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DEVELOPMENT OF A LARGE TRUCK SAFETY DATA NEEDS STUDY PLAN

Vol. I - Summary

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16. Abstract

This report discusses the results of a study to determine the data needs necessary to address truck safety issues and to develop a data collection and analysis plan.

Priority truck safety issues that are amenable to truck accident data analyses were identified through survey techniques. These issues led to development of a list of data elements for accident and exposure (vehicle travel) data. Alternative procedures for collecting the data elements were examined. Sample size requirements necessary to develop statistically reliable estimates of truck accident rates were established.

The recommended plan for near-term resolution of the large truck safety issues calls for sampling accident and exposure data from numerous jurisdictions throughout the country. The report presents the elements of the plan and necessary cost investment.

Volume I is the technical report summary and Volume II is the complete technical report.

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INTRODUCTION -

Over the past 25 years, the trucking industry in the United States has increased substantially. Truck traffic, which was 18 percent of the total vehicle miles traveled in 1962, has increased to 27 percent in 1982 (1). While the Federal Highway Administration (FHWA) has always been concerned with the influence of trucks on highway safety, the increases in truck traffic and changes to traffic composition have heightened their concern. As a result, special interest has been placed on allowable weights, lengths of trucks and the use of multiple trailers.

Since the Highway Act of 1956, which gave FHWA responsibility for Federal truck size and weight limits on the Interstate system, many changes in these restrictions have been adopted. As a result, truck characteristics have changed considerably over the years. Trucks are now not only heavier and longer but exhibit other changes as found in trailer configurations, axle lengths and number of axles. With the passage of the 1982 Surface Transportation Assistance Act, double-trailer trucks (tractor-semitrailer plus full trailer) are becoming more common. As this trend is expected to continue, Federal and State governments can anticipate proposals for additional changes in size and weight limits. As the limits of restrictions increase, the importance of realizing the potential safety impacts of such changes becomes critical.

Past debates concerning these changes have emphasized safety as a major issue, and in all cases it has been found that adequate information concerning the safety implications of proposed changes has been sadly lacking.

While size and weight issues have recently dominated FHWA's concerns about truck safety, there are a host of additional questions and issues regarding large truck safety on the highway which are still unresolved. Examples of issues of concern to FHWA and to individual States include whether double-trailer trucks (doubles) have a higher accident rate than tractor-semitrailer trucks (singles), the causes of truck accidents and the impact of larger trucks on highway design criteria.

In recognition of these unresolved issues, the FHWA, under its Federal Coordination Program of Research and Development Project 1-U, Truck Safety, contracted for a study which has the following objectives:

1. Determine the immediate and long-term truck safety data needs.

2. Develop a work plan for use by FHWA in the collection and analysis of the priority truck safety data.

The data needs study plan that would result from this effort would give the direction and coordination to individual research studies and data collection activities so that relevant issues regarding large truck safety can be addressed in a systematic manner.

This report summarizes the results, conclusions and recommendations of the study. Volume II, under the same title, provides complete documentation.

THE PRIORITY TRUCK SAFETY ISSUES

The identification of critical truck safety issues resulted from three sequential activities. The first was a literature review that identified numerous issues which had been addressed in the past. The second and most influential activity was to interview representatives of several operating offices of FHWA. The third effort was to convene a panel of five experts in truck safety research.

The result of these activities was a comprehensive list of truck safety issues which are itemized in Volume II. From that list several were identified as priority truck safety issues that could be addressed through accident analyses. These are listed in Table 1.

These were indicated as priority issues because they needed to be resolved for one or more of the following reasons:

- To make better-informed decisions concerning limitations on truck size, type or weight.

- To make better-informed decisions concerning restricting certain truck types under certain highway or operating conditions.

- To make better-informed decisions concerning regulating the truck operations and/or truck drivers.

- To provide a complete understanding of the factors that affect truck safety that are particularly relevant to the highway interest.

Table 1. Priority truck safety issues.

