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A COMPARATIVE STUDY OF SIX DATA SOURCES' ABILITY FOR ESTIMATING INTERSTATE MOTOR CARRIER VMT

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ABSTRACT

Several Federal Government agencies require estimates of vehicle miles of travel (VMT) by interstate commercial trucks. These estimates are essential in determining accident exposure and accident rates for these trucks, and in determining highway investment needs and the allocation of highway costs. VMT estimates are currently based on various nationwide transportation surveys and/or data sources using various estimation procedures. Unfortunately, these data sources and estimation procedures do not provide consistent estimates. A summary of evaluation results of these data sources and estimation procedures are presented in this paper. A more detailed report is given in [1].

I. INTRODUCTION

The **numbers of commercial vehicles operating in interstate commerce** and their **vehicle miles of travel (VMT)** are essential information to planners and researchers in the transportation community. These data are used, for example, to

- determine accident exposure and accident rates for vehicles that are subject to government safety operations,
- determine highway investment needs and cost responsibilities related to vehicles, and
- estimate the economic and operational impacts of federal policies and regulations that affect interstate commercial vehicles.

VMT and the numbers of vehicles operating in interstate commerce can currently be estimated from the Bureau of the Census' Truck Inventory and Use Survey (TIUS), Federal Highway Administration's (FHWA) Highway Performance Monitoring System (HPMS), vehicle registrations reported by individual states, and, when it becomes available, the Nationwide Truck Activity and Commodity Survey (NTACS). In addition, there are other potential data sources in meeting the estimation needs, such as the Nationwide Truck Trip Survey (NTTIS) of the University of Michigan Transportation Research Institute (UMTRI), and the International Registration Plan (IRP) of the American Association of Motor Vehicle Administrators (AAMVA).

Each data source has its own scope in terms of the data collection method, target population, data items collected, level of data aggregation, and data validation and estimation procedures. (See Table 1.)

Consequently, different data collection objectives result in incompatible and inconsistent estimates of VMT and of the number of trucks operating in interstate commerce. The levels of inconsistency and incompatibility are amplified significantly when disaggregate estimates are required by different carrier type (i.e., common, contract, and private) and by state. Controversy exists over the best method of combining these data into estimates. This paper focuses on addressing this controversy.

Table 1. Data Availability, Data Collection Frequency and Method, and Data Coverage of Each of the Six Data Sources

Source	Initial year	Collection frequency	No. of states covered (contiguous 48 & D.C.)	Interstate Motor carrier indicator	Carrier type indicator	Truck type included	Collection method	Variable collected	Time lag between data collection & assimilation
TIUS	1967	5 yr	All	Yes	Yes	All	Sampling	Truck mile	2 yr
NTACS	1989	5 yr	All	Yes (3-4 states each truck)	Yes	All	Sampling	Truck mile	[a]
NTTIS	1984	[b]	All except Oklahoma	Yes	Yes	Straight & tractor > 10K GVWR	Sampling	Truck mile	4 yr
HPMS	1978	Continual	All	No	No	All	Sampling	Traffic count	10 months
FUEL TAX	Vary by state[c]	Continual	All	Some states	Some states	Vary by state[c]	Accounting	Gallonage, truck mile or revenue	Vary by state
IRP	1973	Continual	39 (partially)	Yes	Yes	>26K GVWR	Accounting	Truck mile	6 months

[a]Since the NTACS has not been implemented yet, the time lag between data collection and assimilation is unknown.
[b]One time data collection effort.
[c]Some states require written requests, some require funding to support software development in retrieving data, and some provide data upon request.

II. PARAMETERS OF INTEREST

In order to evaluate various data sources in terms of their ability to estimate the number of trucks that operate in interstate commerce and their VMT's, it is important to define the parameters first. Depending on the level of data aggregation, two sets of parameters are defined - one at the state level, and the other at the national level.

First, let the target population be defined as

U = {U_i | U_i is a truck with Gross Vehicle Weight Rating (GVWR[1]) > 10,000 pounds operating in interstate commerce during a given year in at least one of the 48 contiguous states or the District of Columbia}

= $\{U_1, U_2, ..., U_N\}$.

