tailored products. This dataset is derived from a process of monitoring all state vehicle-registration systems for changes in registrations with considerable vehicle detail. Its Commercial Vehicle Market Intelligence Report summarizes "Market Performance," i.e., registrations of GVW3 through 8 by make, month, engine type, and trailer registrations by type. Registrations include new and used vehicles. It may be helpful to examine further opportunities to employ these data for independent analysis or to supplement VIUS efforts.

Similarly, the potential of MCMIS as a statistical data source may supplement the VIUS undertaking. MCMIS has universal coverage of all truck fleet owners with summary descriptions of their vehicle fleets. However, the files are continuously updated with no single "snapshot" of what exists at a given time. FMCSA staff said that those listed are not obliged to notify FMCSA when they cease business, so it can be difficult to find those responsible for updating the data or providing further information.

As noted previously, the establishment records in MCMIS provide information at a summary level on truck fleets owned, including the following:

- Establishment characteristics carrier/shipper interstate or intrastate,
- Cargo transported (30 freight categories),
- Equipment owned/leased (5 freight categories),
- Drivers employed/leased by interstate/intrastate within or outside 100 miles, and
- Highly detailed hazardous materials carried.

In addition to R.L. Polk and MCMIS, the Services Annual Survey and other sources such as the Cass Freight Index could be examined further for their effectiveness in supporting the VIUS design and ultimate dataset. SAS reports trucks owned by type, revenues received by 11 types of products, operating expenses such as personnel, fuels, and purchased freight transportation. These are produced for various truck operators, general freight carriers, TL/LTL, and specialized carriers for local and long distance. The SAS only covers for-hire motor carriers rather than all establishments with trucks.

4.2.1.7 Monitoring CVUS

CVUS may produce as much data as previous VIUS-like approaches and do so more quickly and cheaply. CVUS draws its sample from provincial registration files so that distances, x-y coordinate locations, and fuel consumption can be recorded, conducted on a quarterly basis through use of an instrument connected to the engine port.

In the present design, CVUS includes all light vehicles (less than 4.5 tons), medium trucks (between 4.5 and 15 tons), and heavy trucks (15 tons or more). It excludes such vehicles as motorcycles, buses, motorized equipment, and off-road vehicles.

The present plan also permits the recording device to obtain answers to queries posed to the vehicle operator. These have included trip purpose information and a count of persons on board. Questions can be tailored to truck operators as desired.

The passenger version of the survey has been under testing since late 2011 with more than 8,000 vehicles tested generating a dataset with more than 500 million observations. The truck version has had a single test so far with interested carriers in the summer of 2012. Successful data were developed from 72 vehicles with 440,000 observations per truck. These data are accumulated from a data-logging device, the Ottoview autonomous electronic data logger, connected to the engine, which monitors all aspects of the vehicle's function. A touch screen device also is being tested for the driver. This device obtains reason for stop, trip purpose, land use at location of stop, vehicle configuration, vehicle body type, cargo unit measure and weight, and broad cargo description (8 categories). Each time the driver picks up or delivers goods, the driver is instructed to record a new trip. Trips defined as vocational (no goods delivered/contractors, etc.) are given a different set of questions. Some stops, such as those for fueling, changing drivers, food/rest, or equipment checks, are not considered trip stops.

A more recent comprehensive full-scale test in Ontario achieved a 41 percent acceptance rate, but data were only captured among a third of vehicles. In addition to recruitment issues, this test had to deal with driver lack of skill in responding, data port issues, and survey fatigue among large fleets. In short, there are both technical and logistical threats to potential success.

Under the existing approach, the provinces agree to have their registration files accessed for sampling purposes, and truck operators (and private users in the passenger survey) must be recruited to have instruments placed on their vehicles. CVUS offers various inducements to gain acceptance. Such a survey approach can provide VIUS-like data products in even greater specificity, precision, and speed. It is, in effect, a full-scale vehicle-based O/D survey.

4.2.1.8 Expected Results

All of the lines of inquiry on a VIUS-like dataset can be conducted in parallel and a design for the reinstatement of the VIUS completed over a 2-year cycle. Given sufficient lead times, the financial structure for the survey also can be put in place.

4.2.2 Implementation Scenarios

The multi-path process envisioned generates several scenarios, as follow:

Scenario A: Direct Reinstatement assumes that the past process is the best model for the present design.

Scenario B: MCMIS Alternative assumes that a MCMIS sample frame is viable and a wholly internal DOT program is established.

Scenario C: CVUS Model Implemented assumes that monitoring of CVUS activity in Canada demonstrates that this approach can be the basis for a new VIUS structure and replaces the existing options in the long term.

4.2.3 Potential 5-Year Progress

It is envisioned that the multi-path process could be completed and a survey system put in place within 5 years. Given the path selected, design would require 6 months to a year, and pretesting would require another year. The historical VIUS process was a quinquennial undertaking conducted in parallel with the economic census in years ending in 2 or 7. This would create a mismatch in schedules and could force a delay until 2022 if the 2017 window were missed. There are no reasons to tie the survey to the economic census, although that was its genesis. If DOT were to take responsibility, it could conduct the survey whenever scheduling permitted, such as an annual process. When it is determined whether CVUS can be implemented in the United States, such a survey could be implemented in 5 years.

4.2.4 Rationale for Recommendation that a VIUS-Like Survey be Harmonious with CVUS

4.2.4.1 Technical Feasibility

The survey was conducted by the Census Bureau within the last 10 years, so the documentation is likely available to reestablish a new VIUS-like survey.

Mining state vehicle-registration records would be straightforward. The R.L. Polk Company has maintained those records for decades. It may be possible to negotiate with each state jurisdiction separately, but this may be complex and costly. Polk provides access to summary material from the states at no cost on its website. There would likely be no technical barriers to overcome, other than the issue of declining response rates common to other survey approaches.

Expansion of TIUS to VIUS involved only the name change in 1997. Incorporating all vehicles into the survey and obtaining a national framework of the entire motor vehicle fleet's characteristics and activity represents a third universe, beyond households and establishments, that would be available to the transportation community.

There may be technical challenges with the MCMIS option in sample and survey design. Respondents are expected to update their records every 2 years and there are lags and gaps in reporting.

CVUS is underway, providing instruments to a sample of vehicles to monitor total daily trip making with onboard equipment requiring some driver input (e.g., trip purpose, occupancy). The United States could follow this development and perhaps a more formalized relationship. Early results indicate that caution may be required in pursuing such a survey on a large scale.

4.2.4.2 Institutional Feasibility

BTS would fulfill the administrative roles for all these prospective activities. The relationship with Canada is directly BTS's role and responsibility. It is also possible that VIUS reinstatement and expansion, and the data mining activities of registration files, could be undertaken by FHWA or FMCSA. The Census Bureau may not need to have a role in VIUS activity—a direct Polk relationship with DOT might prove more effective in engaging ultimate users closer to the product. An internal DOT effort built around MCMIS might involve no more than inter-administration coordination.

Publication of findings might be an issue in a Polk arrangement, particularly with proprietary materials. More specialized and detailed access might require negotiation with Polk regarding protection of their arrangements with states and attendant costs. A similar relationship with FMCSA would not have the proprietary concerns but would have public disclosure constraints. There may not be legal barriers to an observer status regarding CVUS for the U.S. BTS and the North American Transportation Statistics interchange.

4.2.4.3 Operational Feasibility

There are minimal operational conflicts to reinstating the survey. There probably would be small operational changes at the Census Bureau were the survey to be expanded to a full VIUS. One operational option is an annual approach that culminates in a detailed survey over 3 to 5 years. This would likely add to purchase costs with Polk. Minor operational changes also might be required of Polk for sampling and supporting any prospective data mining operation. It would be beneficial to consider the MCMIS approach in parallel with the Polk effort. FMCSA may provide copies of files to BTS for research and analysis. There do not appear to be any operational constraints to a prospective Canadian relationship.

4.2.4.4 Geographic Scalability

Given the nature of the registration files, the survey probably would be a state-level survey, with roughly equal state observations, aggregated for a national summary picture. The 2010 Oak Ridge National Laboratory (ORNL) study proposed a series of sampling options to improve national statistical quality at lower cost but apparently at the expense of quality. If the intent were to establish national truck VMT and ton-miles, then the sampling design could be modified considerably.

4.2.4.5 Financial Feasibility

Financial resources will be central to this effort. There likely would be minor but not substantial fees involved with Polk. Much of the materials of interest are available free from Polk and MCMIS. Data processing costs can be more with the MCMIS approach. Were the survey approach to become an annual effort, the costs of selecting the Polk sample could be more than mining the registration files. Similarly, monitoring CVUS would probably entail no more than a minor cost. Of course, instituting such a survey in the United States would be a long-term and expensive undertaking, with a possible trade-off between the costs of an annual survey and that of using onboard equipment. The logic of the CVUS approach might well favor a MCMIS approach.

The reinstatement of VIUS and expansion to a full vehicle survey would probably be a significant undertaking. An analysis conducted for the FHWA Office of Freight Management and Operations by ORNL in 2010 estimated program costs for the expanded survey at about $12 million per survey cycle. This was a maximum, and costs—depending on design—might be as low as $9 million. Such costs would be subject to negotiations with R.L. Polk for developing the sample structure. The MCMIS approach might be slightly less expensive; where file operations are substituted for purchase costs as in a Polk arrangement, this approach may have greater survey expenses.

4.3 Agent-Based Models for Freight Transportation

Agent-based modeling (ABM) is a new modeling approach in the field of freight transportation modeling. A main characteristic of these frameworks is that firms are modeled as the decision-making units, they interact with each other directly within the modeling system, and their future behavior may be altered by past interactions. This approach seeks to improve state-of-practice models that are typically four-stage models, through better representation of firm behavior and their logistics and supply chains decisions (Hensher and Figliozzi, 2007; Roorda et al., 2010). This research addresses innovative strategies for obtaining truck-activity data. Such strategies typically include data "collection" or data "capture." This strategy deals with data "production," that is, data that are the outcome of model simulations.

References for use of modeling-based approaches for the creation of new data (e.g., a new data source) include *NCFRP Report 26: Guidebook for Developing Subnational Commodity Flow Data* (http://www.trb.org/Publications/Blurbs/169330.aspx); *NCHRP Report 738/NCFRP Report 19: Freight Trip Generation and Land Use* (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_739.pdf); and NCFRP Project 25-1, Estimating Freight Generation Using Commodity Flow Survey Microdata (http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3492).

4.3.1 Current State of the Opportunity

4.3.1.1 Identification of Present Conditions

Agent-based modeling is "a computational method that enables a researcher to create, analyze, and experiment with models composed of agents that interact within an environment" (Gilert and Terna, 2000). ABMs are often also characterized by agent learning and complex behavior that is emergent from models with simple rules. In the transportation literature, agent-based models are sometimes referred to as "microsimulation models." Strictly speaking, agent-based modeling can be considered an extension to microsimulation, in which agents interact, learn, and adapt, often leading to emergent behaviors.

Several frameworks have been proposed recently (Roorda et al., 2010; Samimi et al., 2010; and Liedtke, 2009). These proposed frameworks vary in their details but typically they model the interaction between firms (strictly speaking, firms can include one or more business establishments, although some published papers used the terms *firms* and *business establishments* interchangeably) that act as shippers, carriers, and receivers, and include the following key processes:

- How firms start, select their locations, and make other long-term strategic decisions (in most cases this is treated as exogenous to the framework);

- How firms select other firms to supply goods and services (a supply-chain choice), resulting in the exchange of a certain fixed amount of commodity over a defined period of time;
- How firms, as shippers, determine shipment size and frequency (although sometimes the receiving firm is also involved in this decision-making process);
- How firms, as shippers, make logistics decisions (choice of mode—trains vs. trucks, whether to consolidate—bundling of shipments or use warehouses or distribution centers, vehicle types and vehicle scheduling) or make outsourcing decisions (choice of carriers); and
- How firms, as carriers, make route choice (this often includes tour-based modeling).

The main focus of this strategy, truck movements, is produced at the end of all these processes. Some of the individual processes, such as tour-based modeling and logistics choices, are not ABMs per se, since agents only make decisions but do not interact with one another directly in making the decisions. Nevertheless, it is important that all of the processes are discussed here, as they are integral parts of the ABM framework.

Many of the proposed frameworks are similar in principle, but different research groups make different technical choices to operationalize the ABM framework. For example, to model how firms select other firms to supply goods and services, Wisetjindawat et al. (2007) used multinomial logit choice models to determine the supply chain based on buyer-supplier pair characteristics and characteristics of the industry; Liedtke (2009) proposed the use of a guided Monte Carlo algorithm that considers product availability, transportation costs, and supply-chain vulnerability (sensitivity to distance); Roorda et al. (2010) proposed a method that examines in great details how firms interact in markets, form alliances, and agree to contracts; and Outwater et al. (2012) plans to use game theory to understand firms' procurement strategies and thus commodity flow origins and destinations (from notes taken at "An Agent-Based Economic Extension to CMAP's Mesoscale Freight Model," Chicago Metropolitan Agency for Planning (CMAP), September 19, 2013).

To date, research in ABM for forecasting freight demand has no operational prototype for policy analysis. Although Outwater and colleagues are developing a demonstration model for CMAP, it is a proof of concept model, which is not calibrated with real data.

If implemented, ABM could be used to generate information on supply chains (i.e., the interactions among shippers, receivers, and intermediaries). Currently, there is no data program that is responsible for capturing, analyzing, and delivering supply-chain information. One of the key challenges for obtaining this information is the complexity of a supply chain. The ABM models specifically simulate the simultaneous operations and interactions of multiple agents, in an attempt to re-create and predict the appearance of complex phenomena. The process is one of emergence from the lower (micro) level of systems to a higher (macro) level. As such, a key notion is that simple behavioral rules generate complex behavior. These principles could, and are, being used (e.g., the model for CMAP) to re-create supply chains.

4.3.1.2 Data Sources and/or Analytical Methods

The development of ABM requires highly disaggregate data, and this is the biggest challenge in implementing this approach. Early on, the main difficulty was an uncertainty about what types of data sources would be necessary to model carrier behavior. Identifying the relevant quantitative and qualitative data sources, obtaining them, and validating the model would seem to require a significant amount of effort. Without an existing data platform, the initial expense for this strategy would likely be cost prohibitive. If such an investment were made, the model development costs could be quite modest.

Samimi et al. (2010) has outlined the four types of data that are needed for the development of an ABM for freight transportation that provide focused direction on the contents of a necessary data platform: (1) business establishments, (2) shipments and supply chains, (3) the freight transportation networks, and (4) zone-to-zone freight flows.

Business establishments—To provide the necessary base population of business establishments, information about the establishments by geographic zone is needed. In the ideal case, for each establishment there is information on employee size, annual turnover, square footage, number of franchises, types and amounts of the commodities coming into and shipped out of the establishment by tonnage, and dollar value. Samimi et al. (2010) commented that obtaining accurate information on the commodities is challenging, since most firms work with a wide variety of goods.

Samimi recommended the best available data for a model in Chicago was County Business Patterns (CBP). It is an annually updated dataset that provides the number of establishments, number of employees, and payroll data by industry classification by geographical zone. However, the usefulness of this dataset is limited due to data suppression for business confidentiality reasons. There are many missing values in the disaggregate dataset, and key information such as the number of employees and payroll data are only provided in aggregated form. Urban et al. (2012) subsequently documented the use of this data for the development of the Chicago model for CMAP.

To get information about commodities coming into and shipped out of an establishment, Samimi et al. (2010) recommended the use of "input-output accounts" that provide general information on the type of industries producing or using a specific type of commodity. Input-output accounts also provide information on the values of the required commodities to produce a unit output of an industry. This dataset is also used in Urban et al. (2012).

Shipments and supply chains—Samimi et al. (2010) discussed supply-chain data and shipment data under a single heading, as it is conceivable that one can construct the supply chain for a given firm based on the detailed information about the shipments. Ideally, for each acting agent involved in the shipping process (shippers, receivers, and other intermediaries), information regarding their primary activity, number of employees, annual turnover, establishment square footage, and number of branches would be useful. Additionally, the shipment characteristics (e.g., weight, value, dimensions, time sensitivity, commodity type, origin, and destination of the commodity) and shipping specifications (haul time, cost, mode, and damage risk of the shipping process) also would be important. The CFS provides a foundation for these data elements.

Samimi et al. (2010) developed a tailored survey (known as FAME) to fill this data gap. Similarly, in Canada, to understand supply chains, Cavalcante and Roorda (2013), have conducted their own survey (a stated preference survey) to understand how contracts are formed between shippers and carriers. Shipment and supply-chain data are more available in Europe. Advances in the understanding of shipment size and mode choice were made possible by the Swedish Commodity Flow Survey (CFS) (e.g., De Jong and Johnson, 2009; Habibi, 2010; and Windisch et al., 2010), and the French shipment database known as ECHO (e.g., Arunotayanun and Polak, 2009; Combes, 2010).

Freight transportation networks—As with all transportation models, a representation of the highway and road network would be needed. Samimi et al. (2010) recommended the North American Transportation Atlas Data (NORTAD) be made available to the public by BTS.

Zone-to-zone freight movements—The commodity flow between each zone pair for each specific commodity type is required for the validation of such a framework. If available, the dollar values and tonnage figures are necessary, and shipping distances would be useful. The categorization of commodities such as distinguishing functional products that would be efficiency driven (e.g., meat and dairy) from innovative products (e.g., electronics) that would be price driven, is an important model design decision that needs to be made at an early stage of model development. Outwater and colleagues have made some progress in this area as part of the model development for CMAP.

Samimi et al. (2010) recommended the FAF as the most comprehensive survey-based data that is available publicly. It provides information on the commodity value and tonnage, by origin and destination zones, mode of transportation, and type of the commodity.

Other data—Furthermore, for model validation, Samimi et al. (2010) recommended that shipment volumes at terminals and mode share for different final products may be used to assess the accuracy of the supply chains and logistics modules, and average daily truck traffic on links and roadside intercept survey of trucks may be used for validating the final truck flows.

Additionally, not discussed in Samimi et al. (2010), or most other freight transportation research articles reviewed, is the potential use of panel surveys (i.e., undertaking interviews/surveys with the same businesses multiple times at regular intervals). Although panel surveys are relatively difficult to conduct compared with cross-sectional data, they are particularly suitable for measuring processes and transitions (Hassan et al., 2010). This kind of data will be particularly useful for understanding and validating emergent behaviors observed in ABMs.

4.3.1.3 Key Challenges

There are challenges in both conceptual development as well as data collection, as follows:

- Agents in businesses are highly heterogeneous and diverse (compare to passenger transportation models). For example, firms may differ in size by order of magnitude (whereas household sizes do not vary as much). Furthermore, there are huge variations in how firms operate (e.g., some want to minimize uncertainty, some want to minimize regrets, and some focus on maximizing efficiency).
- Data availability is a barrier to progress. Data related to supply chains and logistics are often proprietary; firms tend to be unwilling to participate in surveys because the value of time is high in the business context. Within a firm, it is often not clear who makes logistics decisions. The data availability for small firms can be problematic.
- ABM for freight transportation is a new kind of model. Its functionality and limitations may be unfamiliar to the transportation planning and policy-making community. For this new tool to become mainstream in policy analysis, dialogues with the DOT, MPOs, and other stakeholders about ABM would be needed.