1. What is the safety record of various truck types and what are the principal variables that affect their safety?

   Specific truck characteristics of principal concern include:
   - number of trailers
   - weight
   - overall and/or trailer length
   - width (especially for highways with lanes less than 12 feet in width)

   Truck characteristics of a lesser concern include:
   - trailer type
   - cargo type
   - empty vs. partially or fully-laden
   - fleet size
   - trip type

   Specific driver characteristics of concern are:
   - driver type (i.e., employment status)
   - driving age and/or experience

   Specific highway characteristics of concern are:
   - urban/rural environment
   - design type
   - volume of all vehicles and trucks
   - geometric elements

   Time of day (especially day vs. night destination) is of concern as well.

2. Where do truck accidents occur on various highway types and does this vary by truck type? Of particular concern are the incidence of truck accidents at the following features:

   - interchanges, especially ramps
   - steep grades
   - intersections
   - curves
   - railroad-grade crossings
   - (no) passing zones on two-lane highways
   - narrow bridges
   - narrow pavements

3. What types of accidents occur for the different truck types? Of particular concern are the relative incidence of:

   - single vs. multiple vehicle accidents
   - jackknife, rollover, fire, cargo spillage, etc.
   - equipment failure

4. The effectiveness of restricting trucks by lane or time-of-day for freeway facilities.

It should be emphasized that these are the issues that may be addressed through accident analysis. Also, they are primarily those which are of concern to the highway engineering community. Undoubtedly there are many other "priority" issues which deal with the driver (e.g., training, licensing, drugs, alcohol, etc.) and the vehicle (crash worthiness, safety equipment, etc.). These issues are being addressed through the efforts of the National Highway Traffic Safety Administration (NHTSA), the Bureau of Motor Carrier Safety (BMCS) and others.

OVERVIEW OF ANALYSIS PLAN

The appropriate analysis methodology is dependent upon the specific issues that need to be resolved. However, given the list of priority issues and the interrelationships, it is appropriate to pursue an analysis methodology and data collection plan that would allow for a comprehensive evaluation of all, if not most, of the issues.

The first issue listed in Table 1--What is the safety record of various truck types and what are the principal variables that affect their safety?--is comprehensive by itself, and it is the most demanding in terms of data elements, the need for both accident and travel data and sample size. A data collection plan that satisfies this issue will be adequate for the other issues.

The proposed experimental design calls for establishing reliable accident rates for certain truck types and certain highway types so that statistical comparisons can be made. In addition, data on other key factors related to the truck, the driver, the highway and the environment would be collected so that correlation analyses could be performed to establish which variables affect truck accident rates. Other accident data would provide information on various aspects of the accident related to location, type, conditions, etc.

The development of accident rates requires the matching of accident data with exposure data (i.e., vehicle miles) for specific truck types. Given that it is not possible to include all truck accidents and all truck exposure in the nation, sampling would be required. Sampling of accidents could be based on a sample of highway sections stratified by a "type" classification or for all highways of concern within a sample of jurisdictions or States. Likewise, exposure data would have to be sampled. It is not necessary that exposure data be collected for the same highways that supply the accident data.

The sample size would be dictated by statistical requirements necessary to achieve a reliable estimate of the accident rate in question and the desirability of distinguishing a certain minimum difference between two accident rates.

REQUIRED DATA ELEMENTS AND DATA COLLECTION OPTIONS

The data elements that need to be collected are a function of the variables of the study design. These variables can be:

- Dependent--the measure being used for the evaluation, e.g., accident rate.
- Independent--variables that are known to or are assumed to affect the dependent variable.
- Control--an independent variable which is fixed in the design.

There are numerous variables which are known or believed to affect truck accident safety. Of these, the following are considered the most critical and relevant to the issues:

1. Truck type,
2. Truck length,
3. Truck trailer type,
4. Truck gross weight,
5. Truck driver type,
6. Truck highway type, and
7. Highway volume.

Each of these is discussed briefly below, including how the data could be collected.

1. Truck Type

Probably the most critical safety issue is the ability to compare the safety record of various truck "types". Hence, truck type should be considered as a primary independent variable in the data collection plan. Table 2 provides truck type classification recommendations for safety evaluation purposes.

Table 2. Recommended truck type classification.

1. Single-unit (straight) truck--all trucks with the cargo unit and tractor on a single frame having two or more axles with at least six tires (2-0 and 3-A).