Within U, each truck will fall into only one of the following four strata for a particular year. Strata 1, 2, 3, or 4 contain those trucks that operated most of the time during the particular year as private, common, contract, or exempt carriers, respectively. With N_i trucks in stratum i, there are in total N (i.e., $N_1+N_2+N_3+N_4$) trucks with GVWR greater than 10,000 lbs operating in interstate commerce.

Let U_{ij} be the j^{th} truck in stratum i where i = 1, 2, 3, 4 and j = 1, 2, 3, ..., N_i. With each U_{ij}, there are two vectors, $\vec{VMT}_{ij}$ and $\vec{T}_{ij}$, where

$\vec{VMT}_{ij}$ = $<VMT_{ij1}, VMT_{ij2}, ..., VMT_{ijk}, ..., VMT_{ij,49}>$,

VMT_{ijk} = the number of miles travelled in state k for truck j of stratum i during the particular year,

$VMT_{ij.}$ = total VMT for truck j of stratum i during the particular year,

$\vec{T}_{ij}$ = $<T_{ij1}, T_{ij2}, ..., T_{ijk}, ..., T_{ij,49}>$,

T_{ijk} = $\begin{cases} 1 \text{ if } VMT_{ijk} > 0, \\ 0 \text{ if } VMT_{ijk} = 0, \end{cases}$ and

$T_{i.k}$ = total number of "different trucks" in stratum i that travelled in state k during the particular year,

for k = 1, 2, ..., 49. It should be emphasized that if a given truck travelled in two different states in the particular years, it will be counted twice at the national level. Therefore, $T_{...}$ does not equal the total number of heavy trucks operating in interstate commerce.

II.1 Parameters at the state level

Two parameters of interest **at the state level** are:

$VMT_{i.k}$ = the total number of miles travelled in state k by all trucks in stratum i during the particular year, and

$T_{i.k}$.

II.2 Parameters at the national level

Two relevant parameters **at the national level** are:

(1) $N_{i..}$ = the number of trucks operating in interstate commerce by carrier type i, and

(2) $VMT_{i..}$ = total VMT of these trucks by carrier type i.

Note that $T_{i..}$ is not equal to $N_{i..}$.

III. DATA SOURCES

The six major data sources evaluated in terms of their ability to estimate the parameters at the state and national level in this study are given in Table 1.

The first three data sources are "nationwide" sample surveys which are likely to be conducted periodically - TIUS and NTACS every five years and NTTIS every two years provided there is sufficient funding. The remaining three data sources are collected under reporting systems which provide uninterrupted annual data. These data sources are evaluated in terms of data accuracy, data item availability, and estimation precision. They are also assessed based on the following set of questions:

(1) the number and kinds of vehicles included;
(2) accessibility of the data to a user;
(3) frequency of the data collection;
(4) time lag between the data collection and availability to the public;
(5) the vehicle configurations and vehicle definitions.

It should be emphasized that the evaluations are not made on the basis of how these data sources perform in general or with respect to their intended uses. Instead, the evaluations are made on the basis of how these data sources perform in estimating the specific parameters of interest for this study.

III.1 Truck Inventory and Use Survey (TIUS)

As the Nation's transportation survey, TIUS provides data on the physical and operational characteristics of the Nation's truck population. It is based on a probability sample of all of the trucks that were in operation and registered in one of the 50 States or the District of Columbia during TIUS' sample years - years ending in 2 and 7. Trucks owned by federal, state, and local governments, ambulances, buses, and motor homes are excluded.

The sample selection method for the 1987 TIUS was stratified random sampling. The truck population within each state was categorized into five body types (strata): (1) pickup, (2) panel truck, van, utility vehicle, jeep and station wagon on truck chassis, (3) small single-unit truck with GVWR less than 26,000 lbs., (4) large single-unit truck with GVWR greater than or equal to 26,000 lbs.,

and (5) truck tractor. Uniform truck body type classifications across all states were achieved prior to the sample selection. A random sample was then selected from each stratum within each state. Based on a set of statistical assumptions adopted by the Bureau of the Census, the final sample size of the 1987 TIUS was 134,321 trucks.