4.3.1.4 Key Opportunities

Draw on existing behavioral research. Although many of the ABM frameworks for freight transportation were developed recently, many behavioral studies of the decision-making processes within ABM took place before the existence of these frameworks. A summary of relevant behavioral freight models that can be potentially adapted is presented in Table 4-5. The

Table 4-5. Summary of relevant behavioral freight models since 2004.

Relevant Behavioral Freight Models		Liedtke (2006)	Holguín-Veras et al. (2007)	De Jong and Ben-Akiva (2007)	Combes and Leurent (2007)	Maurer (2008)	Friesz et al. (2008)	Wang and Holguín-Veras (2009)	De Jong and Johnson (2009)	Arunotayanun and Polak (2009)	Holguín-Veras et al. (2011b)
Firm synthesis		X	--	--	--	--	--	--	--	--	--
Supplier choice/shipper-carrier interactions/carrier-receiver interactions		X	X	--	X	--	X	--	--	X	--
Shipment size and frequency choice		X	--	X	--	X	--	--	X	--	X
Logistics decisions	Mode choice	--	--	--	--	X	--	--	--	--	X
	Consolidation/Use of warehouse	--	--	--	--	X	--	--	--	--	--
	Vehicle type choice	--	--	--	--	X	--	--	--	--	--
	Vehicle scheduling	--	X	--	--	--	--	--	--	--	--
	Route planning and tour formation	X	--	--	--	X	--	X	--	--	--

Source: De Jong et al. (2013)

development of new ABM models can be accelerated by drawing heavily on these previous and ongoing behavioral studies.

Build on private-sector supply-chain and logistics research. Extensive research in logistics planning and supply-chain management has been done by the private sector. Research on ABM of freight demand modeling can build on this. Examples of research that bridge this private-sector and public-sector gap include Maurer (2008) who integrated a commercial software package for logistics decision making (known as CAST) with a national freight model and Friedrich (2010) who demonstrated that the optimization techniques used in logistics planning of the German food sector can be used for wider freight transportation forecasting.

4.3.1.5 Expected Results

Results that can be expected from these models are freight shipments by mode and path for origins and destinations. These results are expected to be more behaviorally realistic and accurate than those from conventional models.

However, ABM modeling for freight transportation is still in its infancy, so the probability that it can be used as a successful data production strategy for truck-activity data in the short term (5 years) is low.

4.3.2 Implementation Scenarios

Two implementation scenarios are discussed: a rapid development path and a long-term development path. The rapid development path would rely on the adaptation of existing freight behavior models and minimum data collection to calibrate existing models, whereas the long-term development path would entail new behavioral research, data collection, and concept development.

The rapid development path would result in a model for demonstration purposes only. It would be just a proof of concept and could not be used for forecasting purposes. The ABM model being developed for CMAP is in this category. An enhanced supplier choice model that builds on concepts from game theory is expected to be ready by June 2014.

The long-term development path would generate new behavioral research through new data collection and concept development. There is consensus in the academic literature that better understanding of supply chains and logistics will be beneficial (De Jong, 2013). The understanding of market interactions and contract formation is a topic that is less understood but important to freight demand forecasting, as it recognizes that "freight transport is the output of an economic market which converts commodity flow into vehicle flows" (Cavalcante and Roorda, 2013). Previous studies suggested that confidentiality issues can be a problem. One way to circumvent such issues is the use of stated preference surveys as demonstrated in Cavalcante and Roorda (2013).

This research team suggests that research on the use of ABM in freight modeling continue. The team believes that the long-term development path is the most likely. At the same time, furthering the development of such models is not high risk, as the unique benefits of applying ABM methods will become documented during this development time, which in itself will provoke increasing interest in its application. The benefits can best be characterized as follows:

- ABM gives insights into causes of emergent phenomena—Emergent phenomena result from the interactions of individual entities, which are difficult to understand and predict. Truck activity results from the behavior of, and interactions among, many different players including individual vehicle drivers. ABM may be the only way to model the resulting traffic behaviors.
- ABM uses a natural description of a network—When one is attempting to describe truck movements, ABM makes the model seem closer to reality. ABM has the potential to describe what firms (suppliers and receivers) and individuals (truck operators) actually do in terms of the movement of freight.

4.3.3 Potential 5-Year Progress

Developing agent-based models for freight transportation will be a long-term effort. It is highly unlikely that a fully operational prototype would be available in the next 5 years. Development is expected to be slow. At the time of the writing of this report (late 2013), to the best of the authors' knowledge there was one transportation consultancy in the United States (Resource Systems Group) that was actively working on this topic. However, it is a very active area in academia with research teams from Germany, Japan, Canada, and the United States making significant contributions to the field. Another U.S. consultancy, Cambridge Systematics, worked on the CMAP ABM in 2010 to 2011. In the next 5 years, we will likely see a gradual development process, with elements of the ABM framework being introduced to existing practical freight models. In particular, the understanding of some decision processes can be considered more advanced, namely shipment size and frequency and tour-based modeling.

4.3.4 Rationale for Recommendation that ABM Implementation Would Be a Long-Term Activity

4.3.4.1 Technical Feasibility

As noted in this chapter, the number of agent-based applications in freight modeling has been growing in recent years. ABM appears well suited for obtaining a picture of truck activity, in which large numbers of firms and individuals interact in complex ways. The technical feasibility of this approach is increasing and there may be further applications of ABM as a companion to microsimulation.

4.3.4.2 Institutional Feasibility

The institutional feasibility of this strategy is high, given that the FAF and augments to it have been administered and financed by FHWA. FHWA is sponsoring current developmental work on ABM.

4.3.4.3 Operational Feasibility

The challenge with implementing ABM in this context is the acquisition or availability of data. As noted in this chapter, specific data are needed to support ABM model development. Data need to be documented, their sources identified, and their utility validated.

4.3.4.4 Geographic Scalability

Assuming that the data were available and that an agent-based simulation model could be developed, the information obtained would be at all levels of geography—national, state, regional.

4.3.4.5 Financial Feasibility

The financial resources for model development over the long-term would be minor. Building a necessary data infrastructure to support ABM at the national level would involve more extensive costs. If a GPS framework were to be implemented, it would reduce the cost requirements. However, the transportation community would still be left with finding a source of commodity-specific flows at the requisite level of geography. One future source might come with the advent of the Internet of Things. The Internet of Things is a scenario in which objects, animals, or people are provided with unique identifiers and the ability to automatically transfer data over a network without requiring human-to-human or human-to-computer interaction. Increasingly, objects are embedded with Radio Frequency Identification (RFID) and sensors to track how products move through supply chains, and that generates masses of (real-time or logged) location data (see, for example, McKinsey, 2013). If these data can be made available to researchers, they may provide a rich source of information to support modeling of the freight transportation system.

CHAPTER 5

Conclusions and Future Research Needs

This research project focused on assessing and developing strategies for obtaining comprehensive truck-activity data. The key objectives were to gauge the current state of the practice for obtaining and reporting truck-activity data, identify the issues and limitations in current sources, develop data-gathering strategies with a chance of success at overcoming current challenges, and pull together implementation scenarios for a subset of recommended strategies. To do so, the research team reviewed literature, evaluated datasets, and interviewed key informants.

5.1 Innovative Approaches

This research identified key gaps in truck-activity data on VMT, ton/ton-miles, value/value-miles, O/D flows, vehicle speeds, and transportation costs. Although there are sources for these data, they are highly fragmented and users need to piece together information from many sources to answer key policy questions. The most comprehensive source, the CFS, is conducted only every 5 years, making it difficult to accurately model the intervening years. The CFS also lacks necessary information at finer levels of geography. This research reviewed the feasibility of strategies for obtaining truck-activity data that would provide improved coverage of key data elements and the trucking industry universe (i.e., for-hire carriers, owner-operators, shipper-owned trucking for long-distance and local geographies).

The strategies assessed included improvements to existing Census-based surveys (like the CFS and T&W surveys), the creation of new surveys (a VIUS-like survey and an industry supply-chain survey), identification of new sources of operations data (like GPS or LPR data), better use of MCMIS records and R. L. Polk data, and an ABM approach. In identifying the menu of strategies for which feasibility assessments would be performed, the research team focused on improving existing approaches rather than on creating something entirely new.

Total feasibility scores across the feasibility reviews highlighted the likely chances of successful implementation of the following three approaches:

- **New VIUS-Like Survey** would provide vehicle activity (for pickups, minivans, or other light vans, light single-unit trucks, heavy single-unit trucks, and truck-tractors) by range, products carried, VMT, industry, and type of operator at the national and state levels. Using either information from MCMIS or R. L. Polk as a sampling frame would enlarge coverage of the trucking industry universe. This approach would use the same basic survey design, processing, reporting procedures as the historic VIUS. An additional improvement would be to model the new VIUS-like survey after the CVUS, which uses onboard equipment to capture trip making and could create a harmonized U.S.-Canadian survey. It is possible that this survey could be implemented within 5 years, benefiting from the Canadian process, but resolving financial considerations within this timeframe would be challenging.
- **National Freight GPS Framework** that amassed GPS data derived from truck movements would provide VMT data and O/D flows by time of day. Appended with other attributes to become multi-attributed traces, one can obtain or calculate these data by vehicle type, commodity type, load type, average load, route, time of day, speed, or average speed by the truck stop, corridor, metro area, state, multi-state region, or national levels. A new app, My Trip Matters (MTM), could be an answer to the challenges of identifying the best type of GPS device and of gaining cooperation among truckers, while providing protections for privacy and security. Using MTM, truckers would opt-in to the data program. Within the next 5 years, the entire MTM program could be up and running, including development of a location service app and set-up of the necessary cloud-based operating and processing environment. Federal legislative action may be necessary to empower FHWA to collect GPS trace data from trucks.

- **Agent-Based Modeling** has the possibility of representing a large part of the trucking industry universe, both interregional as well as intraregional truck movements. There is also the significant possibility of filling gaps in VMT and O/D flow data. It is conceivable that if successfully implemented, ABM also could be used to generate here-to-fore lacking information on supply chains (i.e., the interactions among shippers, receivers, and intermediaries). The ABM models specifically simulate the simultaneous operations and interactions of multiple agents (firms and individuals) that could provide the best source of information on trucking activities. However, the best-case scenario for this strategy is one of long-term development.

The research team suggests that resources be devoted to further the development of these three strategies for obtaining truck-activity data.

5.2 Additional Research Needs

The feasibility reviews conducted as part of this research resulted in suggestions regarding other strategies reviewed in this report. These include the following:

- **Expansion of the Trucking and Warehousing Survey.** The Trucking and Warehousing Survey represents the most comprehensive set of transportation industries available, with reporting on an annual and quarterly basis. Its weakness is that it does not encompass shipper-owned vehicle fleets engaged in own-account haulage. The research team suggests that university-based or other researchers consider deriving modeled information on VMT, tonnage, and value for carriers and owner-operators from this survey.
- **Design of a New Industry-Based Supply-Chain Survey.** Supply-chain data is a major gap in freight transportation data. There is currently no data program responsible for capturing, analyzing, and delivering supply-chain information. Opportunities for further research include (1) exploratory research on developing a typology of supply chains for survey purposes and (2) qualitative research on how shippers choose modes and routes.
- **Creation of an Operations Data Analysis Platform.** Operations data is one of the richest sources of timely and detailed data about trucks traveling on public infrastructure. These data represent private, for-hire (TL, LTL), heavy and tractor-trailer, and light or delivery services trucks. Although extensively collected by states and reported to FHWA, the currently generated reports do not include VMT and do not use weigh-in-motion (WIM) data to look at freight flows.
- **Obtaining Data from License Plate Readers (LPRs).** LPR is an image-processing technology used to identify vehicles by their license plates. LPR systems use cameras, computer hardware, and software to capture an image of a license plate, recognize its characters by converting them into readable text, and check the license plate against designated databases for identification. Although a subset of the data from such systems—specifically, large volumes of observations of different commercial vehicles at different locations and points in time—could be analyzed to develop information about truck travel patterns, there are a number of technical and institutional issues that severely limit its applicability to obtaining truck-activity data at the present time. This strategy may be most beneficial if monitored for ongoing developments that could make it more feasible in future years.

5.3 Future Visions

This research took an evolutionary approach to identifying innovative strategies that could be used to collect truck-activity data. But the future will bring new "disruptive" opportunities for data gathering. To conclude this report, two possibilities for future areas of research are discussed. As mentioned in the last chapter relating to the Internet of Things, both of these opportunities are related to types of connectivity that could become a rich source of information to support modeling of the freight transportation system.

5.3.1 Autonomous Vehicles

Self-driving (or autonomous) vehicles are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking. Autonomous vehicles are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode. A product to decrease motor vehicle accidents, several states, including Nevada, California, and Florida, have enacted legislation that expressly permits operation of self-driving vehicles under certain conditions. As many as 20 other states are considering similar legislation. These experimental vehicles are at the highest levels of a wide range of automation.

The highest levels of automation (Levels 3 and 4) depend on "connected car" technology. Vehicles at Level 3 enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions. The Google car is an example of such limited self-driving automation. Vehicles at Level 4 are designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

The Office of the Assistant Secretary for Research and Technology (formerly the Research and Innovative Technology Administration [RITA] of U.S.DOT) characterizes its vision of "connected cars" as requiring "a wireless communications network that includes cars, buses, trucks, trains, traffic signals, cell phones, and other devices. Like the Internet, which provides information connectivity, connected vehicle technology provides a starting point for transportation connectivity that will potentially enable countless applications and spawn new industries" (Intelligent Transportation Options, 2013a; 2013b). Among vehicles, infrastructure, and wireless devices provide continuous real-time connectivity to all system users (Intelligent Transportation Systems, 2013b).

A convergence of communications and sensor-based technologies enabling autonomous vehicle operation also could be used to obtain information about trucking activity. The two-way flow of information would be from driver to vehicle to infrastructure to other vehicles. Data archiving would occur using cloud-based services. Although the technology is in early stages, NHTSA is conducting research on self-driving vehicles so the agency can establish standards for these vehicles should they become commercially available. The first phase of this research is expected to be completed within the next 4 years.

5.3.2 Product Traceability

As with the advent of autonomous vehicles, advances in product traceability technology have largely been driven by safety. For example, food traceability is at the heart of food safety. It involves the ability to identify, at any specified stage of the food chain (from production to distribution), from where the food came (one step back) and where it went (one step forward)—the so-called "one-up, one-down" system (OUOD). This necessitates that each lot of each food material is given a unique identifier, which accompanies it and is recorded at all stages of its progress through its food chain (International Union of Food Science and Technology, 2013). Because multi-ingredient foods may include materials from a variety of food chains and countries, traceability systems of multiple countries are often involved.

There are many approaches for unique identification of food and other products. Current practice often involves combining different relevant data fields such as a global trade identification number (GTIN) with a handler's production lot or batch number. Other, less used possibilities include serialized GTINs or unique identification numbers (UIDs) as used by the U.S. Department of Defense, or a globally unique identification number (GUID) as used by other manufactured product industries. Unique codes may be stored, presented, and transmitted in a variety of ways including ear tags for livestock, printed human-readable data, barcodes, 2D barcodes, and electronically through RFID tags. Commercially available hardware and software and solutions providers offer many ways for recording, storing and retrieving data. Tracking devices are not only becoming much less expensive (new devices are known as "throwaways") but smaller and less intrusive. One technology involves edible bar codes that are the size of a dust speck and thinner than a strand of hair.

In October 2013, the Food and Drug Administration issued a report on two pilot projects—one on tomatoes and one on chicken, peanut butter, and spices used in processed food—on how food can be rapidly tracked and traced as well as what types of data are needed and how the data can be made available to FDA (Institute of Food Technologies, 2013). The challenge in using this type of information as a source of truck-activity data is that there is no standardization of data requirements or standardization of recordkeeping. The FDA is in early stages of information collection for rulemaking, which means that any type of national system is at least 7 to 10 years away.

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APPENDIX A

Statistical Compilations

A.1 Freight Facts and Figures

A.1.1 Overview

Freight Facts and Figures is an annual snapshot of the volume and value of freight flows in the United States, the physical network over which freight moves, the economic conditions that generate freight movements, the industry that carries freight, and the safety, energy, and environmental implications of freight transportation. This snapshot helps decisionmakers, planners, and the public understand the magnitude and importance of freight transportation in the economy. The statistics are at the national level only.

A.1.2 Sources

Freight Facts and Figures derives its information from CFS, Vehicle Inventory and Use Survey (VIUS) (last conducted in 2002), the Freight Analysis Framework (FAF), Highway Performance Monitoring System (HPMS), and North American Transborder Freight (NATB) data. VMT estimates for trucks are based on the latest HPMS data available. The FAF is used to estimate tons of freight moved by truck and the value of freight moved by truck. Number of trucks and truck VMT by product carried is derived from VIUS (data available stops at 2003). The NATB data are used to estimate the value and tonnage of trade with Canada and Mexico by truck and value of U.S. exports to and imports from Canada and Mexico by truck. Other information available includes number of trucks (single-unit 2-axle 6-tire or more, combination) and trucks as a percent of all highway vehicles. The source for that information is the VM-1 table in Highway Statistics, which relies on a variety of sources for its information, including vehicle-registration data and data such as the R. L. Polk vehicle data.

A.1.3 Reliability

Reliability of the information is dependent on the source used for estimating the specific tables.

A.1.4 Time Series

Reports have been produced annually since 2004. Tables that rely on VIUS only include time series through 2002.

A.1.5 Availability

The report is produced by the Office of Freight Management and Operations, FHWA. An electronic version is available at www.freight.dot.gov.

Table A-1. Freight Facts and Figures.

Freight Facts and Figures	
Definition of Truck	Single-unit 2-axle 6-tire or more, combination
Data Items of Interest	VMT Tons Value
Geographical Level	National
Source Data	Derived from Multiple Sources
Data Gathering Method	N/A
Agency in Charge	FHWA
Years Covered	2004-2011

A.2 National Transportation Statistics

A.2.1 Overview

The U.S. Department of Transportation's BTS is charged with developing transportation data and the information that will help to advance policy decisionmaking about transportation systems. First published in 1970 and continually since then, the *National Transportation Statistics* (NTS) series and associated dataset captures a broad sweep of this information. The NTS includes transportation system physical components, related safety records, economic performance, energy use, and environmental impacts. A notably large resource, the 2011 NTS publication comprised more than 260 data tables with their associated sources and accuracy statements in addition to discussion on a select set of transportation policy-specific topic areas (U.S. Department of Transportation, 2000–2011).

A.2.2 Coverage

NTS captures information on the transportation system, but is a critical piece to a collection of reports published by BTS. Release of the NTS usually coincides with the release of two companion document reports: *Transportation Statistics Annual Report* and *State Transportation Statistics.* Together these publications provide some additional policy insight and focused analysis on top of the transportation system data.

In at least the most recent decade, the vehicle miles traveled (VMT) measure has been used through NTS to characterize traffic and roadway volume on segments of the U.S. transportation network. The NTS measure of VMT is based on data from the Highway Performance Monitoring System (HPMS), which is a dataset maintained by FHWA. The NTS table "Roadway Vehicle-Miles Traveled (VMT) and VMT per Lane-Mile by Functional Class," is entirely based on this VMT data. Here, VMT is reported for urban and rural areas by interstate, other arterial, collector, and local function classes from the HPMS source data.

NTS also reports an inventory of truck fleets by use and tables that summarize the fuel economies of domestic and imported light trucks as well as trucks by weight. These inventories characterize the trucking population in terms of light, medium, light-heavy and heavy trucks by weight categories ranging from less than 6,000 lb to 130,000 lb or more.