2. Single-unit (straight) truck w/trailer--a single-unit truck pulling any type trailer (2-1, 2-2, 2-3, 3-2, 3-3).

3. Tractor-semitrailer (semi or single trailer)--a truck combination consisting of a tractor with two or more axles and a semitrailer with one or more axles (2S1-2, 2S2-2, 3S1-2, 3S2-2).

4. Tractor-semi + full trailer (double trailer)--a truck combination consisting of a tractor with two or more axles, semitrailer with one or more axles and a full trailer with one or more axles (2S1-2, 2S2-2, 3S1-2, 3S2-2).

or

- 4A. Turnpike double--three-axle tractor and two two-axle semitrailers each 40 to 48 feet long coupled by a two-axle dolly.
- 4B. Rocky Mountain double--three-axle tractor, a two-axle 40- to 48-foot semitrailer, a one-axle dolly and a second 27- or 28-foot single-axle semitrailer.
- 4C. Twin-trailer truck--a double-trailer truck with a two- or three-axle tractor and two single-axle semitrailers, each usually 27 or 28 feet long, coupled by a single-axle dolly.

5. Tractor-semi + two full trailers (triple trailer)--a truck combination consisting of a two- or three-axle tractor, a semitrailer with one or more axles, and two full trailers with one or more axles each.

1/ The codes in the parenthesis are those used in the HMPS vehicle classification.

Under this classification, a maximum of seven types of trucks could be identified with three different types of double-trailer trucks. By grouping the two single-unit trucks together and the three double-trailer trucks together, a minimum of four truck types would be identified. While grouping the two single-unit trucks into one type may be reasonable, it is recommended that the distinction between the three types of "double" be retained if possible.

Unfortunately, truck type according to this classification is not available from the vast majority of States' accident record systems. Hence, it will be necessary to establish the truck type by either: 1) modifying the States' police accident report form, 2) using a supplemental form on which this item and other truck data elements are recorded by the police for truck accidents, or 3) through follow-up survey investigations.

Exposure, i.e., vehicle miles of travel, will also be necessary. Unfortunately, the vehicle classification structure being used in Highway Performance Monitoring System (HPMS) and by the States does not exactly match that suggested in Table 2. Also, coverage of count stations across all types of highways, discussed later, is not available. Hence, sample counting to obtain exposure is needed.

2. Truck Length

The relationship of truck length to truck safety continues to be an unresolved issue warranting investigation. It is an issue which can be limited just to tractor-semitrailer combinations. This is because there is more variability in lengths for this truck type and the issue primarily deals with how long the trailer can be for this type of truck.

Vehicle length for trucks involved in accidents would have to be obtained from some form of supplemental data collection effort as it is not available from any police accident report form. The alternatives for collecting this data element are the same as for truck type.

Likewise, since overall truck length is not readily available from any existing counting system, it will require special data collection. The most cost-effective method would be to take measurements of a sample of tractor-semitrailers (assuming the analysis is limited to that truck type) at weigh stations, rest areas or truck stops.

However, this method would limit the analysis and resolution of the issue to those types of roadways where the exposure sampling can be conducted.

3. Trailer Type

Distinguishing truck safety by trailer type was not identified as a priority issue. Still, it is desirable to consider this variable since it is a factor influencing accident rates. In an analysis of single- versus double-trailer combinations, it would be more reliable if similar trailer types were compared. This would ensure that any effect due to trailer type is controlled. To do this it is necessary, then, to identify trailer type in the accident and exposure data collection system.

While there are many trailer types, the classes shown in Table 3 should be sufficient. This essentially establishes four trailer types with all others being grouped into a fifth class.

Trailer type is not recorded on police accident reports, so it would require supplemental investigation through either of the alternative procedures suggested for truck type. To obtain corresponding exposure data, counts would have to be made to supplement the truck type exposure data collection.

4. Truck Gross Weight

The relationship of gross truck weight to truck safety is a priority safety issue that should be addressed. However, due to difficulties in obtaining the required accident and exposure data, it should be limited to those higher classes of roadway types where truck weight data is available. Also, the analysis, and therefore data collection, should be limited just to tractor-trailer combinations, both singles and doubles.

Limiting the analysis to higher classes of roads is in recognition of the limited data on truck travel by weight categories. This data comes primarily from weigh stations which, for the most part, are limited to interstates and primary routes. However, advances in portable weigh-in-motion devices could allow for sampling across a larger group of highways.