The complete results of the 1987 TIUS will not be published until mid 1990, hence the response rate for the 1987 survey is not known at this point. However, the response rate for Washington, the first state to have published results from the 1987 TIUS, was 81.7%. For reference purposes, the response rates for the two previous TIUS surveys were 90% in both 1977 and 1982.

In each stratum, estimates of the number of trucks for each characteristic were estimated by expanding the observations from the respondents to represent all trucks in the stratum. Expansion factors were the ratios of the total number of trucks in a stratum divided by the number of sample respondents for that stratum. This type of estimation procedure relies on an assumption that the characteristics of nonrespondents are the same as those of the respondents. The amount of bias introduced by this practice depends on the extent to which the nonrespondents differ from the respondents.

III.2 Nationwide Truck Activity and Commodity Survey (NTACS)

The NTACS is a follow-on to the 1987 TIUS to obtain additional information on commodities carried, safety features, operational characteristics, and relationships between truck usage, economic factors, geography, and highway classes. NTACS will provide basic commodity flow information for trucks which has not been measured since the last Commodity Transportation Survey in 1977 by the Bureau of the Census.

The target population for NTACS includes all operational trucks in 1989 that were registered in the U.S. on July 1, 1987, and that fall within the scope of the 1987 TIUS. However, the 1989 NTACS sample will be a subsample of the 1987 TIUS sample respondents.

The sample selection method for NTACS is stratified two-phase three-stage sampling. Because the NTACS sample is a subsample of the sample respondents to the 1987 TIUS, the selection of the TIUS sample is the first phase, and the NTACS' sample selection is the second phase of the procedure. There are to be three stages to NTACS sampling. In the first stage, the trucks will be selected from the 1987 TIUS sample respondents. In the second stage, two one-week periods (for long-haul trucks) or one one-week period (for other trucks) of the year will be selected for each selected truck. In the third stage, a sample day and a substitute sample day will be selected from each selected week for each selected truck. The need for a second day of data collection is to provide more information on the geographical variability of vehicle movement for long-haul commodity carrying trucks. Approximately 44,000 trucks will be sampled.

Mail-out of the questionnaires will begin in September 1989. The respondent will be asked to report detailed travel data during sampled days. Two follow-ups will be performed to improve the survey response rate. Responses will be edited for reasonableness and consistency. The complete results of the NTACS are expected to be available in late 1991.

III.3 National Truck Trip Information Survey (NTTIS)

The purpose of the NTTIS is to provide information on the day-to-day use of the truck which was not collected by the TIUS. NTTIS was a one-time data collection effort, implemented during the period between 1984 and 1987. Complete results of the NTTIS became available in 1988.

The target population for NTTIS consists of all large commercial trucks (GVWR greater than 10,000 pounds) in the United States. The source of the sampling frame for NTTIS was R. L. Polk and Company. Vehicle registrations as of July 1, 1983 were used. The Polk data for California did not include trucks with model years before 1973, and the state of Oklahoma prohibited the use of its data for statistical purposes. Hence, the NTTIS sampling frame excluded trucks registered in Oklahoma and pre-1973 model-year trucks in California. Trucks included in the survey were categorized into one of the following strata: (1) straight trucks, (2) all road tractors, or (3) unknown.

A stratified two-stage cluster design was used to select the sample. For each selected truck, four days of detailed travel data over a twelve-month period were collected. Taking into account the nonresponse rate, the final realized sample sizes were 2,601 tractors and 2,511 straight trucks.

Data for the NTTIS were collected primarily by telephone. The data collection effort was implemented in five phases. In Phase 1, initial contacts were made to secure the owners' cooperation, and to confirm vehicle identification. Vehicle misclassification was discovered in this phase. About 40% of the trucks selected from the tractor strata were found to be straight trucks, while 4% of the straight trucks should have been listed as truck tractors. Phases 2 through 5 corresponded to the data collection of four sample days for each sample truck (Phase 2 was for the first sample day, etc.) Information on individual trips on the survey day were exactly mapped onto special atlases developed by UMTRI.

Data editing was both manual and computerized. When a reported value was questionable or when a value was missing, imputed figures were developed. The most common data item that was imputed was "cargo weight". The level of imputation was estimated to be under 10%[2]. The numbers of responses for each of the four sample days differ for different phases. Of the 5,112 trucks selected, the overall response rate was 86%.