Information about U.S. truck fleets also is presented. These summary tables present the annual total fleets of automobiles and trucks that are used for a variety of purposes (business, government, utilities, police, taxi, and rental). The data is collected from private source Bobit Publishing Co., and specifically the annually issued *Automotive Fleet Fact Book.* Eno Transportation Foundation, Inc., another private source, provides data covering ton-miles of freight carried by intercity trucks (no distinction by truck characteristics) through the one-time report *Transportation in America* (2007), but otherwise ton-miles for truck freight shipments comes from BTS estimates (U.S. Department of Transportation, 2012a).

A.2.3 Sources

The NTS integrates data from a variety of sources including the Highway Performance Monitoring System, BTS publications, and private sources.

A.2.4 Reliability

Due to standard rounding of mileages reported by road and type, the component values may not add to the totals reported. In some cases, the number of road systems underlying a mileage report differs from year to year. For example, 2012 NTS Table 1-36 notes that in 2009 data excludes 823 miles of federal-agency-owned roads and 71 miles of other non-federal-agency-owned roads. The data from 2008 exclude 788 miles of federal-agency-owned roads, 2007 data exclude 788 miles of federal-owned roads and 437 miles of local government-owned roads, 2006 data exclude 788 miles of federal-owned roads and include 274 miles of miscoded roads, and 2005 data exclude 770 miles of federal-agency-owned roads. This suggests that any comparison of the averages from one year to the next should consider the underlying system of roads.

Table A-2. National Transportation Statistics.

National Transportation Statistics	
Definition of Truck	Truck definition varies by source, ranging from detailed weight, axle, and other physical characteristics to a broadly aggregated truck category
Data Items of Interest	VMT (by vehicle type and geography functional class) Ton-miles (by geography functional class)
Geographical Level	National
Source Data	Secondary: federal databases and other national sources
Data Gathering Method	Integration of existing reports and surveys
Agency in Charge	BTS
Years Covered	1970-1990, 1991-2011 (every year) always an annual

A.2.5 Time Series

Between 1960 and 1990 new editions to NTS were added annually. Starting in 1991 the rate was increased to a 1-year release cycle with updates to much of the transportation data available on a quarterly basis through the BTS website.

A.2.6 Availability

Annual updates to the report are available on the BTS website.

A.3 Transportation Energy Data Book (TEDB)

A.3.1 Overview

Policymakers and analysts need to be well informed about activity in the transportation sector. The organization and scope of the Transportation Energy Data Book (TEDB) reflects the need for different kinds of information. In this vein, the TEDB is a compendium of data on transportation with an emphasis on energy. Designed for use as a desktop reference, the TEDB represents an assembly and display of statistics and information—e.g., VMT, value of cargo, tons, and average speed—that characterize transportation activity and present data on other factors that influence transportation energy use. The TEDB is produced by Oak Ridge National Laboratory (ORNL) for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. The TEDB was first published in 1976 and has continued to Edition 31. The purpose of this document is to present relevant statistical data in the form of tables and graphs.

In January 1976, the Transportation Energy Conservation (TEC) Division of the Energy Research and Development Administration contracted with ORNL to prepare a Transportation Energy Conservation Data Book to be used by TEC staff in their evaluation of current and proposed conservation strategies. The major purposes of the data book were to draw together, under one cover, transportation data from diverse sources, to resolve data conflicts and inconsistencies, and to produce a comprehensive document. The first edition of the TEC Data Book was published in October 1976. With the passage of the Department of Energy (DOE) Organization Act, the work being conducted by the former Transportation Energy Conservation Division fell under the purview of DOE's Office of Transportation Programs.

A.3.2 Coverage

The coverage of the TEDB is slightly different across the editions. The latest edition of the TEDB consists of 12 chapters that focus on various aspects of the transportation industry. Among these chapters, Chapter 3, All Highway Vehicles and Characteristics, and Chapter 5, Heavy Vehicles and Characteristics, contain relevant data to truck activity while other chapters deal with energy, light vehicles, alternative fuel vehicles, fleet vehicles, household vehicles, non-highway modes, greenhouse gas emissions, and criteria pollutant emissions. Specifically, Chapters 3 and 5 have the following tables:

- Chapter 3: World Production of Trucks (2000–2010); Truck Registrations for Selected Countries (1960–2010); U.S. Trucks in Use (1970–2010); Shares of Highway Vehicle-Miles Traveled by Vehicle Type (1970–2010); Trucks in Operation

Table A-3. Transportation Energy Data Book (TEDB).

Transportation Energy Data Book (TEDB)	
Definition of Truck	• Two-axle, four-tire trucks (pickups, vans, and sport-utility vehicles) vs. other single-unit trucks; and combination trucks • Light (light truck) vs. heavy vehicles (Class 3-8 single-unit trucks[a] and Class 7-8 combination trucks[b])
Data Items of Interest	VMT, value of cargo, tons, ton-miles, and average speed
Geographical Level	National, selected local
Source Data	Highway statistics, federal Fleet Report, Commodity Flow Survey, Heavy Truck Duty Cycle Project
Data Gathering Method	N/A
Agency in Charge	Oak Ridge National Laboratory (ORNL)
Years Covered	1970-2010

[a] Class 3-8 single-unit trucks include trucks over 10,000 lbs gross vehicle weight with the cab/engine and cargo space together as one unit. Most of these trucks would be used for business or for individuals with heavy hauling or towing needs. Very heavy single-units, such as concrete mixers and dump trucks, are also in this category.

[b] Class 7-8 combination trucks include all trucks designed to be used in combination with one or more trailers with a gross vehicle weight rating over 26,000 lbs. The average vehicle travel of these trucks (on a per truck basis) far surpasses the travel of other trucks due to long-haul freight movement.

and Vehicle Travel by Age (1970 and 2001); and Heavy Truck Scrappage and Survival Rates.
- Chapter 5: Summary Statistics for Class 3–8 Single-Unit and Class 7–8 Combination Trucks (1970–2010); Share of Trucks by Major Use and Primary Fueling Facility (2002); Fuel Economy for Class 8 Trucks; Class 8 Truck Weight by Component; Gross Vehicle Weight vs. Empty Vehicle Weight; and Growth of Freight in the U.S. (Comparison of the 1997, 2002, and 2007 Commodity Flow Surveys).

The sources used represent the latest available data. There are also three appendices that include detailed source information for some tables, measures of conversion, and the definition of Census divisions and regions. A glossary of terms and a title index are included.

A.3.3 Sources

As a secondary analysis, the TEDB refers to several primary data sources such as Highway Statistics, Vehicle Inventory and Use Survey, Class-8 Heavy Truck Duty Cycle Project, and Commodity Flow Survey.

- VMT of Medium/Heavy Trucks: The TEDB cites Highway Statistics, specifically Table VM-1. Data series is the total of vehicle travel data in Tables 5.1 and 5.2.
- Major Use of Trucks: The TEDB cites Vehicle Inventory and Use Survey.
- Fuel Economy for Class-8 Trucks as Function of Speed and Tractor-Trailer Tire Combination: The TEDB cites Class-8 Heavy Truck Duty Cycle Project Final Report, ORNL.
- Growth of Freight in the United States (Value of Cargo, Tons, and Ton-Miles): The TEDB cites Commodity Flow Survey, specifically Table 1a.

A.3.4 Reliability

In any attempt to compile a comprehensive set of statistics on transportation activity, numerous instances of inadequacies and inaccuracies in the basic data are encountered. Where such problems occur, estimates are developed by ORNL. To minimize the misuse of these statistics, an appendix is included to document the estimation procedures. The attempt is to provide sufficient information for conscientious users to evaluate the estimates and form their own opinions as to the utility of the data. Clearly, the accuracy of the estimates cannot exceed the accuracy of the primary data, an accuracy that, in most instances, is unknown. In cases where data accuracy is known or substantial errors are strongly suspected in the data, the reader is alerted. In all cases it should be recognized that the estimates are not precise. The majority of the statistics contained in the data book are taken directly from published sources, although these data may be reformatted for presentation by ORNL. Consequently, neither ORNL nor DOE endorses the validity of these data.

A.3.5 Time Series

The latest edition builds on a 36-year tradition of data books. Every edition the TEDB brings new data, more likely related to fuel economy. For example, the 30th and 31st editions added the following truck-related tables, respectively:

- Table 3.13. Heavy Truck Scrappage and Survival Rates: Data for heavy trucks, which had been in previous editions, is added back into the report.
- Table 3.1. World Production of Cars and Trucks, 2000–2010: A new table comparing global production of trucks today and 10 years ago.

A.3.6 Formats and Availability

Editions are available for download in PDF format and as a single file; however, for ease of downloading, it may also be downloaded in sections. Spreadsheets of the tables in the TEDB can be found on the Web (cta.ornl.gov/data).

As of August 2012, a hard copy for Edition 30 and 31 is also available by e-mail request. There is no charge for the book or for shipping.

A.4 Trucking Activity Report (TRAC)

A.4.1 Overview

Trucking Activity Report (TRAC) is a newsletter based on confidential information furnished by ATA's members (i.e., motor carriers). TRAC includes a summary of trucking activity, looks at key aspects of motor carrier operations, and provides a summary of economic events directly affecting the trucking industry. TRAC also provides benchmarking statistics for both truckload and less-than-truckload carriers. The monthly report is generated from surveys of participating ATA member carriers and provides information on changes in traffic, revenues, mileage, and equipment trends. In this report, VMT and average load are highlighted.

A.4.2 Background

Based on an ongoing survey of truckload and less-than-truckload carriers, TRAC provides the following information:

- VMT by operation range: Truck mileage by 0–500 miles; 500-1,000 miles; and 1000+ miles;
- VMT by equipment type: Dry van; flatbed; refrigerated; and bulk/tank;

Table A-4. Trucking Activity Report (TRAC).

Trucking Activity Report (TRAC)	
Definition of Truck	All trucks (excluding vehicles used by the government and on farms, but including all weight classes)
Data Items of Interest	VMT, average load
Geographical Level	National
Source Data	N/A
Data Gathering Method	Survey of members
Agency in Charge	American Trucking Association (ATA)
Years Covered	1973-2012

- Average load by operation range and equipment type; and
- Other: revenue; equipment utilization; traffic; and employee turnover and workforce changes.

A.4.3 Sources

Each month, ATA sends surveys out to for-hire motor carriers asking them for the data published in TRAC. ATA then matches up the carriers in the latest month and only uses those carriers that also provided data in the previous month. ATA then calculates a percent change for all the carriers combined (or for selected groups—dry van, flatbed, refrigerated, and bulk/tank) for all data categories (e.g., loads, revenue, miles, etc.) and moves the previous not seasonally adjusted index for that category up or down by the percent change.

A.4.4 Reliability

Since the survey is conducted only on member carriers, the results are subject to sampling errors. So, ATA Economics and Statistic Department uses normative units such as Truck Tonnage Index rather than natural units. For quality control, ATA also compares the seasonally adjusted (SA) index with the not seasonally adjusted (NSA) index.

A.4.5 Time Series

A complete historical monthly database of the TRAC indexes goes back to the early 1990s.

A.4.6 Formats and Availability

TRAC is available to only individual subscribers. TRAC is e-mailed to subscribers between the 14th and 18th of every month.

In parallel with TRAC, ATA also publishes the Monthly Truck Tonnage Report (MTTR) every month and the Motor Carrier Report (MCR) every year. Like TRAC, ATA conducts a confidential survey of motor carriers but focuses on their balance sheets and income statement data along with information on tonnage, mileage, employees, transportation equipment, and other related items. The aggregate results are available in these reports.

MTTR includes an up-to-date, comprehensive analysis of tonnage trends exploring the underlying factors affecting the demand for trucking services. MTTR contains the summary of general freight carriers' system-wide tonnage volume indexed and adjusted, and provides comparisons with other pertinent economic indicators.

The data ATA collects for the MCR are very similar to the financial and operating statistics forms that motor carriers with revenue in excess of $3 million are required to file with the U.S. Department of Transportation. Since DOT will not distribute the post-2003 annual Form M filings to ATA or the public at large without an expensive Freedom of Information Act (FOIA) request, the ATA Motor Carrier Annual Report is the only source for aggregate data.

A.5 Transportation Statistics Annual Report (TSAR)

A.5.1 Overview

The Transportation Statistics Annual Report (TSAR) presents key indicators along with data and information about the performance and impacts of the U.S. Transportation System. The report focuses on closing data gaps and improving the ways in which transportation statistics are collected, analyzed, and published. In this sense, it is a very different type of report than other transportation summary studies in that it reports on the practice of transportation reporting. The 16th edition of the report was released in 2010, containing more than 260 data tables, citations for all original data sources, and a full glossary and list of acronyms.

TSAR specifically focuses on 13 topics, as mandated by Congress through US Code 49, section 111(c)(5). These thirteen areas are:

1. Productivity in various parts of the transportation sector,
2. Traffic flows for all modes,

Table A-5. Transportation Statistics Annual Report (TSAR).

Transportation Statistics Annual Report (TSAR)	
Definition of Truck	Truck is only reported at the aggregate level and is based on the Commodity Flow Survey data
Data Items of Interest	Ton Ton-miles Value of cargo
Geographical Level	National
Source Data	Summary tables are primarily based on data from the Commodity Flow Survey
Data Gathering Method	Reproduction of data from other transportation reports
Agency in Charge	BTS
Years Covered	1994-2010

3. Intermodal transportation database,
4. Travel times and measures of congestion,
5. Vehicle weights and characteristics,
6. Demographic, economic, and other variables influencing traveling behavior,
7. Costs for passenger travel and goods movement,
8. Availability and use of mass transit,
9. Frequency of vehicle and transportation facility repairs,
10. Safety and security for travelers,
11. Connectivity and condition of the transportation system,
12. Transportation-related variables that influence domestic and global competiveness, and
13. Consequences of transportation for the human and natural environment (U.S. Department of Transportation, 2012b).

A.5.2 Coverage

Data points reported on TSAR are based on a variety of BTS, DOT, and RITA initiatives to capture information about the transportation system in the United States. BTS serves as the lead federal statistical agency responsible for culling information from such data sources as the Survey of State Funding for Public Transportation, the Livable Communities and Environmental Sustainability highlights from the Omnibus Household Survey, and information about hazardous material shipments as reported on the Commodity Flow Survey (CFS). This information is organized in TSAR around the DOT strategic goals: promoting safety, building livable communities, improving the state of good repair, fostering economic competitiveness, and supporting environmental sustainability of the U.S. transportation system. BTS-specific recommendations for improving the existing survey methods used to capture transportation patterns are presented in the TSAR section "Improving Transportation Statistics." As a composite of many different surveys, the coverage for TSAR is limited to the data sources underlying any given table (U.S. Department of Transportation, 2011).

Hazardous material shipments made by freight trucks are reported by value, tons and ton-miles at the national level by hazard class (e.g., explosives, gasses, flammable liquids). This information is from the 2007 Commodity Flow Survey released by BTS and U.S. Department of Commerce. On another table, hazardous waste shipment patterns for 2007 are compared to non-hazardous waste by transportation mode—in this case, the truck category is characterized in the aggregate as well as by "for-hire truck" and "private truck."

A.5.3 Sources

Sources include a variety of transportation surveys and reports generated for the national level by the federal government, state departments of transportation, local governments, and other organizations invested in the health of U.S. transportation. All sources and references are documents in TSAR. Data for shipments made by truck is limited to information on the Commodity Flow Survey.

A.5.4 Reliability

As a composite of information from several data sources, TSAR reliability depends on the data sources underlying any given table. For truck data this is specific to the Commodity Flow Survey.

A.5.5 Time Series

TSAR was first published in 1994 and continued through 2010; updates after that period are not available.

A.5.6 Availability

TSAR reports are available on the BTS website.

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APPENDIX B

Primary Data Sources

B.1 American Trucking Trends (ATT)

B.1.1 Overview

ATT is the almanac of U.S. trucking that amalgamates various data sources. ATT is produced by ATA's Economics and Statistics Department and provides data items of interest—VMT, tons, and value of cargo—as a secondary analysis.

ATT identifies significant trends in truck tonnage, freight revenue, and revenue share for the motor carrier industry, as well as facts about North American trucking. Specifically, Chapters 2, 7, and 8 of this report cover trucking performance and international surface trade, which contains data items of interest. The contents of ATT include

- Trucking Performance: Commodity Flow Data; trucking failures; truck tonnage; truck revenue; revenue per mile and revenue per ton; and Trucking Producer Price Indexes;
- Fleet Demographics: Registrations;
- International Trade: surface trade by transportation mode; truck trade by commodity; and truck trade by U.S. state; and
- Vehicle miles and fuel consumption; and emissions.

B.1.2 The Basics

Differing amounts of detailed information are available per primary data source to complete the sections under the heading, The Basics. Where information could not be located, the section on The Basics, has been omitted.

B.1.2.1 How Are the Data Generated?

As a secondary analysis, ATT cites the following data sources for data items of interest:

- Value of Cargo by truck type—For-hire truck and private truck: 2007 Commodity Flow Survey;
- Value of Cargo by commodity—Exports and imports by commodity: North American Transborder Freight Data;
- VMT—Single-unit and combination truck: Highway Statistics 2008;
- Tons: Monthly Truck Tonnage Trends and Trucking Activity Report.

Table B-1. American Trucking Trends (ATT).

ATT	
Definition of Truck	All trucks (excluding vehicles used by the government and on farms, but including all weight classes)
Data Items of Interest	VMT, tons, value of cargo
Geographical Level	National
Source Data	Commodity Flow Survey, North American Transborder Freight Data, Highway Statistics, Monthly Truck Tonnage Trends, and Trucking Activity Report
Data Gathering Method	N/A
Agency in Charge	ATA
Years Covered	1999-2009

ATT also uses other data sources, as follows, for other parts of this report:

- Avondale Partners, LLC (Nashville, TN 37203); Employment and Earnings (Washington, D.C. 20210: Bureau of Labor Statistics, U.S. Department of Labor); Employment and Wages Annual Averages (Washington, D.C. 20210: Bureau of Labor Statistics, U.S. Department of Labor); Energy Information Administration (Washington, D.C. 20585: U.S. DOE); FMCSA (Washington, D.C. 20590: U.S. Department of Transportation); Insurance Institute for Highway Safety (Arlington, VA 22201); Large Truck and Bus Crash Facts 2007 (Washington, D.C. 20590: FMCSA, U.S. Department of Transportation); Martin Labbe Associates (Ormond Beach, FL 32174); National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data (Research Triangle Park, NC 27601: U.S. Environmental Protection Agency); Producer Price Indexes (Washington, D.C. 20210: Bureau of Labor Statistics, U.S. Department of Labor); *Wall Street Journal* (New York, NY 10281: Dow Jones Co.); Vehicle Inventory and Use Survey (Washington, D.C. 20230: Census Bureau. U.S. Department of Commerce); and Ward's Communications (Southfield, MI 48075).

B.1.2.2 What Auditing Procedures Are Used?

ATT's statistical reliability depends on the quality control of original data sources.

B.1.2.3 How Can the Data be Accessed?

ATT is on an annual basis. In parallel with ATT, the ATA also publishes the Standard Trucking and Transportation Statistics (STATS) based on secondary analysis. STATS is a quarterly update featuring data on everything from state fuel taxes to stock performance.

ATT's trucking industry data are provided in easy-to-read graphical and tabular formats for ease of interpretation and analysis and available in book, CD, and downloadable PDF formats.