Limiting the analysis to tractor-trailer combinations (singles and doubles) reflects the fact that gross weight data would be very difficult to collect for straight trucks and that weight relationships for this truck type is not a priority concern. While it is recognized that the analysis for double-trailer trucks will suffer from small sample size, data should be collected for this truck type as well as for tractor-semitrailers.

Information on gross weight for trucks involved in accidents will require special data collection as discussed previously.

Table 3. Recommended truck trailer type classification.

1. Van--cargo is completely hidden from view; cargo unit has solid top, sides, front and rear.

2. Tank, liquid carrier--may have different configurations but it contains a liquid substance.

3. Platform--flat cargo carrying unit with no sides or top structure.

4. Bulk commodity--loose or semiloose solids carrier, e.g., agriculture products, cement, etc., has sides but no hard top.

5. All other cargo body types.

5. Truck Driver Type

It is often stated without evidence that so-called "owner-operators" are overinvolved in truck accidents compared to employees of fleet operators. If this is true, then the analysis of truck accident rates should consider this situation in the experimental design. Specifically, since most, if not all, operators of double-trailer trucks are employed drivers, then in a comparison of singles vs. doubles it would be important to factor out accidents involving singles with owner-operators.

The classification of operators is not clear-cut, but in general there appears to be three groups:

1. Owner-operator--one who owns the tractor and possibly the trailer.

2. Leased operator--driver who is "leased" to a fleet operator for a single trip or longer but is not a regular employee. The rig may be leased as well.

3. Employed driver--driver who is employed on a regular basis by a fleet operator, either common or private.

While some errors may occur, identification of owner-operator may be made from the standard police report by matching the driver to the owner identification.

Exposure data for this element will be difficult to obtain. It will require supplemental surveys conducted on the road at weigh stations, rest areas or truck stops. Since exposure data will be limited to highways where these facilities exist, the analysis will need to be limited to those highway types.

6. Highway Type

A key issue is to identify the relationship of truck safety to the highway type. Along with truck type, highway type is considered a primary independent variable.

Currently there is no formal highway "type" classification. However, for the purpose of addressing the issues of truck safety, highway types should be determined by primary design features. The features selected were:

- Function,
- Access control,
- Number of lanes,

- Divided or undivided, and

- Urban vs. rural areas.

Using national inventories of highway mileage and vehicle mileage traveled, the highway types shown in Table 4 were developed. Elimination of lower order types may be required due to low exposure for the large trucks.

Data from the typical police report does not by itself allow for assigning the truck accident to one of these highway types. However, it can be established by checking the State highway inventory file.

Exposure data for trucks operating on any of these highway types can be obtained by using this classification for section sampling. The design features that establish the highway type classification are recorded for the HPMS section sample; hence, the HPMS provides a mechanism for selecting study sections and for eventually factoring up to a national estimate.

7. Highway Volume

Another variable known to affect accident rates in general is the traffic volume, typically expressed as the average annual daily traffic (AADT). While the AADT for a highway where an accident occurs is not available from the police report, it can usually be obtained from State or local traffic files given the route identification and location. If sites from the Highway Performance Monitoring System are used for exposure sampling, then the volume is obtainable from that file.

Other Data Elements

The aforementioned factors are key data elements that, as a minimum, need to be collected to address the priority issues. There are, of course, numerous other data elements which relate to the accident and which are, for the most part, available from the standard police accident report form. These are listed in Table 5.

SAMPLING PLAN

Several alternatives were considered for sampling truck accident rates. These alternatives were dependent upon the assumption of how key accident data elements not currently available from police accident reports are collected. The alternative data collection assumptions led to three options for sampling accident rates:

Table 4. Highway type classification.