The estimated number of trucks in stratum i of state k was derived by multiplying the observed numbers of trucks in the sample by an expansion factor which was adjusted for nonrespondents. A similar procedure was used to expand the sample total VMT.

NTTIS data made it possible for UMTRI to produce three different estimates of average annual mileage: (1) self-reported mileage, (2) odometer readings, and (3) mapped mileage derived from the travel on the individual survey days. UMTRI believes that the estimates based on odometer readings are the most accurate, and that the self-reported estimates are at least 15% higher than the ones derived from odometer readings.

III.4 Highway Performance Monitoring System (HPMS)

HPMS has been implemented to assess the highway systems by continually monitoring the physical conditions and usage of the systems. More specifically, HPMS is a data collection effort designed to provide current statistics on the mileage and usage of highways, to evaluate highway programs by monitoring changes in highway characteristics and performances, and to improve knowledge of the condition and performance of highway pavements. The state highway agencies implement HPMS with the guidance from the FHWA. Summary statistics are published in "Highway Statistics" by the FHWA annually.

The target population for HPMS consists of all highway systems in either rural, small urban, or individual urbanized area. Unlike other data sources, such as TIUS, NTACS, and NTTIS, which focus on the travel characteristics of individual "vehicles", HPMS focuses on the usage of individual "road sections". However, it should be noted that HPMS does provide information on the amount of travel by vehicle type.

A stratified probability proportional to size design was used to select the sample of road sections. A stratum is defined as a specific traffic volume group within a highway functional system and an area type.

Traffic count data in terms of the total number of axles are collected by automatic traffic recorders for at least 14 consecutive days in a month. These data are used to determine the "baseline" travel pattern which includes seasonal, day-of-week traffic patterns as well as trend. Since there is an enormous cost in collecting these data, many sample sections are located at existing weight stations. Typically, a state has between 30 to 50 counters distributed throughout the state.

To calibrate "baseline" data, coverage count programs are implemented on selected road sections to collect traffic count data for usually a one-day period. These data are used in conjunction with the baseline data to establish annual traffic counts for these road sections.

Each vehicle is classified into one of 13 vehicle types based on the axle count and the length of the wheel-base. Several studies noted the improvements in vehicle classification since 1982, and concluded that most of the tested systems were able to correctly classify at least more than 91% of the vehicles, which meets the 90% accuracy level required by the HPMS [2], [3], and the tested equipments tended to undercount heavy single unit trucks with an error up to 33.6%. These studies also concluded that all tested systems had problems with slow-moving vehicles (< 20 mph) and vehicles in queues.

To convert the total number of axles into the total number of vehicles, an "average number of axles per vehicle" (Axle Correction Factor) is used. For example, if a total of 2,000 axles were counted in a given stratum and if the "Axle Correction Factor" for that stratum is 2.03 axles per vehicle, then the estimated number of vehicles traveled in that stratum during the monitoring period is 985 (=2,000/2.03).

The total DVMT (Daily Vehicle Mile of Travel) of sample sections in a given stratum is first calculated by summing the products of the estimated number of vehicles in the sample road section in that stratum and the length of that section of road. The estimated stratum DVMT can be developed by multiplying the total sample section DVMT by the corresponding expansion factor (the ratio of the **total** mileage in a stratum to the total **sampled** mileage in that stratum).

III.5 International Registration Plan (IRP)

The International Registration Plan (IRP) is a registration reciprocity agreement among states of the United States and provinces of Canada. It provides payment of license fees on the basis of **fleet** mileage operated in various jurisdictions and is designed specifically for interstate motor carriers. As of the end of 1988, there were 39 states and one Canadian province participating in the Plan.

Under IRP, a truck operator files a single registration in his/her base state. Annual licence fees are calculated based on fleet mileage accrued during the previous period. On the registration forms, the carriers provide information on the total **fleet** mileage, number of trucks in the fleet, vehicle type, carrier operation type, individual IRP jurisdictions and non-IRP states in which the fleet will be operating, and the percentages of their miles in these IRP jurisdictions and non-IRP states.