B.2 ATR Classification Count Data

B.2.1 Overview

Traffic count data are collected by sensors installed by state departments of transportation in America's roadway network. There are more than 6,000 of these sensors installed in roads that are collecting data 24 hours a day, 365 days a year. A vast majority of these sensors only collect volume data. But there are sensors that are able to differentiate the types of vehicles that are on the roads, which allows for analysis of fleet mix and comprehensive understanding of truck volumes.

B.2.2 The Basics

B.2.2.1 How Are the Data Generated?

Classification count data are generated exclusively by roadway sensors. There are a number of sensors that can be installed about the road surface; however, permanent subsurface classification counters are currently the system used for continuous counters that operate 24 hours a day every day of the year.

B.2.2.2 What Auditing Procedures Are Used?

Classification counts are used in HPMS calculations (discussed later in this appendix) and are often used by state DOTs to develop behavior models for road segment types that can be used to better understand short counts data. Short counts data is collected once every 1 to 5 years for a short period of time ranging from 1 day to 2 weeks. This data is used to establish the current AADT for the segment by adjusting with

Table B-2. ATR classification count data.

ATR Classification Count Data	
Definition of Truck	8 FHWA classes for trucks[a]
Data Items of Interest	Volume
Geographical Level	National, state
Source Data	Primary data
Data Gathering Method	Roadway sensors
Agency in Charge	Various
Years Covered	Varies depending on source

[a] Body type and GVW determined the following five truck strata: (1) pickups; (2) minivans, other light vans, and sport utility vehicles; (3) light single-unit trucks (GVW < 26,000 lb); (4) heavy single-unit trucks (GVW ≥ 26,000 lb); and (5) truck-tractors.

seasonal weighting. Continuous count class data is reported to TMAS, which uses the following automated checks for data quality:

- Duplicates within the batch
- Fatal error occurs if
  - No C in the 1st digit of the record
  - Record length less than number of characters based on station data field 15
  - No station ID in the record (columns 4-9)
  - No corresponding station in National Database
- Critical errors occur if
  - Volume checks
    - Record includes 7 or more consecutive zero hours
    - Record includes zero hour volume with one or more
    - Boundaries with over 50 vehicles
    - 24 hours of data not in a given record
    - Any hourly volume exceeds the max per hour per lane value
    - Splits check show unbalanced directional volumes greater than
    - 5 percent variance from 50 percent
    - MADT from same month previous year not within 30 percent
- Caution flags occur if
  - Classification checks
    - Percent class by day maximum check
    - Percent class by day based on historical value" (Jessberger, 2009)

State DOTs and, in this case, occasionally MPOs or other local planning organizations, have control over collecting the microdata and maintaining the physical machines. This means that the state of practice of maintaining good data varies greatly across the country. Review processes for class counts data tend to be automated by different software that often accompanies the counting hardware, sometimes with additional third-party software for using traffic count data.

B.2.2.3 How Are the Data Maintained?

Classification count data is required to be reported monthly to FHWA for HPMS and VMT calculation. The responsibility to collect and maintain the data is, however, the responsibility of individual state DOTs, and can be considered part of their work plan for the collection in the Intelligent Transportation System (ITS) programs.

B.2.2.4 How Can the Data be Accessed?

Continuous count data is rolled into HPMS data and is used to for FHWA's monthly VMT calculations, however, no other summary data of classification counts is available. Some state DOTs provide summary data from their counts data on their website at varying intervals. As of the writing of this report, the researchers could not find any agency that publicly publishes the microdata for classification counts. However, agencies will often make the data available upon request.

B.2.2.5 How Were the Data Archived?

The FHWA keeps the microdata archived in TMAS. Additionally, all of the states have different archiving programs as directed by their ITS programs.

B.2.2.6 Do Metadata Exist?

Classification counts have benefited from the wide adoption of the metadata descriptions in FHWA's Traffic Monitoring Guide.

B.2.2.7 What Are Previous Uses of the Data?

The most widely used dataset derived from continuous count classification data is FHWA's monthly nationwide VMT report, Travel Volume Trends (TVT). Individual state DOTs also often publish count data in monthly and annual reports on paper and often publish them on their websites.

B.3 ATRI per Freight Performance Measures Initiative

B.3.1 Overview

Since 2002, ATRI, working closely with FHWA, has led the Freight Performance Measures (FPM) program, which evaluates the effectiveness of the highway system to facilitate fast, efficient goods movement. Performance measurements are produced for this program through the use of real, anonymous, private-sector truck data sourced through unique industry partnerships. ATRI's FPM database currently contains billions of truck data points from several hundred thousand unique vehicles spanning more than 7 years. These data, which include periodic time, location, speed and anonymous unique identification information, are used by ATRI researchers to produce the following:

- Average speed, travel time, and reliability of truck movement on large transportation networks such as the Interstate Highway System;
- Quantification and ranking of highway bottlenecks, urban congestion and localized system deficiencies on the nation's freight transportation system;

Table B-3. ATRI per freight performance measures initiative.

ATRI per Freight Performance Measures Initiative	
Definition of Truck	Commercial fleets
Data Items of Interest	Truck speeds
Geographical Level	Selected states and regions
Source Data	Primary data
Data Gathering Method	Onboard communications equipment used to record GPS data
Agency in Charge	ATRI and FHWA
Years Covered	Continuous since 2003

- Crossing time and delay statistics at freight significant U.S.-Canadian border crossings; and
- Information describing demand for truck routes and highway facilities throughout the U.S.

These efforts have already had a promising start, ATRI's first report using FPM web to understand bottlenecks has led to the State of Illinois promising to address the report's Number 1 bottleneck in the United States, which is outside of Chicago (ATRI and FHWA, 2011).

N-CAST is the second-generation product following FPM web that has greater coverage of the national highway system and reduces the segmentation for measurement from 3 miles to 1 mile. In its current state, even though it has better granularity and coverage than the FPM tool and is by far easier to use, it does not allow the user to query by time, and only shows the average speed for A.M., midday, and P.M. peaks without any indication of when the data was gathered.

B.3.2 The Basics

B.3.2.1 How Are the Data Generated?

The FPM database consists of billions of truck position data points. These data points are derived from wireless technology and global positioning systems used by the trucking industry as an operations management tool. Each data point received by ATRI contains, at the very least, a unique identifier, a latitude reading, a longitude reading, and a time/date stamp.

B.3.2.2 What Auditing Procedures Are Used?

Raw data is processed for N-CAST using both proprietary and off-the-shelf software and methods, as well as significant back-end hardware. The resulting processed data represents average truck speeds that are derived from the spot speeds of individual trucks.

B.3.2.3 How Are the Data Maintained?

ATRI has been collecting GPS data from GPS vendors to the trucking industry since 2002. It is currently unclear how often they receive new data and what the nature of the contracts they have with providers are, if any.

B.3.2.4 How Can the Data be Accessed?

Both systems take GPS microdata, link it to a highway segment and then summarize the average speed by time on those segments. FPM web can be accessed at freightperformance.org; you must request and receive a password from administrators before accessing the data and instructions. N-CAST is not yet currently available, but is planned to be hosted on FHWA's website.

B.3.2.5 How Are the Data Archived?

Both systems are archived centrally by ATRI in online systems.

B.3.2.6 Do Metadata Exist?

Metadata is available for both the FPM web CSV files as well as the N-CAST shapefiles; the metadata is included in the appendix.

B.3.2.7 What Are Previous Uses of the Data?

ATRI has produced several reports on the state of the national freight network using early analysis of these datasets (American Transportation Research Institute, 2011). Otherwise, these datasets are too new to have any documented uses in the public domain.

B.4 Cass Information Systems

B.4.1 Overview

Cass is a business process outsourcer that serves large corporations with expense management by processing complex invoices and providing post-processing and analysis of these expense areas. Cass customers are large enterprises with complex payables such as those for freight, parcel, utilities, and telecom expenses. Based on data derived from paying freight invoices from its customers, Cass publishes four indexes that

Table B-4. Cass information systems.

Cass Information Systems	
Definition of Truck	For-hire transportation carriers
Data Items of Interest	Freight volumes and expenditures
Geographical Level	National
Source Data	Primary data (invoices and payment service audits)
Data Gathering Method	Reporting from Cass Information Systems' customers
Agency in Charge	Cass Information Systems
Years Covered	Continuous since 1990

are relevant to truck activity: Cass Freight Index, a measure of North American freight shipments and expenditures; Cass Truckload Linehaul Index, reflecting fluctuations in U.S. domestic truckload linehaul rates; Cass Intermodal Price Index, measuring changes in U.S. domestic intermodal costs; and Cass/INTTRA Ocean Freight index, a measure of fluctuation in U.S. import and export ocean container activity.

B.4.2 The Basics

B.4.2.1 How Are the Data Generated?

Data within the Freight, Truckload Linehaul, and Intermodal Price Indices include all domestic freight modes and are derived from $22 billion in freight transactions processed by Cass annually on behalf of its client base. These companies represent a broad sampling of industries including consumer packaged goods, food, automotive, chemical, original equipment manufacturers (OEM), retail, and heavy equipment. Cass claims that the diversity of shippers and aggregate volume provide a statistically valid representation of North American shipping activity.

The Freight Index uses January 1990 as its base month. The index is updated with monthly freight expenditures and shipment volumes from the entire Cass client base. Volumes represent the month in which transactions are processed by Cass, not necessarily the month when the corresponding shipments took place. The January 1990 base point is 1.00. The Index point for each subsequent month represents that month's volume in relation to the January 1990 baseline. For the Freight Index, each month's volumes are adjusted to provide an average 21-day work month. Adjustments also are made to compensate for business additions/deletions to the volume figures. These adjustments help normalize the data to provide a sound basis for ongoing monthly comparison.

The Truckload Linehaul index is an indicator of market fluctuations in per-mile truckload pricing. The index isolates the linehaul component of full truckload costs from other components (e.g., fuel and accessorials), providing an accurate reflection of trends in baseline truckload prices. The index uses January 2005 as its base month and a baseline of 100.0 for that date.

The Intermodal Price Index is an indicator of market fluctuations in per-mile U.S. domestic intermodal costs. The index includes all costs associated with the move (linehaul, fuel, and accessorials). It is based on costs as of January 2005 and uses a base value of 100. Until March 2013, this index was known as the Cass Intermodal Linehaul Index and measured changes in linehaul rates only.

Data for the Ocean Freight Indexes are derived from the data for executed shipments processed within the INTTRA e-commerce platform between the U.S. and a select group of 25 leading impact and export trading partner countries that account for the vast majority of container activity into and out of the U.S. INTTRA's platform processes transactions for more than 21 percent of the world's ocean container traffic.

The Ocean Freight Indexes use January 2010 as their base month. The indexes are updated monthly and are driven by ocean container activity processed on the INTTRA portal. Container activity is included for the month in which the container's shipping instructions were submitted to the ocean carrier, which usually occurs 2 to 3 days prior to vessel departure.

The January 2010 base point for each index is 1.00, so the index points for each subsequent month represent that month's volumes in relation to the January 2010 baseline. INTTRA applies a same-store sales methodology, measuring differences generated by the same customers for the selected timeframes. Excluding new customer volumes enables year-over-year measurements on a like-for-like basis, providing a sound basis for ongoing monthly comparison.

Export data included in the index is derived from cumulative shipment activity of U.S. exports to the twenty-five countries receiving the largest container volumes. Data for imports is derived from total shipment activity for imports to the U.S. from the top twenty-five overseas origins.

B.4.2.2 How Can the Data be Accessed?

The indexes are available by subscription from Cass Information Systems (http://www.cassinfo.com/Transportation-Expense-Management/Supply-Chain-Analysis/Transportation-Indexes). There is no cost to subscribe.

B.5 Commodity Flow Survey

B.5.1 Overview

The Commodity Flow Survey (CFS) is a shipper-based survey conducted every 5 years as part of the economic census. The survey is a joint project of the Bureau of the Census and BTS. It is conducted as part of the Census Bureau's quinquennial economic census to capture data on the flow of goods and materials by mode of transportation. CFS provides a national- and state-level data view on domestic freight shipments in mining, manufacturing, wholesale, auxiliaries, and selected other industries. This level of detail provides a national perspective of systemic shipment flow. CFS was first released in 1993; however, it revised and dramatically expanded the Census Bureau's Commodity Transportation Survey, conducted in 1963, 1967, 1972, and 1977. No data were published from a limited version attempted in 1983 (see http://www.census.gov/econ/cfs/faqs.htm).

B.5.2 The Basics

B.5.2.1 How Are the Data Generated?

CFS is a shipper-based survey that gathers data from shipments in the United States. With the exception of operating status and the verification of name and location, CFS does not collect data on shipper or receiver descriptors. CFS includes the following shipment data:

- Shipment ID number, date, value, and weight;
- SCTG commodity code;
- Commodity description;
- Destination (and port of exit in the case of exports);
- Mode(s) of transportation;
- Mode of export; and
- Hazardous material (hazmat) code.

CFS collects shipment data from a sample of establishments selected from the U.S. Census Bureau Business Register. These establishments are from manufacturing, mining, wholesale, select retail and service industries (electronic shopping, mail-order houses, and fuel dealers), and auxiliary establishments (i.e., warehouses and managing offices) of multi-establishment companies. CFS does not include establishments from the following industries: crude petroleum and natural gas extraction, farms, government establishments, transborder shipments, imports (until the shipment reaches the first domestic shipper), and remaining service industries. Many of these industries (e.g., farms and government establishments) are not included in the Business Register. Each establishment selected is mailed a questionnaire four times during the year. For each questionnaire, the establishment provides specific data about a sample of individual outbound shipments during a pre-specified 1-week period (Quiroga et al., 2011).

B.5.2.2 What Auditing Procedures Are Used?

The methodology for survey design and implementation is available at http://www.bts.gov/publications/commodity_flow_survey/methodology/index.html.

The document also covers data collection, imputation and estimations from that dataset, the sampling and non-sampling error, as well as the reliability of estimates.

B.5.2.3 How is the Data Maintained?

CFS is a survey given to shippers every 5 years as part of the economic census, starting in 1993. The CFS was conducted in 1993, 1997, 2002, 2007, and most recently in 2012. Preliminary estimates from the 2012 survey were released December 10, 2013. Final data will be released December 2014.

Table B-5. Commodity flow survey.

Commodity Flow Survey	
Definition of Truck	Truck definition includes for-hire truck, private truck, and truck
Data Items of Interest	VMT (by geography) Ton (by commodity type and geography) Ton-miles (by commodity type and geography) Value of cargo (by commodity type and geography)
Geographical Level	National, state, and selected metro areas
Source Data	Primary shipper-based survey
Data Gathering Method	Survey
Agency in Charge	BTS, U.S. Department of Transportation and Bureau of the Census, U.S. Department of Commerce
Years Covered	1993, 1997, 2002, 2007, 2012

B.5.2.4 How Can the Data be Accessed?

A variety of high-level summaries are available for download and viewing in HTML, xls, and csv formats from the BTS website for the Commodity Flow Survey at http://www.bts.gov/publications/commodity_flow_survey/.

The data can also be accessed through the U.S. Census's American Fact Finder 2 at http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml.

The microdata is available at the U.S. Census Bureau, however it is not publicly available due to confidentiality concerns for the private firms who participate in the study. Access to the microdata is available through the Census Bureau's Center for Economic Studies on a limited research-only basis. Access requires a substantial justification process, an extensive approval process and membership in the Census Bureau's center where the data can be accessed only within the center, with very strict permissions and clearances.

NCFRP Project 25: Freight Trip Generation and Land Use, involves research that uses the microdata to understand the relationships between business types and truck trip generation. The research will be undertaken utilizing 2007 CFS microdata reviewed at one of the Census Bureau's Research Data Centers (BTS, 2011).

B.5.2.5 How Are the Data Archived?

The data is archived centrally, in summary form online by the Bureau of Transportations Statistics and in microdata form by the U.S. Census Bureau at its census centers.

B.5.2.6 Does Metadata Exist?

The metadata (e.g., electronic listings, paper details) and instructions are available for download on the BTS Commodity Flow website at http://www.bts.gov/publications/commodity_flow_survey/survey_materials/index.html.

B.5.2.7 What are Previous Uses of the Data?

The main use of the Commodity Flow Survey is in constructing the Freight Analysis Framework. It is also used in commercial products such as Global Insight Transearch data. Both of these datasets leverage CFS to produce what is seen as more usable freight data.

For the National Cooperative Highway Research Program (Donnelly, 2011) Rick Donnelly of Parsons Brinckerhoff, Inc. interviewed a total of 22 state and 15 MPO planners from across the country and reported that "No ongoing applications of the CFS by states and MPOs are known." He states, "it is likely that many use the tabular summaries published for each state to support broad policy analyses or document trends." He found that instead, most state and MPO planners were using the Freight Analysis Framework to support their statewide, or even local, freight models.

B.6 Economic Census

B.6.1 Overview

The economic census is the foundation for measuring business activity across the U.S. economy, and response to it is required by law. The economic census has been taken as an integrated program at 5-year intervals since 1967 and before that for 1954, 1958, and 1963. Prior to that time, individual components were taken separately at varying intervals. Its beginnings trace to the 1810 Decennial Census, when questions on manufacturing were included with those for population. The first census of business, covering retail and wholesale trade, was conducted in 1930, and shortly thereafter was broadened to include some service trades. The 1954 economic census was the first to fully integrate census taking for various kinds of business. The census provided comparable statistics across economic sectors, using consistent time periods, concepts, definitions, classification, and reporting units. The census of transportation began in 1963 as a set of surveys covering travel, transportation of commodities, and trucks. Starting in 1987, census publications also reported on

Table B-6. Economic census.

Economic Census	
Definition of Truck	Truck definition local trucking, long-distance trucking, courier, and messenger services
Data Items of Interest	Cost
Geographical Level	National to local level
Source Data	Survey of business establishments
Data Gathering Method	Survey
Agency in Charge	Bureau of the Census
Years Covered	Long history, currently every 5 years in years ending in 2 and 7

business establishments engaged in several transportation industries, paralleling the data on establishments in other sectors. The final major expansion of the economic census took place in 1992, adding more transportation industries, plus finance, insurance, real estate, communications, and utilities, a group accounting for more than 20 percent of U.S. GDP. The 1997 economic census was the first major statistical report based on NAICS.

The current economic census has a broad scope and coverage—minerals, construction, manufacturing, wholesale, retail and accommodations, service industries, transportation, communication, utilities, and finance, insurance, and real estate services. The economic census covers data for 1,000 industries, more than 28 million establishments (including approximately 7.4 million employer businesses and 21.1 million non-employer businesses), 13,000 goods and services products, and 15,000 different geographies. It includes the Survey of Business Owners, the Business Expenses Survey, and the Economic Census of Puerto Rico, Guam, Virgin Islands, Commonwealth of the Northern Mariana Islands, and American Samoa. As noted elsewhere, BTS conducts the Commodity Flow Survey, which is part of the economic census. The economic census has a unique role. It includes some 40 billion data cells and 1,641 data product releases.

B.6.2 The Basics

B.6.2.1 How Are the Data Generated?