<u>URBAN</u>

1. Interstate and other freeways and expressways, more than two-lane, divided, full access control.

2. Interstate and other freeways and expressways, more than two-lane, divided, partial access control.

3. Other principal arterials, two-lane, undivided, no access control.

4. Other principal arterials, more than two-lane, divided, no access control.

5. Other principal arterials, more than two-lane, undivided, no access control.

6. Minor arterials, two-lane, undivided, no access control.

7. Minor arterials, more than two-lane, divided, no access control.

8. Minor arterials, more than two-lane, undivided, no access control.

9. Collectors, two-lane, undivided, no access control.

<u>RURAL</u>

1. Interstates, more than two-lane, divided, full access control.

2. Other principal arterials, two-lane, undivided, no access control.

3. Other principal arterials, more than two-lane, divided, full access control.

4. Other principal arterials, more than two-lane, divided, partial access control.

5. Other principal arterials, more than two-lane, divided, no access control.

6. Minor arterials, two-lane, undivided, no access control.

7. Minor arterials, more than two-lane, divided, no access control.

8. Major collectors, two-lane, undivided, no access control.

9. Minor collectors, two-lane, undivided, no access control.

Table 5. Additional truck accident data elements.

1. Accident severity type
2. Number injured
3. Number of fatalities
4. Vehicle identification number
5. Number of vehicles involved
6. Type of other vehicles involved
7. Hazardous cargo
8. Driver age
9. Driver condition
10. Route identification
11. Location on route
12. Collision type
13. Non-collision type
14. Contributing factors
15. Roadway features
16. Time
17. Date
18. Environmental conditions
19. Pavement conditions

1. From geographically representative sections of highway types.

2. From a sample of highways within several States.

3. From a sample of highways within geographically representative jurisdictional units.

The first option of a stratified sample of highway sections is possible only when traffic and accident record systems contain both the required data elements and the information necessary to select a national sample of sections. Currently these requirements are not met; however, a long-term plan for FHWA truck accident research should be moving in this direction. It offers the possibility of continuous data collection and analysis at modest costs.

The second option calls for a number of selected States that have or are willing to develop the capability to collect accident data elements by modifying or supplementing the police accident report form. However, based on preliminary data from the ongoing seven-State double-trailer truck monitoring study, there appears to be substantial differences in accident rates among the States. Because of this variance in accident rates among the States, estimates of sample size suggest that virtually all States would have to be involved in such a survey in order to obtain acceptable levels of precision.

The third option was considered to provide the most practical shorter-range strategy for collection of the required data. In this case, primary sampling units (PSU's) would be selected, within which accident and exposure data could be collected. A typical PSU consists of a county or group of counties.

Within the PSU, accident data would come from the standard police accident report supplemented by additional required truck data obtained by the police investigator using a supplemental short form. To encourage participation, the police department could be compensated for each accident report completed. Alternatively, the standard accident report would be provided to outside investigators shortly after the accident occurred. The investigators could then make contact on a timely basis with the truck owner or driver and obtain the required data elements.

Exposure data would come from three sources:

1. Existing State traffic and classification counting programs,

2. Weigh stations, and

3. Special manual 24-hour coverage classification counts.

State-collected traffic volume and classification data available for selected sites would be employed to develop AADT values and some truck exposure.

Data from permanent weigh stations or portable stations (i.e., weigh-in-motion) would be used for tractor-trailer weight exposure data. Special attention would have to be given to the problem of empty trucks that might go by unweighed or over-legal-limit trucks that might pass by the stations. Also at weigh stations, data on overall length for tractor-semitrailers could be obtained as well as classification of drivers by operator type.

In order to obtain truck exposure by truck and trailer type, manual counting would have to be made at a minimum of two sections per PSU. The sections should be sampled from the HPMS sample and represent those section types, presented in Table 4, that are being examined. Counting should represent a 24-hour period so that both day and night exposures are sampled. A two-person team, one for each direction of traffic, could obtain a 24-hour count over a period of three days. Representation of seasons of the year would be obtained by conducting the exposure counting throughout the entire year.

This manual counting program is considered the minimum necessary to achieve an acceptable level of exposure estimate reliability at a reasonable cost. It is emphasized, however, that the 48-hour counting program recommended in FHWA's Traffic Monitoring Guide (2) would be preferable.

SAMPLE SIZE REQUIREMENTS

If a statistically significant difference is to be observed between accident rates for certain truck types, then the sample size must be sufficiently large to ensure a reliable estimate of the statistic. The parameters that affect sample size requirements include the expected accident rate, the desired percentage of difference to be detected and the confidence level related to a Type I or II error.