Data availability varies from member to member. Some members are able to provide data immediately after the registration period on computerized format. On the other hand, some members do not have adequate resources to prepare the data for external requests. In these cases, the time lag between data collection and assimilation can be as much as six months.

III.6 State Fuel Tax Reports

Each state collects fuel taxes or compatible taxes (i.e., weight-distance tax) from vehicles which travel in its jurisdiction for the privilege of using its highway system. Each state has different taxation requirements, tax structures, and administrative agencies [4]. Some states tax vehicles which are diesel powered; some states tax vehicles with GVWR greater than 18,000 pounds; some states tax vehicles which are interstate buses, etc. Since each state administers its own fuel tax reporting program, there is a significant degree of diversity among states with respect to fuel tax data. Data availability also varies from state to state.

In 1983, the International Fuel Tax Agreement (IFTA) was formed to assist the inter- and intra-state fuel tax collection process. The main purpose of this Agreement is to uniform the administration of motor fuels use taxation laws with respect to motor vehicles

operated in interstate commerce and to maintain one license for each truck. Currently, IFTA has 13 participating state members.

Both IFTA and IRP apply to any vehicle operating in interstate commerce that: (1) has two axles and GVWR exceeding 26,000 pounds, or (2) has three or more axles regardless of vehicle weight, or (3) is used in a combination when GVWR of such combination exceeds 26,000 pounds.

IV. EVALUATIONS OF DATA SOURCES

IV.1 Ability to Estimate Parameters at the State Level

It should be emphasized that the parameters of interest in this study are: (1) T_{ik}, the number of trucks of carrier type i traveled in state k, and (2) VMT_{ik}, the amount of VMT traveled in state k by these trucks. The key factor is the number of miles traveled in state k by these trucks, but not the number of miles traveled by trucks registered in state k.

IV.1.1 TIUS

Data from the TIUS can provide estimates of the total number of trucks registered in a state, the associated total VMT and in-state VMT (the amount of travel occurred in a given state by trucks registered in that state). **However, estimates of T_{ik} and VMT_{ik} are not available.** There are a few major limitations in the TIUS data. First, double-counting in vehicle registration exists and would likely cause overestimation. Second, VMT's estimated by the drivers (self-reported) are likely to be higher than the actual mileage based on odometer readings as was observed in the NTTIS. Third, in 1982 there was a two-year lag between when the data were collected and when the complete survey results became available. Fourth, since the TIUS is conducted every 5 years, interpolations will be needed for the intermittent years.

In addition, two minor limitations on these estimates should be pointed out. First, the operation type of a sampled truck is defined as the "most typical" type of operation if more than one types are checked on the survey form. Second, there is no information to identify trucks operating in interstate commerce that are operated for private business.

IV.1.2 NTACS

In mid 1991 when data from the NTACS become available, one will be able to estimate the total number of trucks registered in a state and their total VMT, and to identify the three most frequently travelled states for each sampled truck. **Estimates of T_{ik} and VMT_{ik} are not available.**

IV.1.3 NTTIS

Data from the NTTIS could be used to estimate the parameters of interest by state and by carrier type. However, there are two major limitations in the data. One is the sample size which is too small to provide reliable estimates at the state level. The other limitation is the extraordinarily high cost (both in time and effort) of the data collection method - mapping individual trips that occurred in the sample days onto special atlases. It is difficult to project when the next NTTIS will be implemented.

IV.1.4 HPMS

The state-specific traffic count program in the HPMS leads to uncertainty and concern over the accuracy and reliability of the data. In addition, given its specific goal, the HPMS does not collect enough information to meet the estimation needs. Hence, even with uniform data collection procedures across all states, data from the HPMS are still unable by themselves to estimate the parameters of interest.

IV.1.5 IRP

Data reported in the IRP include the number of trucks that are registered in a state and that are operating in interstate commerce, and the associated VMT's by IRP jurisdiction. Unfortunately, data on VMT's for trucks registered in non-IRP states and for trucks with GVWR less than 26,000 pounds are missing. These missing data create gaps so that none of the 48 contiguous states plus the District of Columbia has complete truck VMT data. However, as more states become members of the IRP, it becomes a strong candidate as a data source for providing the desired estimates.