The economic census is primarily conducted on an establishment basis. In the economic census, large- and medium-sized firms, plus all firms known to operate more than one establishment, are sent questionnaires to be completed and returned to the Census Bureau by mail or via online reporting. A company operating at more than one location is required to file a separate report for each location or establishment. Companies engaged in distinctly different lines of activity at one location are requested to submit separate reports, if the business records permit such a separation and if the activities are substantial in size. For the 2012 census (according to the Bureau of the Census), nearly 4 million businesses with paid employees received census forms. These forms were sent to most businesses in nearly every industry in the private, non-farm economy and every geographic area of the United States, Puerto Rico, and other U.S. island areas. Although the precise cutoff varies from industry to industry, most businesses with four or more paid employees, and a sample of smaller ones, receive census forms. For most very small firms, data from existing administrative records of other federal agencies were used instead. These records provide basic information on location, kind of business, sales, payroll, number of employees, and legal form of organization.

B.6.2.2 What Auditing Procedures Are Used?

The methodology for data processing and treatment of non-response can be found at http://www.census.gov/econ/census07/www/methodology/data_processing_and_treatment_of_nonresponse.html.

B.6.2.3 How is the Data Maintained?

The economic census is conducted every 5 years in years ending in 2 and 7.

B.6.2.4 How Can the Data be Accessed?

Full statistical tables from the economic census can be found in American FactFinder. All 2012 economic census results will be released intermittently on the Internet at American Fact Finder, starting with the Advance Report in March 2014.

With very few exceptions, the public use versions for economic census microdata files are limited to data presented in aggregate form. Access to these data is only granted to qualified researchers on approved projects with authorization to use specific datasets.

B.6.2.5 How Are the Data Archived?

The data is archived centrally, in summary form online and in microdata form by the U.S. Census Bureau.

B.6.2.6 Does Metadata Exist?

The metadata (e.g., electronic listings, paper details) are available in American FactFinder.

B.7 Freight Analysis Framework

B.7.1 Overview

The Freight Analysis Framework (FAF) integrates data from the Commodity Flow Survey (CFS), other data sources, and models to create a comprehensive picture of freight movement among regions of the United States by all modes and along major highways for tonnage moved by truck. The FAF has gone through three major updates, with a fourth planned following release of data from the 2012 CFS. Each major update creates estimates of tons, ton-miles, and value by mode for each origin-destination pair of regions for the benchmark year, 20-year forecasts of the benchmark flows, and estimates of tons moved by truck on individual highways for the benchmark year and final forecast year. The benchmark is the most recent economic census year ending in 2 or 7, for which the CFS measures about three-fourths of the

Table B-7. Freight analysis framework.

Freight Analysis Framework	
Definition of Truck	Includes private and for-hire truck; private trucks are owned or operated by shippers and exclude personal-use vehicles hauling over-the-counter purchases from retail establishments: excludes utility and construction vehicles
Data Items of Interest	Tons, ton-miles, value by origin, destination, mode, and commodity; truck tons by major highway
Geographical Level	National, state, and state portions of major metropolitan areas and balances of states; truck tons for major routes
Source Data	Various sources
Data Gathering Method	Synthetic data (modeled)
Agency in Charge	FHWA
Years Covered	1997, 2002, 2007, provisional estimates from 2008 through most recent year, forecasts to 2040

tonnage in the FAF. Modal and economic data are used for provisional annual estimates for years since the last benchmark. The next FAF will be benchmarked for 2012.

B.7.2 The Basics

B.7.2.1 How Are the Data Generated?

The Freight Analysis Framework is a freight model based foremost on the Commodity Flow Survey (CFS) and Highway Performance Monitoring System (HPMS). In addition, a large number of other datasets are used to fill in CFS data gaps. Although the research team was not been able to find a concise list of data sources used in the FAF, the data sources that follow are all mentioned in the FAF3 documentation.

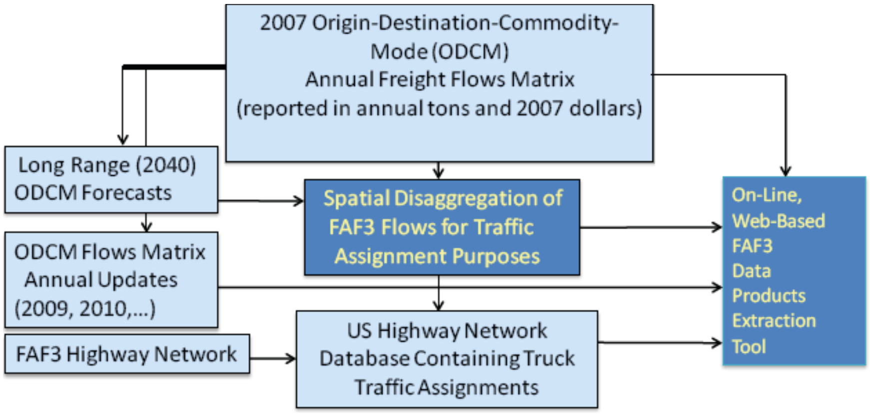
- 2007 U.S. Commodity Flow Survey
  - http://www.bts.gov/publications/commodity_flow_survey/index.html
- Surface Transportation Board's Public Use Railcar Waybill Data
  - http://www.stb.dot.gov/stb/industry/econ_waybill.html
- U.S. Army Corps of Engineers' 2007 Waterborne Commerce O-D-C Data
  - http://www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm
- U.S. Department of Agriculture's 2007 Census of Agriculture and 2008 Agricultural Statistics
  - http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/usappxb.pdf
- 2002 Vehicle Inventory and Use Survey (VIUS)
  - http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/usappxb.pdf
- 2008 Fisheries of the United States
  - http://www.st.nmfs.noaa.gov/st5/publication/fisheries_economics_2008.htmlInter
- 2002 U.S. National Input-Output Accounts reported by the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce
  - http://www.bea.gov/industry/io_benchmark.htm
- Import and export data
  - http://www.iwr.usace.army.mil/ndc/db/foreign/data/
- Municipal Solid Waste-BioCycle and Beck/Chartwell Studies
  - http://www.jgpress.com/biocycle.htm
- 2007 Municipal Solid Waste-Franklin/EPA Study
  - http://www.fal.com/solid-waste-management.html
  - http://www.epa.gov/epawaste/nonhaz/municipal/msw99.htm
- U.S. Census Bureau's Foreign Trade Database
  - http://www.census.gov/foreign-trade/reference/products/index.html
- PIERS Import/Export Database
  - http://www.piers.com/
- 2007 BTS Transborder Freight Database
  - http://www.bts.gov/transborder/
- U.S. Air Freight Movements
  - http://www.transtats.bts.gov/
- 2007 U.S. Census Bureau-County Business Patterns
  - http://www.census.gov/econ/cbp/
- U.S. DOE-Energy Information Administration
  - http://www.eia.doe.gov/emeu/aer/contents.html

B.7.2.2 What Auditing Procedures Are Used?

The methodology for creating the FAF3 network can be found on the FHWA website in a series of reports on creating different parts of the FAF.

http://faf.ornl.gov/fafweb/Documentation.aspx

The FAF3 documentation describes in detail the disparate data sources that are brought together to complete the FAF3 Origin-Destination Estimates and freight flows for the U.S. highway system (see Figure B-1).



Source: A Description of the FAF3 Regional Database and How It Is Constructed (Southworth et al., 2011)

Figure B-1. Principal FAF3 data products.

B.7.2.3 How Are the Data Maintained?

The FAF is an ongoing project that is funded by FHWA using in-house staff and contractors, including Oak Ridge National Laboratories.

As an internal program at FHWA, it is subject to the work program and resource allocation decisions made in future years.

B.7.2.4 How Can the Data be Accessed?

The FAF is maintained in several different formats (MS Access, CSV, dbf, ESRI shapefiles, TransCad files) online at http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm. The data also can be accessed via a data summary and extraction tool at http://faf.ornl.gov/fafweb/Extraction0.aspx.

B.7.2.5 How Are the Data Archived?

The data is archived centrally at the websites of FHWA and ORNL.

- The Data Summary and Extraction Tools are available at http://faf.ornl.gov/fafweb/Extraction1.aspx
- The regional and state data is available at http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/
- The network database and flow assignment is available at http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/netwkdbflow/index.htm

B.7.2.6 Does Metadata Exist?

Metadata in HTML and PDF is available for all datasets at their individual websites.

B.7.2.7 What Are Previous Uses of the Data?

The following list is from Best Practices for Incorporating Commodity Flow Survey and Related Data into the MPO and Statewide Planning Process (Donnelly, 2011).

B.7.3 Use in Planning and Policy Studies

- The Binghamton (NY) Metropolitan Transportation Study used the FAF2 regional origin/destination data to create summaries of trading partners, imports and exports, and domestic flows by commodity and mode of transport for their portion of the New York remainder zone.
- The Maine DOT created summaries of base and forecast year inbound, outbound, and internal flows for the state by commodity and mode of transport. Several charts and tables of these data were included in their Integrated Freight Plan Update.
- The West Coast Corridor Coalition generated summaries of trade flows through West Coast seaports in order to better understand trade and traffic patterns associated with trade with the Pacific Rim over the next 20 years.
- Fresno County (CA) used the FAF2 to validate 2002 truck traffic estimates produced by the Intermodal Transportation Management System. Because Fresno sits in "the remainder of California" they used both databases at that level. Data from the FAF2 were used to convert value to tons for comparison, and the results were used in Phase III of the San Joaquin Valley Goods Movement Study.
- The Texas DOT and Baltimore Metropolitan Council (MD) used the FAF2 origin-destination trip matrices as a comparison to Reebie Transearch data used in various studies. In Texas, the comparison was carried out as part of a study of the impacts of the North American Free Trade Agreement (NAFTA). In Baltimore, it was used to validate Transearch

estimates of county-level flows by county, direction, and composition.

- Broward County (FL) identified routes into and from Port Everglades in Fort Lauderdale using the FAF2 origin-destination database.
- The Delaware Valley Regional Planning Commission developed tables from the FAF2 origin-destination database to illustrate domestic and foreign freight flows into the Philadelphia (PA) region. The latter included summaries of exports, imports, and trading partners. This information was included in their Freight Facts and used by policymakers and the public to better understand regional freight trends.

B.7.4 Use in Freight Modeling

- The Appalachian Region Commission used the FAF2 regional origin-destination matrices to factor a county-to-county trip matrix synthesized from the FAF1 data. Twelve commodity groups were defined, and flows were converted from annual tons to daily trucks. The resulting demand was assigned to a multimodal network and further adjusted to match observed counts using synthetic matrix estimation. Forecasts for 2020 and 2035 also were developed.
- The American Association of Railroads developed growth factors from 2002 to 2035 from the FAF2 and then applied them to existing county-to-county trip matrices derived from the STB Carload Waybill Sample. The results were assigned to the ORNL rail network to estimate flows and levels of service in primary rail corridors.
- The Atlanta Regional Commission developed an external trip model for their freight model using the FAF2 origin-destination database. Their modeling region was expanded to match the boundaries of the FAF2 zone it resides in, and flows crossing this cordon were allocated to counties within the Atlanta region.
- FAF2 estimates of international flows and through trips passing through Indiana were included in a post-processor for their statewide model truck component. The freight flows generated complemented the internal freight and non-freight truck flows generated by the statewide model.
- The Florida DOT is developing a methodology for allocating the FAF2 origin-destination flows to regions within the state, and eventually to the county level. The FAF2 will be used in conjunction with other data to generate the county-level estimates. These will be used to update and validate their statewide freight model, to include derivation of generation and production parameters for internal and special generator trips. Mode split factors will be developed as well.
- The FAF2 origin-destination database was used to develop estimates of internal-external and through truck trips for a truck model of the San Diego region. Particular attention was paid to modeling of truck trips crossing the U.S.-Mexico border.
- A multi-level statewide model was developed in Maryland, where the FAF2 origin/destination database and forecasts are used to model truck flows through, into, and out of the state. As part of this process the flows are allocated to the county level across the country and then assigned to the ORNL freight network to define the entry and exit points of interstate flows entering the modeling area.

B.8 GPS Truck Data—University of Washington Study

B.8.1 Overview

The Washington State Department of Transportation (WSDOT), Transportation Northwest (TransNow) at the University of Washington (UW), and the Washington Trucking Associations partnered on a research effort to collect and analyze global positioning system (GPS) truck data from commercial, in-vehicle, truck fleet management systems used in the central Puget Sound region. The research project collected commercially available GPS data and evaluated their feasibility to support a state truck freight network performance monitoring program. WSDOT was interested in using this program to monitor truck travel times and system reliability, and to guide freight investment decisions.

Table B-8. GPS truck data from the University of Washington study.

GPS Truck Data – University of Washington Study	
Definition of Truck	Commercial fleets
Data Items of Interest	Truck speeds and origins and destinations
Geographical Level	Selected states and regions
Source Data	Primary data
Data Gathering Method	Onboard communications equipment used to record GPS data
Agency in Charge	Washington State Department of Transportation/ University of Washington
Years Covered	N/A

B.8.2 The Basics

B.8.2.1 How Are the Data Generated?

The data was generated by GPS transponders on trucks. WSDOT and UW initially approached trucking companies who readily agreed to share their data with the project. However, a lack of technical support made collecting the data from the firms very difficult. This obstacle was overcome by negotiating (paid) contracts with GPS and telecom vendors to obtain the data.

B.8.2.2 What Auditing Procedures Are Used?

One of the big advantages to the research conducted at the University of Washington, compared to other efforts (e.g., ATRI), is the careful documentation of the auditing procedures used on the data. First, a number of tests were made to determine the accuracy of spot speeds on GPS data points; these tests concluded that the spot speeds were highly accurate.

When using a dataset, automated routines were written to discard points more than 20 feet from the roadway and points with a heading 15 degrees different from the road as well as consecutive points that change heading too quickly. Overall about 20 percent to 30 percent of the data is discarded due to data quality issues.

B.8.2.3 How is the Data Maintained?

These projects were funded by the State of Washington, there is no ongoing program, and each state or agency would have to negotiate their own contracts to get GPS data for their region. Similar datasets can be obtained through non-disclosure data-sharing agreements with individual fleet managers, data aggregators, or other third-party agencies or organizations.

B.8.2.4 How Can the Data be Accessed?

The final papers for the GPS projects in Washington are available online with summaries of their findings. In another project, a visualization site was developed in Google maps called Drive–net which is available at http://www.uwdrive.net/. Individual non-disclosure data-sharing arrangements can be made with fleets or third-party data aggregators.

B.8.2.5 How Are the Data Archived?

The microdata is archived in a decentralized system and not available.

B.8.2.6 Does Metadata Exist?

There is no standard yet for using GPS data in freight planning. In this case, the data elements included truck ID (anonymized per trip), latitude, longitude, speed, and heading. Sometimes additional fields are available.

B.8.2.7 What Are Previous Uses of the Data?

GPS data is used for navigation and tracking, its primary uses. Using it for planning and analysis is still very new and most studies have concentrated on bottlenecks and freight performance measures.

B.9 Heavy/Medium Truck Duty Cycle (H/MTDC) Projects

B.9.1 Overview

The Heavy/Medium Truck Duty Cycle (H/MTDC) Projects are a critical element in DOE's vision for improved heavy vehicle energy efficiency and are unique in that there is no other existing national database of characteristic duty cycles for heavy and medium trucks. They involve the collection of real-world data on heavy/medium trucks for various situational characteristics (rural/urban, freeway/arterial, congested/free-flowing, good/bad weather, etc.) and look at the unique nature of heavy/medium trucks' drive cycles (stop-and-go delivery, power takeoff, idle time, short-radius trips) to provide a rich source of data—in particular, VMT, average load, and average speed—that can contribute to the development of new tools for fuel efficiency and modeling, provide DOE a sound basis upon which to make technology

Table B-9. Heavy/Medium Truck Duty Cycle (H/MTDC) Projects.

Heavy/Medium Truck Duty Cycle (H/MTDC) Projects	
Definition of Truck	Heavy truck (Class 8) and medium truck (Class 7)
Data Items of Interest	VMT, average load, average speed
Geographical Level	Local
Source Data	N/A
Data Gathering Method	Onboard sensors
Agency in Charge	Oak Ridge National Laboratory (ORNL)
Years Covered	2006-2008 (HTDC) and 2009-2010 (MTDC)

investment decisions, and provide a national archive of real-world-based heavy/medium-truck operational data to support heavy vehicle energy efficiency research.

The H/MTDC Projects are sponsored by DOE's Office of Vehicle Technologies (OVT). They involved efforts to collect, analyze, and archive data and information related to Class 7 medium-truck and Class 8 heavy-truck operation in real-world highway environments. Led by ORNL, the projects involve industry partners (e.g., Dana Corporation of Kalamazoo, Michelin Americas Research Company of Greenville, and Schrader Trucking of Jefferson City for HTDC; and H.T. Hackney Company and Knoxville Area Transit for MTDC). These partnerships and agreements provided ORNL access to Class 7 and 8 trucks for collection of duty cycle data.

The HTDC project involved identification of a fleet, fleet instrumentation, and field testing that included initial data collection, development of a data management system, and quality assurance and verification of the collected data. The MTDC project involves the collection of data from multiple vocations (local delivery, urban transit, towing and recovery, and utility) and multiple vehicles within these vocations (three vehicles per vocation) while the vehicles conducted their normal operations. The results of H/MTDC cover the following:

- VMT by truck-tire combination: Duals (regular dual tires)-duals, duals-new generation single wide-based tires (NGSWBTs) NGSWBTs-duals, and NGSWBTs-NGSWBTs;
- VMT by speed (average speed): Idling; 0–5 mph; 5–10 mph; . . . ; 70–75 mph; and 75–85 mph; and
- Other: Fuel efficiency by load level (average load: tractor only, light load, medium load, and heavy load), truck-tire combination, speed, trip type, transmission type, and type of terrain.

B.9.2 The Basics

B.9.2.1 How Are the Data Generated?

HTDC—Sixty channels of data were collected at 5 Hz from 6 instrumented tractors and 10 instrumented trailers for more than 1 year during the field operational test (FOT). Much of the data, including fuel consumption, was collected from the vehicle's databases. Other instrumentation included a GPS system that provided three-dimensional location; a real-time vehicle weight system; a weather station to obtain precipitation, wind direction, and wind velocity data; and a system to collect road condition data. A data acquisition system was developed, hardened in the pilot testing, and utilized in the FOT.

MTDC—To collect the duty cycle data, ORNL developed a data acquisition and wireless communication system that was placed on each test vehicle. Each signal recorded in this FOT was collected by means of one of the instruments incorporated into each data acquisition system (DAS). Native signals were obtained directly from the vehicle's data buses. Special equipment collected information available from a GPS including speed, acceleration, and spatial location information at a rate of 5 Hz, and communicated this data via the specific protocol. The self-weighing system (determines the vehicle's gross weight by means of pressure transducers and posts the weight to the vehicle's data bus) was used to collect vehicle payload information. A cellular modem facilitated the communication between the data collection engine of the system and the user, via the Internet. The modem functioned as a wireless gateway, allowing data retrievals and system checks to be performed remotely. Seventy-three signals from the different deployed sensors and available vehicle systems were collected. Because of the differences in vehicle databases, not all desired signals were available for both types of vehicles. The additional sensors, including the GPS-based and the self-weighing units, and a wiper switch used to collect basic rain data, were incorporated directly into the DAS.

B.9.2.2 What Auditing Procedures Are Used?

HTDC—The collected data was quality assured and archived for use in various data analyses. Two software tools were developed to support data analyses. The first involves the ability to identify data files within the database that conform to performance criteria selected by the user. The identified files were then downloaded and utilized by the user. A second software program is the DCGenT prototype that allows a user to identify files corresponding to a set of user-designated criteria. These files were statistically decomposed into histograms of speed and acceleration, and used to generate a synthetic duty cycle of user-designated duration that is characteristic of the segments from which it was derived. The tool is currently a prototype and still requires some additional effort before it is released.