The last three parameters can be defined in terms of a coefficient of variation (CV). Table 6 shows the attained CV for certain levels of: 1) difference to be detected, 2) Type I error and 3) Type II error. The attainment of some minimum CV value is basic to the experimental design and sampling plan requirements.

The number of PSU's required is dependent upon variance of accident rates between PSU's, as well as the variance in exposure between and within sampled sections. To determine an optimal sampling design (i.e., a mix of PSU's, accident counts, exposure sites and days of sampling), a cost model was used which, when combined with the expression for the sampling errors noted above, would yield the number of PSU's for a given funding level and an estimate of the attained CV. The cost model considers the following:

1. The overhead cost to conduct the study which is estimated at $350,000 and $500,000 for a study of one and two years of accident and exposure data respectively.

2. The cost to enroll a PSU which is estimated at $1,440 per PSU.

3. The cost to obtain accident data which is estimated at $10 per accident for the supplemental data.

4. The cost to collect the manual exposure data which is estimated at $1,525 per site.

Table 7 shows the number of PSU's that would be required for six funding levels (total of all costs noted above) and the resulting CV's. A comparison of these CV's with those shown in Table 6 gives an indication of the level of confidence and detectable difference associated with the CV's.

CONCLUSIONS

The development and implementation of a data collection plan to address large truck safety issues are beset with several significant obstacles which are enumerated below:

1. The relatively low number of accidents associated with certain truck types makes it difficult to amass statistically sufficient sample sizes of accident counts. Just to be able to detect reasonable differences in accident rates for singles vs. doubles across all highway types requires large sample sizes due to the low number of doubles in accidents.

Table 6. Coefficient of variation for different levels of detectable difference, and Type I and Type II error.

Detectable Difference (Percentage)	Probability of Type I Error	Probability of Type II Error	Coefficient Variation
10	0.10	0.10	0.028
15	0.10	0.10	0.041
20	0.10	0.10	0.055
25	0.10	0.10	0.069
25	0.10	0.15	0.085

Table 7. Optimum sampling plans for different funding levels.

Funding Level	No. of PSU's	Attained CV
$ 850,000	97	0.076
1,100,000	147	0.062
1,350,000	196	0.054
1,850,000	292	0.044
2,350,000	389	0.038
2,850,000	482	0.034

19,000 ACCS

2. Adequate sample size requirements becomes more difficult to attain when other variables known to affect accident rates are considered. Consideration of factors such as truck weight, length, trailer type, operator type, traffic volume, day vs. night, etc. require disaggregation of an already insufficient sample size.

3. The inability to identify certain key data elements, primarily concerning the truck characteristics, from the States' police accident reports necessitates supplemental, costly data collection efforts. Not being able to identify just truck type precludes the possibility of amassing large samples of accident counts from State files. Special onsite or follow-up surveys are needed to identify the key data elements of truck type, weight, length, trailer type and operator type.

4. The variability of truck accident rates among the States (as determined from preliminary data from several States) necessitates sampling from many jurisdictions throughout the country. Even if all the truck accidents from a few States can be obtained, the known (to date) variation in rates will introduce substantial probability of error.

Under the existing constraints of regarding data availability from police reports, the most reasonable data collection approach is to sample accident counts and exposure from jurisdictions throughout the country. Cooperative arrangements with police jurisdictions will be needed whereby either the police collect the additional required data elements for truck accidents or provide the report in a timely fashion to an investigator to follow-up. To achieve the levels of confidence required to detect a 10 to 15 percent difference in accident rates between truck types will require close to 300 jurisdictional sampling units and will cost up to $1.85 million over the course of a one-year study.

It is recognized that developing cooperative arrangements with such a large number of jurisdictions will be costly and logistically demanding. Alternatively, then, FHWA may wish to pursue continuation and even expansion of the seven-State double-trailer truck study. While a small sample of States will not provide the needed statistical reliability, it can be the basis for identification of problem areas, and for better formulation of hypotheses and sample size requirements.

In the long- run, the interests of FHWA, the States and the highway safety community are best served if the primary data collection instrument--the police accident report--is modified to provide the key truck data elements. At the very least, all States should have the ability to distinguish three truck types--a straight truck, a tractor-semitrailer truck and a double-trailer truck. This one action will allow yearly monitoring of truck safety as it relates to the major concern of truck type.

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