IV.1.6 State Fuel Tax Reports

The "diversity" in how the fuel taxes are collected from state to state prohibits a general assessment of the data. Moreover, the states' cooperation in providing the data becomes a key factor with respect to "data availability". However, as more states join IFTA, fuel tax data will have great potential in providing estimates at the state level.

IV.2 Ability to Estimate Parameters at the National Level

The parameters of interest at the national level are (1) N_i, the total number of trucks of carrier type i (common, contract, exempt, or private) operating in interstate commerce with GVWR greater than 10,000 pounds, and (2) VMT_i, the total amount of travel (VMT) by trucks of carrier type i.

IV.2.1 TIUS

TIUS is partially capable of providing estimates on the number of commercial trucks by carrier type and on the associated VMT's. The four major limitations (identical to the ones identified in the previous section) still apply: duplicate registration, self-reported mileage, two-year time lag before data become available, and interpolations for the intermittent years.

IV.2.2 NTACS

NTACS is partially capable of providing estimates on the number of commercial trucks by carrier type and on the associated VMT's. Similar assessments on the TIUS

can be applied to the NTACS.

IV.2.3 NTTIS

Data from the NTTIS are capable of providing the estimates. However, there are two major limitations in the NTTIS data. First, there is a four-year lag between the time when trucks were sampled from Polk registration files (1983) and the time when the implementation was completed (1987). The exclusion of trucks registered between 1983 and 1987 is likely to result in underestimations of the VMT's and the number of trucks. Second, serious misclassification of trucks in the original sampling frame introduces larger variances in the estimates than if there had been no misclassification.

IV.2.4 HPMS

HPMS data are capable of providing total truck VMT by truck type, but not the total number of trucks. Since HPMS does not have information on the types of operation (common, contract, exempt, or private) or on the jurisdiction of operation (interstate vs. intrastate), allocation of total truck VMT into different operation types and jurisdiction types by using data from other sources, such as TIUS or NTACS, will be necessary.

IV.2.5 IRP

Not until all of the states become IRP members, can IRP by itself provide the estimates.

IV.2.6 State Fuel Tax Reports

Since fuel taxation requirements vary so greatly from state to state, it is not clear as to how the state fuel tax reports can be of any use to estimate the number of commercial trucks and the associated VMT's by carrier type. However, as more states participate in the IFTA, IFTA data will have great potential in estimating the parameters at the national level.

V. SUMMARY OF EVALUATION RESULTS

An important caveat to the discussion in this paper is that the evaluations of the data sources are **not** made on the basis of how they perform **in general** or relative to their intended uses. Instead, the evaluations are made on the basis of how these data sources perform in estimating the parameters of interest.

Based on the evaluation results, it is concluded that none of the six data sources by itself can provide reliable estimates on the number of trucks (operating in interstate commerce with GVWR greater than 10,000 pounds) of carrier type *i* (common, contract, exempt or private) **traveled** in state *k*, and the amount of travel **occurred** in state *k* by these trucks. However, estimates at the national level can be obtained from a combination of several data sources.

In general, nation-wide transportation surveys such as the TIUS, NTACS, and NTTIS collect the complete set, or at least some, of the information items needed in this study. The major drawback in these surveys is that the high cost and resources necessary to conduct the survey severely limit the frequency of data collection and occasionally the sample sizes. On the other hand, continual data reporting systems such as the IRP, state fuel tax reports (or IFTA), and the HPMS provide uninterrupted data, though the extent of data availability varies over a wide range.

Indeed, estimates derived from a combination of several data sources, such as IRP, TIUS, and NTACS, would likely be the most cost-effective and reliable for the years in which data were collected. Data from the HPMS or state fuel tax reports (IFTA) could be used to develop annual trends (or growth factors) in VMT or traffic counts and used in conjunction with data from the TIUS or the NTACS to extrapolate data for the intermittent years. Work is currently underway to develop a statistical model to accomplish this goal.

REVIEWERS

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FOOTNOTES

[1]Gross vehicle weight rating (GVWR) is the weight of a vehicle when loaded to its capacity.

[2]Personal communication with K. Campbell, University of Michigan, June 1989.