MTDC—Upon installation of the DAS, the sensors were individually monitored through a computer with a wired connection. When the proper operation of the installed sensors was confirmed, the cellular modem was connected and the ability to communicate with the system remotely via the Internet was checked. When all systems appeared to be functioning as intended, the vehicle was released to resume normal operations. In addition, ORNL developed a data-retrieval and archiving system that accessed the vehicles automatically over the air and downloaded the information collected and residing on the onboard DAS. Each day the system e-mailed the ORNL researchers a summary of the data downloaded from each vehicle, highlighting any sensors that showed a percentage of errors above a pre-defined threshold.

B.9.2.3 How Can the Data be Accessed?

The final report on the HTDC and MTDC Projects is available online at: http://cta.ornl.gov/cta/CMVRTC/htdc.html and http://cta.ornl.gov/cta/CMVRTC/mtdc.html.

B.10 Highway Performance Monitoring System (HPMS)

B.10.1 Overview

The HPMS provides data that reflects the extent, condition, performance, use, and operating characteristics of the nation's highways. It was developed as a national highway transportation system database and includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and certain statewide summary information.

It originated in 1965 when Congress directed FHWA to report biennially on the conditions, performance, and future needs of the nation's road and highway networks. Previously, the federal government had conducted several studies that supported the planning of the national system but, unlike other efforts, this call was viewed as a challenge posed by Congress for FHWA to coordinate state-level surveys more regularly and in a more innovative manner. Initially, HPMS was designed to describe the condition of the nation's highway system by capturing the experience of top-level policy decision makers at each of the states. This top-down approach identified many of the high-level highway problems, but by 1978 an approach to collecting regular road segment data was adopted. In 1978, the top-down survey approach was replaced with a continuous, sample-based monitoring program that required annual data reporting instead of relying on biennial studies.

Although the data is aggregated and maintained centrally by FHWA, the states provide for the "counting program" covering all interstate, principal arterial, and other segments of the national highway system, which continuously builds the HPMS data. With this division, the states are responsible for counting equipment such as automatic traffic recorder stations, classification count stations, and real-time ITS deployment data. Because the transportation infrastructure changes over time, states develop a comprehensive count program, which responds to growth areas in the state by sampling those more frequently than lower growth areas (FHWA, 2010).

One of the most significant and visible uses of HPMS data is for the apportionment of Federal-Aid Highway Program funds to the states under current legislation. HPMS also provides data for the biennial Condition and Performance Reports to Congress, which support the development and evaluation of FHWA's legislative, program, and budget options. These data are the source of information used for assessing highway system performance under FHWA's strategic planning process; safety measures in terms of fatalities and injury crashes are benchmarked to VMT; pavement smoothness measured in IRI; and changes in congestion levels to estimate system delay.

In addition, HPMS serves the needs of the states, MPOs, local agencies, and other customers in assessing highway condition, system performance, air quality trends, and future investment requirements. Many states rely on traffic and travel data from HPMS to conduct air quality analyses to determine air quality conformity and to assess highway investment needs using HERS-ST. Finally, these data are the principle source of information for FHWA's annual *Highway Statistics* and other media publications.

B.10.2 The Basics

B.10.2.1 How Are the Data Generated?

These data are collected by the states through a number of means including roadside sensors, GIS, and other methods. The data are obtained by FHWA via a mandated reporting process by the states.

B.10.2.2 What Auditing Procedures Are Used?

Both automatic and manual auditing procedures are used. In regards to HPMS, GIS automated systems are employed to check for link connection and GIS visualizations are used to

Table B-10. Highway Performance Monitoring System (HPMS).

Highway Performance Monitoring System (HPMS)	
Definition of Truck	Truck is reported in terms of light truck, single-unit, combination, tractor, and by axle
Data Items of Interest	VMT (by vehicle type)
Geographical Level	National, state
Source Data	State DOTs and local MPOs
Data Gathering Method	Count-based data on a sample of roads are collected by each state
Agency in Charge	FHWA Office of Highway Policy Information
Years Covered	1982-present

make sure systems have logic flows. There is a large body of automated TMAS quality checks that ensure that good data is collected and bad data is retained but noted.

B.10.2.3 How Are the Data Maintained?

These are ongoing projects funded by FHWA as well as the states that are mandated to submit data.

B.10.2.4 How Can the Data be Accessed?

High-level reports are available for HPMS and monthly reports are available for Traffic Volume Trends. TMAS data is not available to the public. Some of the summarized data also is available in the RITA National Transportation Database as GIS files of coverage, however, some of these files are currently incomplete/incorrect.

B.10.2.5 How Are the Data Archived?

The data are archived centrally at FHWA headquarters in Washington, D.C.

B.10.2.6 Does Metadata Exist?

The metadata for these datasets exists in the HPMS Manual and the Traffic Monitoring Guide.

B.10.2.7 What Are Previous Uses of the Data?

This data is reported to Congress every 2 years to help provide an understanding of the state of the nation's transportation system. The data is heavily used in economic models and the Freight Analysis Framework. The data is also frequently shared between states for the purpose of not only increasing the data quality of the HPMS submittal through peer review, but for use in evaluating their own highway systems' performance.

B.11 Intermodal Market Trends & Statistics (IMT&S)

B.11.1 Overview

The Intermodal Market Trends & Statistics (IMT&S) Report from the Intermodal Association of North America (IANA) provides intermodal industry data based on its information services. In particular, IMT&S includes VMT and average load data through intermodal volume, highway truckload volume, total loads, with associated intermodal and highway revenues. Comparisons of prior quarter and prior year activities are measured, as is current year-to-date activity. Trend charts for activities over the prior 15 months also are illustrated. In addition, trucking statistics include truck capacity analysis, truck load originations, current trucking indicators, heavy-duty truck utilization rate, and trucking analysis and forecasting.

As an industry trade association representing the combined interests of the intermodal freight industry, IANA provides industry data through IMT&S and intermodal information services related to trucking as follows:

- Uniform Intermodal Interchange and Facilities Access Agreement (UIIA)—IANA administers the standard equipment interchange among intermodal trucking companies and others through UIIA. IANA acts as a clearinghouse for the collection and dissemination of insurance information and supporting documentation necessary to meet the program requirements.
- Intermodal Driver Database (IDD)—As a secure, Web-based system for motor carriers, the database houses specific driver information on over 305,000 active drivers. The IDD enables UIIA to furnish accurate and up-to-date driver information in addition to motor carriers' interchange status information via electronic data feeds to UIIA equipment providers.
- Intermodal Tractor Registry (ITR)—ITR provides a registration point for UIIA licensed motor carriers (LMCs) to

Table B-11. Intermodal Market Trends & Statistics (IMT&S).

Intermodal Market Trends & Statistics (IMT&S)	
Definition of Truck	Truck for highway loads of intermodal volume: private[a] vs. rail-controlled[b] and 20/28' trailers, 40/45' trailers, and 48/53' trailers
Data Items of Interest	VMT, average load
Geographical Level	National, states
Source Data	N/A
Data Gathering Method	Survey of IANA's members and participating intermodal marketing companies
Agency in Charge	Intermodal Association of North America (IANA)
Years Covered	2007-2011

[a] A private unit is any piece of equipment other than a rail-controlled unit.
[b] A rail-controlled unit is a piece of equipment owned or paid for by a rail carrier for at least the reported waybill move.

provide tractor/truck information on behalf of their company drivers or owner-operators. Fully integrated with the California Air Resources Board (CARB) Drayage Truck Registry (DTR), IANA can capture information provided by LMC during the ITR Registration Process and maintain both the IANA ITR and CARB DTR tractor/truck information for each driver record.

- Motor Carrier Database—A comprehensive listing of North American intermodal motor carriers, the database contains over 7,000 company listings.

B.11.2 The Basics

B.11.2.1 How Are the Data Generated?

The IMT&S products collect data as follows:

- Intermodal Market Trends & Statistics—A quarterly publication that offers an in-depth examination of intermodal data provided by participating trailer and intermodal marketing companies. In the case of the First Quarter 2011 Report, participating IMCs include APL Logistics; Clipper Express; Compass Consolidators; Hub Group, Inc.; Matson Integrated Logistics; Mode Transportation; Pacer Transportation Solutions, Inc.; Target Transportation; Trailer Transport Systems, Inc.; Twin Modal, Inc.; and Vitran Logistics.
- Five-Year Data File of Industry Activity—A comprehensive report that provides analysts with 60 continuous months of intermodal data used to compile each quarterly issue of IMT&S. Data can be extracted and manipulated for statistical analyses and data point determinations, enabling users to integrate the information with their own business processes. Data includes critical truck statistics: movements by equipment size, type, ownership, and traffic flows between regions (including Canada).
- Equipment Type, Size, and Ownership—Contains all the data used in the compilation of the IMT&S quarterly report regarding equipment size, type, and ownership.
- Average Load—Tractor/trailer loads originated is the estimated number of tractor/trailer loads originated in the United States plus loads that come to U.S. destinations from Mexico and Canada. It is tons divided by the average tons per trailer.
- VMT—Average length-of-haul represents ton-miles divided by tons.

B.11.2.2 What Auditing Procedures Are Used?

This report reflects data submitted by the above railroads and IMCs to IANA. IANA's membership roster of over 900 corporate members includes railroads—Class I, short-line and regional; water carriers and stack-train operators; port authorities; intermodal truckers and over-the-road highway carriers; intermodal marketing and logistics companies; and suppliers to the industry such as equipment manufacturers, intermodal leasing companies, and consulting firms. IANA's associate members include shippers (defined as the beneficial owners of the freight to be shipped), academic institutions, government entities, and non-profit associations. Some region-to-region flows are inflated because this data includes rebills across major interchange points. In the case of First Quarter 2011, participating railroads include BNSF Railway, CN, Canadian Pacific Railway, CSX International, Norfolk Southern Corporation, and Union Pacific Railroad.

B.11.2.3 How Can the Data be Accessed?

IMT&S is available on a subscription basis, in both electronically published and Excel spreadsheet versions. The report is also available for single quarterly copy purchase.

There are three types of IMT&S: Quarterly Analysis of Industry Activities; Equipment Type, Size, and Ownership; and 5-Year Data File of Industry Activity. The quarterly report contains the analysis of the U.S. economy and its potential impact on the intermodal industry, while Equipment Type, Size, and Ownership Data Subscription contains critical rail statistics including movements segmented by equipment size, equipment type, and ownership (whether private or rail-controlled). A Five-Year Data File of Industry Activities provides 60 continuous months of intermodal data, allowing intermodal information to be extracted and manipulated for analyses and data point determinations.

The IMT&S Report contains the data of intermodal and highway truckload movements and revenues. Comparisons of prior quarter and prior year activities are measured, as well as current year-to-date activity. IMT&S includes average load data through movements by trailer size (20', 28', 40', 45', 48' and 53'+), key corridor activity (monthly and quarterly loads by private and rail-controlled trailers), and traffic flows between regions (e.g., Midwest-Southwest, Northeast-Midwest, and South Central-Southwest), including Canada and Mexico (e.g., East-West Canada). IMT&S also includes VMT data through actual length-of-haul (<125 miles, 125-299 miles, 300-549 miles, and 550+ miles). In addition, trucking industry data includes capacity, organizations, current indicators, forecasting, and heavy-duty truck utilization.

B.11.2.4 How Are the Data Archived?

Total intermodal volume is available from 1961 to 2011 and annual intermodal volume figures by rail intermodal and IMC activity are available from 2007 to 2011.

Table B-12. International Registration Plan (IRP) data.

International Registration Plan (IRP) Data	
Definition of Truck	Trucks and truck-tractors, and combinations of vehicles having a gross vehicle weight in excess of 26,000 pounds or 11,793.401 kilograms
Data Items of Interest	VMT
Geographical Level	State
Source Data	N/A
Data Gathering Method	Registration
Agency in Charge	International Registration Plan, Inc.
Years Covered	1973-2012

B.12 International Registration Plan (IRP) Data

B.12.1 Overview

The International Registration Plan (IRP) is a registration reciprocity agreement among U.S. states, the District of Columbia, and provinces of Canada providing for payment of license fees on the basis of fleet distance operated in various jurisdictions. For a truck to be operating anywhere in the United States it needs to be registered with at least one state's Department of Motor Vehicles. If a truck operates in more than one state (or Canada) it can be registered to IRP, and the number of miles (i.e., VMT) it plans to travel in each state must be reported. Trucks hauling goods over legal size or weight limits are required to have a permit from each state in which they travel. Under IRP provisions, motor carriers can operate on an inter-jurisdictional basis in any IRP member jurisdiction displayed on the cab card, provided they have obtained proper operating authority.

The International Registration Plan was initially developed in the 1960s and early 1970s by representatives of the American Association of Motor Vehicle Administrators, with important input from representatives of the interstate motor carrier and truck rental and leasing industries. The plan was conceived as a means of replacing the then-prevailing system of registration reciprocity that was rapidly becoming inadequate for meeting the needs of expanding interstate and international commerce.

With the related International Fuel Tax Agreement, IRP is unique in that it is an inter-jurisdictional agreement administered and managed by the states and provinces that are its members without any significant federal involvement. In an effort to provide increased efficiency to the plan and to offer new services to member jurisdictions, the AAMVA Board of Directors voted to incorporate the plan in 1993. International Registration Plan, Inc. (IRP, Inc.) was established in August 1994.

B.12.2 The Basics

B.12.2.1 How Are the Data Generated?

The data are collected by state DMVs and similar agencies in all jurisdictions of North America via permitting forms.

B.12.2.2 What Auditing Procedures Are Used?

Auditing information is not available for IRP data. However, most states have departments devoted to IRP in their DMV and data are submitted after being checked by DMV employees.

B.12.2.3 How Are the Data Maintained?

The data are constantly maintained and updated monthly by the International Registration Plan, Inc.

B.12.2.4 How Can the Data be Accessed?

The data are not publicly accessible in microdata or summary format.

B.12.2.5 How Are the Data Archived?

The data are archived by each separate state and centrally by International Registration Plan, Inc. (http://www.irponline.org).

B.12.2.6 Does Metadata Exist?

Metadata are not available for IRP.

B.12.2.7 What Are Previous Uses of the Data?

The data are used for apportionment of registration funds between jurisdictions.

B.13 Motor Carrier Financial and Operating Information

B.13.1 Overview

The Motor Carrier Financial and Operating Information (MCF&OI) Program collects annual and quarterly data from motor carriers of property and motor carriers of passengers. The program collects balance sheet and income statement

Table B-13. Motor carrier financial and operating information.

Motor Carrier Financial and Operating Information	
Definition of Truck	For-hire contract and common motor carriers of property and household goods with a gross annual operating revenue of $3 million or more
Data Items of Interest	Tonnage, mileage, cost information
Geographical Level	National
Source Data	State crash surveys as uploaded through SAFETYNET
Data Gathering Method	Computer reporting system and other federal form surveys
Agency in Charge	FMCSA (prior BTS, Interstate Commerce Commission)
Years Covered	Annually, 1938-2003

data along with information on tonnage, mileage, employees, transportation equipment, and other items.

The sponsorship of this data program has shifted from Department of Transportation from the Interstate Commerce Commission (ICC) to the BTS to FMCSA. The annual reporting program was implemented on December 24, 1938 (3 FR 3158). It was a mandatory program (regulations: 49 CFR 369) and covered for-hire contract and common motor carriers of property and household goods. Before 1980, the ICC required detailed financial reports from all classes of motor carriers with annual revenues over $500,000. The reporting requirements reflected the ICC's close economic regulation of the industry. In the years following trucking deregulation, the ICC substantially reduced reporting requirements. It created classes of reporting carriers based on revenues, raised the revenue levels for the various carrier classes, and reduced the information required for each class. Carriers with a gross annual operating revenue of $3 million or more were required to file 8-page annual reports, while carriers with revenues of $10 million or more also needed to file 2-page quarterly reports. The ICC collected data on an annual and quarterly basis from freight and passenger motor carriers. The quality of the data in the latter years of ICC administration declined considerably, due to constraints on resources needed for support and enforcement.

The MCF&OI Program was transferred to BTS from the ICC in 1998 by the "ICC Termination Act of 1995." The relevant excerpt from that legislation follows:

The ICC Termination Act of 1995, which went into effect January 1, 1996, abolished the ICC and transferred some former ICC functions to the Department of Transportation (DOT). The Secretary of Transportation delegated responsibility and authority for the motor carrier financial data reporting program to DOT's BTS. Since Congress preserved the data collection provisions, albeit with some differences, the regulations remain in effect until "modified, terminated, superseded, set aside, or revoked" by BTS. That is, the program remains current and DOT will continue collecting motor carrier financial data as was done when the ICC administered the program.

The U.S.DOT's FMCSA was established on January 1, 2000, as a result of the 1999 Motor Carrier Safety Improvement Act. FMCSA is responsible for preventing commercial motor-vehicle-related fatalities and injuries. The MCF&OI Program was shifted from BTS to this agency in 2004. FMCSA terminated the collection and dissemination of these statistics in 2005.

B.13.2 The Basics

B.13.2.1 How Are the Data Generated?

The data were generated from reports (Form M) filed by carriers. The data provided information on LTL, truckload, parcel, and container categories, as well as specialty freight. Of all the data that were collected, the most valuable might have been intercity miles and total miles operated (stratified by above and below 10,000 lb for truckload); miles by highway, rail, water, and air; tons intercity estimated; total shipment carried intercity; revenue intercity; and ton-miles intercity (two methods of calculation).

B.13.2.2 How Can the Data be Accessed?

Data for the years 1999–2003 (annual) are available from the Transtats website (http://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=170&Link=0).

B.13.2.3 How Are the Data Archived?

Data for the years noted above are available from the Transtats website.

B.13.2.4 What Are Previous Uses of the Data?

The data were used by DOT, other federal agencies, motor carriers, shippers, industry analysts, labor unions, segments of the insurance industry, investment analysts, and the consultants and data vendors that support these users. Among the uses of the data are (1) developing the U.S. national accounts and preparing the quarterly estimates of the GDP; (2) measuring the performance of the for-hire motor carrier industry and segments within it; (3) monitoring carrier safety; (4) benchmarking carrier performance; and (5) analyzing motor carrier safety, productivity, and its role in the economy.

B.14 Motor Carrier Management Information System (MCMIS)

B.14.1 Overview

FMCSA maintains information on the safety and fitness of commercial motor carriers and hazardous material shippers through MCMIS. MCMIS contains state-reported crash, inspection, and compliance records for several hundred thousand active motor carriers, shippers, and other registrants (data elements). Crashes counted in the MCMIS collection include those that are reported by states to the FMCSA computer reporting system called SAFETYNET. Additionally, the MCMIS crash reports are only for those data elements recommended by the National Governors' Association (NGA) and that meet the NGA recommended crash threshold.

A state reportable crash, as defined in the MCMIS data must involve a truck or a bus. As defined by the data parameters, a truck is broadly considered a vehicle that was designed and is used or maintained for carrying property, with a gross vehicle weight rating or gross combination weight rating of more than 10,000 lbs. A bus is referred to as a vehicle with seats for at least nine people, including the driver. To be properly counted within MCMIS, a crash must result in at least one fatality, one injury where the person injured is taken to a medical facility for immediate medical attention, or one vehicle having been towed from the scene as a result of disabling damage suffered in the crash. A record is considered inactive if the entity is no longer in business or is no longer subject to specific oversight regulations for hazardous waste management or other safety regulations.

As of September 2010, the Crash Profile Reports, in part, have been based on the MCMIS Census data. (see http://mcmiscatalog.fmcsa.dot.gov/default.asp).

B.14.2 The Basics

B.14.2.1 How Are the Data Generated?

The data is generated by government mandate self-reporting of any firm that falls under the regulation of the Federal Motor Carrier Safety Regulations (FMCSR) or Hazardous Materials Regulations (HMR) through form MCS-150.

B.14.2.2 What Auditing Procedures Are Used?

The data from participating companies is sent to the subcontractor (Computing Technologies, Inc.), which maintains the associated databases. Although some of the data columns in the census file are metadata columns pertaining to the editing and maintenance of the data, there is no documentation of auditing procedures.

B.14.2.3 How Are the Data Maintained?

MCMIS is an ongoing program funded by FMCSA.

B.14.2.4 How Can the Data be Accessed?

The microdata is available by mail on CD from Computing Technologies, Inc., in a tilde (~) delimited text file. The census file costs $22 dollars and other files vary in price from $12 to $70.

B.14.2.5 How Are the Data Archived?

The data is centrally archived by Computing Technologies, Inc. in Fairfax, Virginia.

Table B-14. MCMIS.

MCMIS	
Definition of Truck	A truck is a vehicle with a gross weight rating or gross combination weight rating of more than 10,000 lbs
Data Items of Interest	VMT (by vehicle type, commodity class, and geography as specific as location, city, and county code for crash data) and average load (by vehicle type, commodity class, and geography specific to city and county location of a crash)
Geographical Level	
Source Data	State crash surveys as uploaded through SAFETYNET
Data Gathering Method	Computer reporting system and other federal form surveys
Agency in Charge	FMCSA
Years Covered	1989-present

B.14.2.6 Does Metadata Exist?

The metadata is publicly available on the MCMIS website at http://mcmiscatalog.fmcsa.dot.gov/.

B.14.2.7 What Are Previous Uses of the Data?

The data is mainly used to track and assess the safe operation of trucking in the United States. Moses and Savage (1991) review the early safety trend following these standards and find that firms that were unsatisfactorily meeting the safety requirements do appear to show substantial improvement in their safety performance over time.

B.15 North American Transborder Freight Data (NATF)

B.15.1 Overview

The BTS North American Transborder Freight Database is used to analyze cross-border freight flows and changes since NAFTA began in 1994. The transborder data captures freight flow geography by commodity type and mode of transportation for U.S. exports to, and imports from, Canada and Mexico from administrative records required by the Census Bureau and Customs and Border Protection (CBP). Historically, these data were obtained from import and export paper documents that the U.S. Customs Service collected at a border, but over time the collection process has become automated. Transborder data is released to the general public through the BTS website on a monthly and annual schedule in a variety of formats.

Beginning with the January 2004 statistics, the transborder data started including freight moving by air and vessel. Previously, only freight moving by land modes were included in the dataset. Beginning in 1997, the transborder data covers only U.S. merchandise trade with Canada and Mexico. Prior to that (April 1994 to December 1996) the data included U.S. trade with Canada and Mexico and trans-shipments that moved from a third country through Canada or Mexico to the United States or from the United States to a third country through Canada or Mexico. Since 1997, trans-shipment data have been removed to provide better comparability of trends by transportation shipment mode between the United States and Canada and Mexico over time. Because the dataset was originally designed to capture trade data rather than freight transportation patterns, certain details are not available—specifically, the volume of shipments carried by land mode "truck" is known, but characteristics of the truck are not (e.g., axles, capacity, engine size). Although the data also includes a category for "mail" (i.e., U.S. Postal Service), this cannot be subdivided to the specific mode used to carry the mail.

In terms of geographical coverage, the transborder data provides statistics on

- U.S. imports and exports of merchandise by commodity type and mode of transportation specific to Canada and Mexico,
- U.S. imports from Canada by U.S. state of destination and Canadian province of origin and from Mexico by U.S. state of destination and port of entry,
- U.S. exports to Canada by U.S. state of origin and Canadian province of destination, and to Mexico by U.S. state of origin and Mexican state of destination and port of exit.

B.15.2 The Basics

B.15.2.1 How Are the Data Generated?

Statistics for imported goods shipments are compiled from the records filed with CBP, usually within 10 days after the merchandise enters the United States. Estimates are made for low-value shipments by country of origin, based on previous bilateral trade patterns and periodically updated.

Statistics for over 99 percent of all commodity transactions are compiled from records filed electronically with CBP and forwarded electronically to the U.S. Census Bureau. Statistics for other transactions are compiled from hard-copy documents filed with CBP and forwarded on a flow basis for U.S. Census Bureau processing.

Statistics for exported goods transactions are compiled from two sources: Electronic Export Information filed in the Auto-

Table B-15. North American Transborder Freight Data (NATF).

North American Transborder Freight Data (NATF)	
Definition of Truck	Road modes include "truck" with no distinction for capacity, axles, or other characteristics.
Data Items of Interest	Ton (by commodity type and geography) and value of cargo (by commodity type and geography)
Geographical Level	National, state, port
Source Data	US Census Bureau (Census) Foreign Trade Division previously unpublished import and export freight flow data by mode of travel
Data Gathering Method	Automated and otherwise recorded U.S. foreign trade statistics
Agency in Charge	BTS
Years Covered	1994-present

mated Export System by exporters and their agents (68 percent), and electronic transmissions from Canada for U.S. exports to Canada (32 percent). Estimates are made for low-value exports by country of destination, and based on bilateral trade patterns.

Statistics for U.S. exports to Canada are based on import documents filed with Canadian agencies and forwarded to the U.S. Census Bureau under a 1987 data exchange agreement. Under this agreement, each country eliminated most cross-border export documents, maintains detailed statistics on cross-border imports, exchanges monthly files of cross-border import statistics, and publishes exchanged statistics in place of previously compiled export statistics.

Freight data points for tonnage and value are captured at the ports of entry and exit, by the automated collection systems as well as U.S. import and export paper records (Transborder, 2012). For land trade, the filing requirements indicate that the mode of transportation is to be recorded as the method of transportation in use when the shipment enters or departs the United States. An example provided in the Transborder 2012 documentation makes this quite clear: If a shipment was sent from Kansas City to the Port of Laredo for export and went via rail from Kansas City to Dallas and then was shifted to truck and arrived and crossed the U.S.-Mexico border by truck, it is supposed to be reported as a truck shipment. As described in the example above, the data collection is not currently set up to capture the nature of these intermodal shipments as the primary point of collection for ton and value is the U.S. border.

B.15.2.2 What Auditing Procedures Are Used?

The transborder data is based on Census- and CBP-run automated collection programs and is therefore not subject to survey sampling errors. However, the data is still subject to several types of non-sampling errors. Because the transborder data are sourced from data collected for measuring trade activity, emphasis is placed on the reliability of those questions (value and commodity classification), and typically these are more rigorously evaluated than transportation data fields (i.e., mode of transportation and port of entry/exit). This reality also explains why data reliability may be better in one direction of trade than another—trade data is primarily used by CBP for import enforcement purposes while it performs no similar function for exports.

Additionally, the use of foreign trade data to describe physical transportation flows might not be direct—different filing procedures from one country to the next may or may not allow for a good estimate as to exactly where goods crossed the border. This is because the filer of information may choose to file trade documents at one port while shipments actually enter or exit at another port.

B.15.2.3 How Can the Data be Accessed?

BTS provides access to the data through an interactive searchable interface called North American Transborder Web. This allows users to create multivariable cross-tabulations on port, geography, and commodity for all modes of transportation. Search results can be viewed as a table online and then downloaded. Historical information is also available in the same resource.

B.15.2.4 How Are the Data Archived?

Transborder data are available from BTS for monthly periods from April 1994 through the present, although not all data elements currently available in the dataset were available beginning at that time.

B.15.2.5 Does Metadata Exist?

The monthly and annual North American Transborder Freight Data can be downloaded in raw table formats. Metadata are available to customize and manipulate these statistics for various purposes.

B.16 Private-Sector Sources of Traffic Data

B.16.1 Overview

The private sector has been providing traffic information for many years. Historically, it has been in the form of radio traffic reports. While this information was useful for

Table B-16. Private-sector sources of traffic data.

Private-Sector Sources of Traffic Data	
Definition of Truck	Commercial fleet
Data Items of Interest	Travel speed, O/D flows
Geographical Level	National (limited)
Source Data	Primary data
Data Gathering Method	All use fleet GPS, state-installed sensors
Agency in Charge	Private-sector source
Years Covered	Depends on source

travelers' route planning, incident management, and congestion mitigation, it was not useful for policy making. But the private-sector has continued to expand its capabilities to provide speed data on corridors that might be useful to policy makers beyond what is currently instrumented by public-sector-operated detection systems. This is done using a combination of fleet-probe GPS data; cell phone probes; privately owned detection infrastructure; aggregated public-sector detection data; incident data (from public and private entities); and, in some cases, historical corridor travel patterns. Arterial coverage remains a challenge, whether through traditional sensor-based deployment or through probe-based applications. However, many arterial management agencies recognize the value in CCTV/video coverage.

The following are several core data elements provided by private-sector companies:

- Date (or day of week for historical data) and time stamp,
- Roadway link identifier,
- Roadway link length, and
- Roadway link travel time or speed (average and specified percentiles for historical data).

A common practice among private-sector traffic data providers is to combine several different data sources and/or data types with proprietary algorithms to produce an estimate of current, up-to-date traffic conditions. This practice is referred to as "blending" or "fusion" and typically each company has their own data blending or data fusion algorithm. Because of this, though, most providers do not isolate truck data from automobile data.

Most providers can provide national coverage capabilities for travel speed data on main roadways, down to the major arterials' street level. This corresponds to the Functional Class (FC) 3 roadways in the TMC location referencing system. Coverage areas for flow data are more limited because infrastructure is needed on public right-of-way. All sources provide data mapped to some system that allows for the geographic identification of the roadway segment to which it applies. Data on a per-lane basis is still in its infancy.

B.16.2 The Basics

B.16.2.1 How Are the Data Generated?

Providers are using an expansive range of data sources including GPS data from fleet vehicles, commercial devices, cell phone applications, fixed sensors installed and maintained by other agencies, fixed sensors installed and maintained by the data provider, and cell phone location. Although there was some overlap, no responding provider utilized exactly the same data model as another provider.

B.16.2.2 What Auditing Data Are Used?

The reliability of these data depends on the source and the way in which the source has treated them. There is some data source blending that may be unavoidable with private-sector vehicle probe data, and that is the blending of different types of vehicle probes. For example, several data providers obtain their real-time vehicle probe data from GPS-equipped commercial fleet vehicles, which could include long-haul freight trucks, package delivery vans, taxi vehicles, construction vehicles, utility/cable/phone service vehicles, etc. When sample sizes are large, it is more likely that different vehicle types will be proportionally represented in the average speed, resulting in less bias. Again, this blending of different probe vehicle types is unavoidable because, at least in the near future, only a sample of all vehicles will be capable of being monitored.

For monitoring mobility and reliability trends over multiple years, there needs to be consistency in the private-sector dataset. There are proven technical means (such as standardized data dictionaries and exchange formats) to ensure consistency among several different data providers. Similarly, core data elements and preferred metadata can be defined to make data integration less difficult. However, the temporal (i.e., time) consistency issue for trend data remains an issue even with data standardization.

One approach to address time consistency for trend data is to ensure that every data provider meets certain accuracy and other data quality requirements. If each data provider meets those specified accuracy targets, then fluctuation between different companies' datasets will be less likely.

B.16.2.3 How Can the Data be Accessed?

There are many different providers of traffic information data and new players are entering the market space every year. In the market for some time have been INRIX, NAVTEQ, AirSage, TrafficCast, and TomTom. The data are accessed at a cost.

B.17 Services Annual Survey (SAS)

B.17.1 Overview

The U.S. Census Bureau conducts the Service Annual Survey (SAS) to provide national estimates of annual revenues and expenses of establishments classified in select service sectors. It includes the Trucking and Warehousing Survey described in the main body of this report. The SAS provides the only source of annual receipts estimates for the service industries. Among many service industries, this report focuses on truck transportation (NAICS 484), which contains VMT data.

The SAS is based on estimates using data from a probability sample and administrative data. The sample includes firms of all sizes and covers both taxable firms and firms exempt from

Table B-17. Services Annual Survey (SAS).

Services Annual Survey (SAS)	
Definition of Truck	Truck transportation in terms of industry (NAICS 484)
Data Items of Interest	VMT
Geographical Level	National
Source Data	N/A
Data Gathering Method	Mail-out/mail-back survey
Agency in Charge	U.S. Census Bureau
Years Covered	1998-2009

federal income taxes. Firms without paid employees (non-employers) are included in the estimates through administrative data provided by other federal agencies and through imputation.

Of the private non-goods-producing industries, services industries account for 55 percent of economic activity in the United States. Most of these industries are surveyed in SAS. The instrument to collect data for SAS is the Annual Services Report. SAS provides estimates of revenue and other measures for most traditional service industries. The United States Code, Title 13, authorizes this survey and provides for mandatory responses.

The 2010 Services Annual Survey report for NAICS 48-49, the transportation and warehousing sectors, was published on February 3, 2010. The data elements in the annual report include the following:

- Estimated annual revenue for employer firms;
- Truck transportation (NAICS 484) estimated sources of revenue for employer firms (local trucking/long distance trucking/other);
- Truck transportation (NAICS 484) estimated revenue by size of shipments (less-than-truckload/truckload), commodities handled (11 categories), origin and destination (United States, Canada, Mexico, and other);
- Truck transportation (NAICS 484) estimated inventories of revenue generating equipment by type (trucks, truck-tractors, trailers);
- Truck transportation (NAICS 484) estimated number of truck miles traveled by trucks operated by employer firms (loaded/empty); and
- Transportation and warehousing (NAICS 48, 49) estimated total expenses for employer firms.

This survey had its genesis in the Transportation Annual Survey (TAS), formerly known as the Motor Freight Transportation and Warehousing Survey, which was conducted between 1985 and 1998. TAS provided national estimates of revenue, expenses, and vehicle fleet inventories for commercial motor freight transportation and public warehousing service industries. It represented all employer firms with one or more establishments that were engaged in commercial motor freight transportation and public warehousing services. Statistics were summarized by kind-of-business classification and provided detailed estimates of operating revenues and expenses for the for-hire trucking and public warehousing industries, as well as inventories of revenue generating freight equipment for the trucking industry at the U.S. level.

B.17.2 The Basics

B.17.2.1 How Are the Data Generated?

Data are generated by a mail-out/mail-back and electronic reporting survey of approximately 72,000 selected service businesses with paid employees, and supplemented by administrative records data or imputed values to account for non-employer and certain other businesses. To be eligible for the list sample, service businesses must be in the Standard Statistical Establishment List, which contains all Employer Identification Numbers (EINs) for listed businesses and all locations of multi-establishment companies. EINs may represent one or more establishments and firms may have one or more EINs.

In the initial sampling, companies are stratified by major and minor kind of business, and by estimated receipts or revenue. All companies with total receipts above applicable size cutoffs are included in the survey and report for all their service industry locations. In a second stage, EINs of unselected companies are stratified by major kind of business and receipts or revenue. Within each stratum, a simple random sample of EINs is selected.

The initial sample is updated quarterly to reflect births and deaths—adding new employer businesses identified in the business and professional classification survey and dropping firms and EINs that are no longer active. During interim periods, service non-employer and other businesses are represented by administrative records data or imputed values (Census Bureau Service Annual Survey Methodology).

There is no indication of the number of establishments surveyed for each particular service sector.

The Quarterly Services Surveys (QSS) are published in a much more timely fashion than the Services Annual Survey, which is currently published 14 months after the close of a survey year.

The first quarter 2012 report was released on June 7, 2012 at 10:00 A.M. The second quarter 2012 report will be released on September 6, 2012 at 10:00 A.M. The third quarter 2012 report will be released on December 6, 2012, at 10:00 A.M.

These reports only have the single variable of estimated quarterly revenue by employer firms by NAICS code. The sample size for the QSS has only 17,000 establishments and imputation rates and coefficient of variation and standard error are reported for each industry revenue estimated included in the report.

B.17.2.2 What Auditing Procedures Are Used?

A number of automated and manual review procedures are used to sort through the survey sample and the sample responses as described by the Census Bureau:

> "We update the sample to represent EINs issued since the initial sample selection. These new EINs, called births, are EINs recently assigned by the IRS, that have an active payroll filing requirement on the IRS Business Master File. An active payroll filing requirement indicates that the EIN is required to file payroll for the next quarterly period. The Social Security Administration attempts to assign industry classification to each new EIN. EINs with an active payroll filing requirement on the IRS Business Master File are said by the Bureau to be "BMF active" and EINs with an inactive payroll filing requirement are said to be "BMF inactive."

B.17.2.3 How Are the Data Maintained?

The data are maintained as an ongoing project by the U.S. Census Bureau's economic census division.

B.17.2.4 How Can the Data be Accessed?

The data can be accessed only in summary format. From 2010 forward, the data is available in the Excel format; for older datasets, the data is only available in PDF format.

B.17.2.5 How Are the Data Archived?

The data is archived centrally by the Census Bureau and is available at the website for Annual and Quarterly Service at http://www.census.gov/services/index.html.

B.17.2.6 Does Metadata Exist?

The documentation and metadata are well documented and available including all of the survey forms, which are designed specifically to the NAICS of the establishment being surveyed and are available on the Census website.

B.17.2.7 What Are Previous Uses of the Data?

The Services Surveys are used to gauge the health of the sectors of the economy that they cover. The Bureau of Economic Analysis uses these data in its preparation of national income and product accounts, and its benchmark and annual input-output tables. The Bureau of Labor Statistics uses the data as input to its producer price indexes and in developing productivity measurements. The Centers for Medicare and Medicaid Services (CMS) uses the data to estimate expenditures for the National Health Accounts. The Coalition of Service Industries uses data for general research and planning. Trade and professional organizations use the estimates to analyze industry trends and benchmark their own statistical programs, develop forecasts, and evaluate regulatory requirements. The media use estimates for news reports and background information. Private businesses use the estimates to measure market share, analyze business potential, and plan investment decisions.

B.18 Transearch

B.18.1 Overview

The Transearch database is a most widely used commercial source of freight-movement data in the United States. It contains U.S. county-level freight movement data by commodity group and mode of transportation. Transearch was originally developed by Reebie Associates. It became a product of IHS

Table B-18. Transearch.

Transearch	
Definition of Truck	Truck as compared to air, rail carload, rail intermodal
Data Items of Interest	O/D flows by commodity, tons by commodity, value of cargo by commodity
Geographical Level	National, state, some local
Source Data	Various commercial, public, and proprietary freight data
Data Gathering Method	N/A
Agency in Charge	IHS Global Insight
Years Covered	1982-present

Global Insight after the firm acquired Reebie in 2005. The historical database combines primary shipment data obtained from 22 of the nation's largest freight carriers with information from public sources, and is accompanied with 30-year forecasts consistent with IHS Global Insight's macro forecasts. Transearch is compiled and produced annually.

B.18.2 The Basics

B.18.2.1 How Are the Data Generated?

Transearch is created each year using the following:

- The Annual Survey of Manufacturers (ASM) to establish production levels by state and industry;
- The Surface Transportation Board (STB) Rail Waybill Sample to develop all market-to-market rail activity by industry;
- The Army Corps of Engineers Waterborne Commerce data to develop all market-to-market water activity by industry;
- The Federal Aviation Administration (FAA) Enplanement Statistics; and
- Airport-to-airport cargo volumes.

In conjunction with information on commodity volumes moving by air from the BTS Commodity Flow Survey, to create detailed air flows, the rail, water, and air freight flow data are deducted from the Bureau of Census ASM-based production data to establish preliminary levels of truck activity. The proprietary Motor Carrier Data Exchange Program provides information on actual market-to-market trucking industry movement activity. The Data Exchange Program includes carriers from both the private and for-hire segments of the industry and both the truckload (TL) and less-than-truckload (LTL sectors). The truckload sample covers about 6 percent of the market; Transearch's LTL sample is about 40 percent. In total, information is received on over 75 million individual truck shipments. By way of comparison, the government's CFS covers about 12 million shipments, spread across all modes. The Rail Waybill's sample rate is about 2.5 percent of all rail freight moves.

Transearch's county-to-county market detail is developed through the use of Global Insight's Motor Carrier Data Exchange inputs and Freight Locator database of shipping establishments. The Freight Locator database provides information about the specific location of manufacturing facilities, along with measures of facility size (both in terms of employment and annual sales), and a description of the goods produced. This information is aggregated to the county level and used in allocating production among counties.

Much of the data exchange inputs from the trucking industry are provided by zip code. The zip code information is translated to counties and used to further refine production patterns. A compilation of county-to-county flows and a summary of terminating freight activity are used to develop destination assignments (FHWA, 2009).

B.18.2.2 What Auditing Procedures Are Used?

The auditing procedures for Transearch Data are not publicly available. Although Transearch data is based on shipping reports from freight companies and claims to collect information from more than 70,000 organizations, the microdata has never been released. Due to the lack of transparency of this data, it is especially difficult for users to tell how reliable the data they are using is. This problem is compounded by the lack of other datasets that can verify the projections of Transearch data.

B.18.2.3 How Are the Data Maintained?

The data are commercially maintained by IHS Global Insight.

B.18.2.4 How Can the Data be Accessed?

The data can be purchased at varying levels of detail from IHS Global Insight.

B.18.2.5 How Are the Data Archived?

The data is archived centrally by IHS Global Insight.

B.18.2.6 Does Metadata Exist?

The metadata for any data purchases is provided with the data.

B.18.2.7 What Are Previous Uses of the Data?

Transearch data is widely used by planning organizations across the United States when fine-grained commodity flow and truck volume projections are required. The Freight Analysis Framework uses Transearch data in its future projections of freight flows.

B.19 Transportation of U.S. Grains: A Modal Share Analysis

B.19.1 Overview

The purpose of Transportation of U.S. Grains: A Modal Share Analysis is to examine trends in the type of transportation used to move grains grown for the food and feed industry. Grains produced in the United States move to domestic and foreign markets through a well-developed transportation system. One mode, truck transportation, with barge and

Table B-19. Transportation of U.S. Grains: A Modal Share Analysis.

Transportation of U.S. Grains: A Modal Share Analysis	
Definition of Truck	Trucks of aggregate term as compared to other modes such as rail and barge
Data Items of Interest	Tons
Geographical level	National
Source Data	N/A
Data Gathering Method	Estimate
Agency in Charge	U.S. Department of Agriculture (USDA)
Years Covered	1978-2010

rail, facilitates a highly competitive market that bridges the gap between U.S. grain producers and domestic and foreign consumers. In this report, tons of grains transported by truck is computed and highlighted.

Barges, railroads, and trucks often compete head-to-head to supply transportation for grains. Despite a high degree of competition in some markets, these modes also complement each other. Before a bushel of grain reaches its final destination, it often has been transported by two or more modes. This balance between competition and integration provides grain shippers with a highly efficient, low-cost system of transportation. The competitiveness of U.S. grains in the world market and the financial well being of U.S. grain producers depends upon this competitive balance. A highly competitive and efficient transportation system results in lower shipping costs, smaller marketing margins for middlemen, and more competitive export prices. Such efficiencies also result in lower food costs for U.S. consumers and higher market prices for U.S. producers.

This analysis of the transportation of the final movement of grain, by mode, provides information about changes in market share among the modes—truck, barge, and rail. Over several years, such work helps identify critical trends affecting the transportation of grain. It also provides a framework to assess public policies that influence the development and success of the nation's transportation infrastructure. Public policies that promote an efficient grain transportation system also promote strong U.S. agricultural and rural economies.

In this analysis, the term "modal share" describes that portion of the total tonnages of grain moved by each mode of transport. These shares, expressed as percentages, were determined by mode for particular types of grains and movements. Grains identified for this analysis were corn, wheat, soybeans, sorghum, and barley. The 1992 and 1998 versions of this study also included rye and oats. Rye and oats were taken out of the calculations for this report because of unreliability due to small volumes, which total less than 1 percent of all grain movements. Transport modes are categorized according to the final movement going to domestic markets or ports for export.

This analysis of grain movements by transport mode updates three previous reports. The initial report was completed in 1992, the second was released in 1998, and the third in 2004. The purpose of this series of reports is to provide information about changes in the competitiveness and relative efficiencies among the modes. The goal of this analysis was to estimate the tonnages of grain railed, barged, and trucked, using secondary data sources. The report analyzes the movements of corn, wheat, soybeans, sorghum, and barley to either the domestic market or to U.S. ports for export.

B.19.2 The Basics

B.19.2.1 How Are the Data Generated?

Accurate data exist for barge and rail freight tonnages and commodities, but not for trucks. Other analyses of grain movements have relied extensively on survey data to overcome this obstacle. This analysis uses the Waterborne Commerce Statistics of the U.S. Army Corps of Engineers to calculate tonnages of barged grain and uses the Carload Waybill Sample from the Surface Transportation Board to estimate the amount of railed grain. Trucking data are derived from known grain production data, as compared to the estimates of the railed and barged volumes of grain. Estimating these modal grain volumes and modal shares on an annual basis provides a data series that tracks changes in grain transportation over time.

The estimates of modal tonnages and shares are based on the amount of grain moved to commercial markets. Tons (truck tonnages) are estimated by subtracting barge and rail tonnages from total tonnages transported. For each crop, total movements are determined first, and then exports are subtracted from the total to get domestic movements. Total rail and barge volumes are subtracted from total movements to get truck movements.

B.19.2.2 How Can the Data be Accessed?

PDF files of documents are downloadable and an Excel data file is also available at http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateA&navID=A

gricultural Transportation&leftNav=AgriculturalTransportation&page=ATModalShareReport&description=Transportation%20of%20U.S.%20Grains:%20%20A%20Modal%20Share%20Analysis.

In parallel with the Transportation of U.S. Grains, USDA shares the Agricultural Refrigerated Truck Quarterly Report (AgRTQ). The AgRTQ provides a view of U.S. regional refrigerated truckload movements, in terms of volume and rates, to gauge the vital component of truck transportation applied to fresh fruit and vegetable markets. The AgRTQ also features a rotating regional focus and a review of relevant issues that impact fresh fruit and vegetable truck transportation. The AgRTQ covers 2003 to 2012 in terms of tons, one item of interest.

B.20 Truck Overweight Permitting Data

B.20.1 Overview

There are federally mandated maximum weights for the National System of Interstate and Defense Highways based on commercial vehicles' gross vehicle weight, single-axle weight, and tandem axle weight. Axle spacing is another consideration that must be taken into account when looking at federal weight compliance. To protect bridges, the number and spacing of axles carrying the vehicle load must be calculated. Thus, a bridge weight formula also is applied to commercial vehicles in determining their compliance with federal weight limits. The federal government does not issue permits for oversize or overweight vehicles. This is a state option. Although states might not report overweight truck permitting nationally, they do report safety compliance, which includes unpermitted weights.

B.20.2 The Basics

B.20.2.1 How Are the Data Generated?

The data are generated by firms seeking permits and provided on forms filled out on paper or electronically and submitted to state DOTs.

B.20.2.2 What Auditing Procedures Are Used?

The data are manually audited by a permitting representative at the DOT before the permit can be approved.

B.20.2.3 How Are the Data Maintained?

Permitting is a self-sustaining ongoing program run by each individual state DOT.

B.20.2.4 How Can the Data be Accessed?

The data are not publicly available in microdata or as summaries.

B.20.2.5 How Are the Data Archived?

The data are archived by each separate state DOT.

B.20.2.6 Does Metadata Exist?

Permitting metadata do not exist.

B.20.2.7 What Are Previous Uses of the Data?

Permitting data is used to ensure the smooth running of oversized and overweight trucks through individual states and jurisdictions and to offset the cost to the state that these vehicles have upon the infrastructure.

B.21 Vehicle Inventory and Use Survey (VIUS) – Discontinued

B.21.1 Overview

The Vehicle Inventory and Use Survey (VIUS), formerly Truck Inventory and Use Survey (TIUS), provided data on the physical and operational characteristics of the nation's truck population, such as VMT. This survey was conducted every 5 years as part of the economic census. Its primary goal is to

Table B-20. Truck overweight permitting data.

Truck Overweight Permitting Data	
Definition of Truck	Commercial vehicles >80,0000 requiring a permit to operate
Data Items of Interest	VMT and origins and destinations
Geographical Level	State
Source Data	Administrative offices requiring permits to use state roads/third parties
Data Gathering Method	Paper electronic forms
Agency in Charge	State office
Years Covered	N/A

Table B-21. Vehicle Inventory and Use Survey (VIUS) – Discontinued ata.

Vehicle Inventory and Use Survey (VIUS) – Discontinued	
Definition of Truck	Light/heavy single-unit trucks and truck-tractors[a]
Data Items of Interest	VMT
Geographical Level	National, state
Source Data	N/A
Data Gathering Method	Survey (stratified sampling and Forms TC 9501/9502)
Agency in Charge	U.S. Census Bureau
Years Covered	1963, 1967, 1972, 1977, 1982, 1987, 1992, 1997, and 2002

[a] Body type and GVW determined the following truck strata (1) pickups; (2) minivans, other light vans, and sport utility vehicles; (3) light single-unit trucks (GVW < 26,000 lb); (4) heavy single-unit trucks (GVW ≥ 26,000 lb); and (5) truck-tractors.

produce national- and state-level estimates of the total number of trucks. VIUS captured private and commercial U.S. truck population licensed (registered) as of July 1 of each survey year. The survey did not consider buses, ambulances, automobiles, motorcycles, and vehicles owned by federal, state, or local governments. It was based on a probability sample of private and commercial trucks registered (or licensed) in each state. A sample of about 136,113 trucks was surveyed to measure the characteristics of nearly 89 million trucks registered in the United States. In 1997, the survey was changed to the Vehicle Inventory and Use Survey due to future possibilities of including additional vehicle types. The 2002 VIUS, however, only included trucks.

The survey contained the following freight demand characteristics:

- VMT by commodity—Annual mileage reported as percentage values: 26 standard commodity categories, including non-freight shipments (personal and empty haul) and 17 categories of hazardous materials;
- VMT by body type—Single-unit or tractor-trailer;
- VMT by the range of operation—Percentage of annual miles: local (50 miles or less), short-range (51–100 miles), short-range medium (101–200 miles), long-range medium (201–500 miles), and long-range (>500 miles);
- Other physical characteristics—Date of purchase, GVW, length, number of axles, and engine type; and
- Other operational characteristics—Major use (type of business); weeks operated; operator classification; and accident incidence.

B.21.2 The Basics

B.21.2.1 How Are the Data Generated?

The Vehicle Inventory and Use Survey (VIUS) was a probability sample of all private and commercial trucks registered (or licensed) in the United States. The sample size for each year is listed in Table B-22.

VIUS excluded vehicles owned by federal, state, or local governments; ambulances; buses; motor homes; farm tractors; and non-powered trailer units. Additionally, trucks that were included in the sample but reported to have been sold, junked, or wrecked prior to the survey year (date varies) were deemed out of scope.

The sampling frame was stratified by geography and truck characteristics. The 50 states and the District of Columbia made up the 51 geographic strata. Body type and gross vehicle weight (GVW) determined the following five truck strata:

1. Pickups;
2. Minivans, other light vans, and sport utility vehicles;
3. Light single-unit trucks (GVW 26,000 lb or less);
4. Heavy single-unit trucks (GVW 26,001 lb or more); and
5. Truck-tractors.

Therefore, the sampling frame was partitioned into 255 geographic-by-truck strata. Within each stratum, a simple random sample of truck registrations was selected without replacement. Older surveys were stratified differently. For the 1963 to 1977 TIUS, the survey was stratified by "small trucks" and "large trucks" (Census Bureau, 2006).

Table B-22. VIUS sample size.

Year	Sample Size
2002	136,113
1997	131,083
1992	153,914
1987	135,290
1982	120,000
1977	116,400
1972	113,800
1967	~120,000
1963	~115,000

B.21.2.2 What Auditing Procedures Are Used?

The detailed methodology for the construction of the survey and the sample are available here at http://www.census.gov/svsd/www/vius/methods.html. The document covers the survey instrument, data collection, estimation of data, sampling variability, and non-sampling error.

B.21.2.3 How Are the Data Maintained?

The data was collected every 5 years as a part of the economic census from 1963 until 2002 when the program was discontinued.

B.21.2.4 How Can the Data be Accessed?

The data for all years of the program can be accessed online at the Census Bureau's website at http://www.census.gov/svsd/www/vius/products.html.

B.21.2.5 How Are the Data Archived?

The data is archived online in .txt and SAS formats at http://www.census.gov/svsd/www/vius/2002.html

B.21.2.6 Does Metadata Exist?

The metadata exists online as a spreadsheet of variables (see http://www.census.gov/svsd/www/vius/Variables.xls) and a full 54-page data dictionary (http://www.census.gov/svsd/www/vius/datadictionary2002.pdf).

B.21.2.7 What Are Previous Uses of the Data?

VIUS data are of considerable value to government, business, academia, and the general public. Data on the number and types of vehicles and how they are used are important in studying the future growth of transportation and are needed in calculating fees and cost allocations among highway users. One of the main benefits was to differentiate working vehicles from personal vehicles that were called trucks. The data also are important in evaluating safety risks to highway travelers and in assessing the energy efficiency and environmental impact of the nation's truck fleet. Businesses and others make use of these data in conducting market studies and evaluating market strategies; assessing the utility and cost of certain types of equipment; calculating the longevity of products; determining fuel demands; and linking to, and better utilizing, other datasets representing limited segments of the truck population.

B.22 WIM Data and Vehicle Travel Information System (VTRIS)

B.22.1 Overview

Every state DOT has a WIM program responsible for the upkeep of WIM stations and archiving and analyzing the collected data. All states are required to submit their WIM data annually to the FHWA Office of Highway Information Management, which uses it as a measure in determining truck VMT as well as for use in creating the Vehicle Travel Information System (VTRIS) reports. For years, FHWA had requested traffic data characteristics such as number of trucks by axle load and, over time, VTRIS has been developed to display and maintain that data (Southgate, 2004). Vehicle type classifications on VTRIS are made algorithmically based on axle weight, spacing, and other freight variables, as well as by sensor. The data also includes environmental information about the site—such as number of lanes, year the station was established, and type of sensors and data-retrieval devices available at the site.

B.22.2 The Basics

B.22.2.1 How Are the Data Generated?

Weigh-in-motion (WIM) sites come in a number of varieties, some of which are portable, but the vast majority of sites are permanent installation sites maintained by state DOTs.

Table B-23. WIM data and Vehicle Travel Information System (VTRIS).

WIM Data and Vehicle Travel Information System (VTRIS)	
Definition of Truck	Vehicle classification (13 categories)
Data Items of Interest	Volume, ton (by vehicle type and geographic location of the weigh-in-motion and automated vehicle classifier systems sites operating in 17 states)
Geographical Coverage	State
Source Data	WIM and AVC type stations as specific sites
Data Gathering Method	Count, weight, and speed (in limited cases)
Agency in Charge	State DOTs, FHWA
Years Covered	1990-present

In recent years, virtual WIM sites have begun to be installed. Virtual WIM couples the WIM sensor and hardware with a camera to capture license plate numbers and visual images of the trucks passing the stations.

According to RITA's national transportation data atlas database 2011 (http://www.bts.gov/publications/national_transportation_atlas_database/2011/), there are 5,553 WIM sites in the United States. However, this count may not be accurate. It may be including all WIM-capable sites or it may include temporary, movable WIM site locations. In either case, it appears to greatly exaggerate the number of sites actively capturing WIM data. There are 1,917 sites in the dataset that have a recorded average weight, which may be a more accurate number. However, in an interview for this project, Steven Jessberger of the Office of Highway Policy Information quoted the number of continuously active WIM sites as close to 800.

B.22.2.2 What Auditing Procedures Are Used?

At the federal level, the VTRIS software does a set of automated procedures to submitted data to check for data quality. Currently, a national set of data reviews for WIM data quality is not published. Also, there is little that can be done at the federal level to increase the quality of the data once it has been submitted.

At the state level, there is established standard for data quality practices as related to WIM and the state of the practice varies widely from state to state. FHWA at the time of this writing is working the National Institute of Standards and Technology (NIST) to develop a data quality standard for WIM data, which would be a huge step forward in the usability of WIM data.

B.22.2.3 How Are the Data Maintained?

WIM programs are often part of a state DOT's larger ITS programs and are maintained as ongoing projects. It is possible for WIM data to be available in live streams, as it often is with new virtual WIM stations and most current installations of WIM sites.

B.22.2.4 How Can the Data be Accessed?

At the federal level, WIM microdata either in its TMG or VTRIS format, is only available by request of FHWA and is not thoroughly documented or maintained. Reports from VTRIS often are included in federal reports, although there is no centralized location to obtain VTRIS data. At the state level, many states publish monthly or annual reports of WIM flows from their WIM programs. WIM microdata is sometimes available upon request.

B.22.2.5 How Are the Data Archived?

There is no current system for archiving WIM data at the federal level. WIM data is often organized simply by the native file system where the data is stored. VTRIS does have a suggested naming scheme for folders containing WIM data but the software does not strictly enforce these patterns.

At the state level, archiving practices vary widely. There are a number of commercial offerings available that create centralized systems for WIM management such as TRADAS or Transmetric. Some states use these tools to create a centralized repository of all ITS data.

B.22.2.6 Does Metadata Exist?

The greatest advantage that WIM enjoys as a dataset, besides its rich content, is the widespread adoption of the simple and powerful Traffic Monitoring Guide standard for WIM records. This metadata is readily available and makes working with WIM data generated by shops with very different practices, easy to accomplish.

B.22.2.7 What Are Previous Uses of the Data?

The greatest focus of WIM data in its nearly 30-year history has been to help understand pavement design. The Long-Term Pavement Planning (LTPP) Projects have made extensive use of high-quality WIM to understand the impact of heavy trucks on different pavement designs as well as bridge pavement designs (LTPP, 2012). Due to the large nature of the dataset and the difficulty of processing the data for analysis, WIM has seen only minor usage for planning purposes although almost all state DOTs do some amount of annual reporting for WIM stations to understand overweight truck flows. With the introduction of virtual WIM technology, many states have been looking into the possibility of using WIM technology to do direct enforcement of overweight vehicle codes, but as of this writing, there are no states actively engaged in this practice.

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation