December 4, 2001

Mr. Joseph A. Clapp
Administrator
Federal Motor Carrier Safety Administration
Room 8202
400 7th Street, SW
Washington, D.C. 20590

Dear Mr. Clapp:

The Committee for Review of the Federal Motor Carrier Safety Administration's Truck Crash Causation Study (TCCS) held its third meeting on August 20–21, 2001, at the National Research Council facilities in Washington, D.C. The enclosed meeting roster indicates the members, liaisons, guests, and TRB staff in attendance. On behalf of the committee, I want to thank the staff members of the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA) for their presentations and responses to committee questions. The committee believes the continuing exchange of views and ideas on this project is highly beneficial.

The meeting provided the committee with an opportunity to review a set of questions stemming from a task force review of several crash files and to discuss again the agency's study methodology.[1] In addition, the committee heard a presentation about the database being prepared for the study and discussed the extent to which this database will be made available to the public. There was further discussion about the need to collect as much measurable data as possible about the crash characteristics of the roadway and vehicles involved. Finally, several committee members again underscored the need for the agency to document its method for assessing the crash data files and to consider using other analysis methods as well.

The committee then met in closed session to deliberate on its findings and begin the preparation of this report, which was completed through correspondence among the members. This report summarizes key points made during the committee's discussions and provides several recommendations to FMCSA. See Appendix A for a review of previous committee decisions that affect the committee's discussion and recommendations.

[1] A task force comprising five committee members—John Billing, Michael Belzer, Anne McCartt, James McKnight, and Frank Wilson—visited Veridian Corporation, an FMSCA crash investigation contractor, in Buffalo, New York on July 9–10, 2001 to review crash case files.

Study Purpose and Agency Expectations

The TCCS is a congressionally mandated study of the causes of truck-involved crashes leading to fatality or serious injury. The results of the study will be used to design and select cost-effective measures for reducing the number and severity of serious crashes involving large trucks. The study will consist of in-depth investigations of a nationally representative sample of 1000 large truck crashes, to be performed by teams of trained investigators from NHTSA's National Automotive Safety Sampling System (NASS) project and FMCSA-funded truck safety inspectors. The full study involves data collection at 24 data collection sites.

FMCSA staff reviewed the study's aims for the committee, emphasizing that the study is designed to enable the agency to draw inferences about circumstances and contributing factors associated with truck crashes, thus helping the agency meet its goals for reducing truck crash fatalities. The committee agrees with the agency that the primary objective of the study is to collect the most complete and accurate possible set of factual evidence for use by agency analysts as well as future researchers. However, the study's goals are complicated by the fact that in more than 40 percent of fatal truck crashes, the driver of the other vehicle is believed to be solely responsible for the crash.[2] Thus the committee remains concerned about whether the data being collected on the 1000 crash cases will yield sufficient causal information to identify the most effective truck-related countermeasures.

The TCCS is important for other reasons as well. It involves the largest nationally representative sample of truck crashes to date and is the first large-scale, on-scene investigation of such crashes. This study is also the first to use a combination of trained crash investigators and truck safety inspectors for data collection. Finally, the truck crash database being developed will be made available to the public and outside researchers as well as FMCSA and NHTSA researchers.

In funding the TCCS, Congress requested "a comprehensive study to determine the *causes* of, and contributing factors to, crashes that involve commercial motor vehicles…[emphasis added]" (Motor Carriers Safety Improvement Act of 1999, Section 224). Extracting causal information in complex events like crashes is quite difficult and depends on collecting reliable and valid data on each possible causal or contributing factor. FMCSA staff informed the committee that the agency is focusing on the contributing factor(s) that increase the risk of crashes; the agency is not attempting to isolate individual or primary causes of crashes. According to the agency, the TCCS—based on the Perchonok method—will yield findings about critical precrash events, the critical reasons for these events, and relative risks in truck crashes. While these findings may help the agency improve the effectiveness of truck crash countermeasures, they may not meet the goals set by Congress. The agency recognizes these expectations and is addressing them as it prepares a crash data analysis plan based on the analysis methodology described by Blower in Appendix B, pp. 13-19. The committee supports this effort and urges the committee to consider other analysis approaches as well. Several committee members also noted that some of the distinctions the agency is making—for example,

[2] Daniel Blower. Relative Contributions of Truck Drivers and Passenger Vehicle Drivers to Truck-Passenger Vehicle Traffic Crashes. UMTRI Report 98-25.

between causation and contributing factors that increase the risk of a crash—may be lost to decision makers and the public. Thus, clarity in both analyses and report writing is critical.

Crash Event Assessment (Study Methodology)

In its first letter report, dated November 15, 2000, the committee noted that FMCSA has chosen a clinical or case analytic methodology for the study. The discussions at this meeting, however, indicated that both a clinical approach (on the part of NHTSA) and a statistical approach (on the part of FMCSA) are envisioned for the analysis. (Material provided to the committee on these approaches is included in Appendix B, pp. 2-8.) While the committee believes that both are rational approaches, it continues to be concerned about whether the methodology to be used in coding and analyzing the data will yield valid results.

There was considerable discussion about how a critical event for each crash is identified in the Perchonok approach. (Appendix C contains background information on this approach provided previously by FMCSA.) The above-mentioned task force, which reviewed preliminary results from five crash investigations, disagreed with several critical events identified by agency analysts and also disagreed among themselves about appropriate critical events. The committee's concern is not whether universal agreement can be achieved on every critical event, but whether the Perchonok method leads analysts to identify a critical event that can be challenged in light of the data in the crash case files.

For example, the traditional Perchonok method does not recognize that failure to take an appropriate or expected action can be a critical event. This point is illustrated by a crash case involving a passenger car that did not stop at a red light and was struck by a left-turning truck (Appendix B, p. 11). In this example, the passage of the nonstopping car into the intersection after the light had turned red was not coded initially as the critical event. Agency staff now recognizes this limitation and has adapted the method to accept a driver's failure to make an appropriate maneuver as a critical event. The risk, however, is that similar challenges, even on just a few cases, could lead to the judgment that the methodology is subjective or arbitrary, which would undermine the study's conclusions. The committee previously urged FMCSA to follow the procedures of the version of the Perchonok method that is recognized as being the most objective for identifying key crash factors—the version shown to have the least bias toward any pre-determined outcome. The agency must thoroughly document the method being used so that other researchers can review the crash cases and independently analyze the results using the agency's method.

Previously the committee urged FMCSA to conduct two independent assessments of each crash case and was informed that such assessments are planned for each of the TCCS's 1000 cases. At the meeting FMCSA reported that it has also established a review panel to make final determinations about critical events in cases where the results of the independent assessments differ and these differences cannot be resolved. This is commendable. Nevertheless, FMCSA should identify the members of the review panel and document the procedures used by the panel to make final determinations.

The agency discussed its plans to examine likely crash causes on the basis of statistical association and relative risk in the aggregate data, as well as case-by-case assessments. (A relative risk calculation regarding brake violations and crashes based on truck crash data collected in Michigan is described in Appendix B, pp. 17–18.) The committee suggests that FMCSA prepare a detailed, theoretically-based analysis plan for testing hypotheses. This plan should include a list of likely causes to be examined using statistical methods; a detailed analysis scenario for each cause; and a description of analyses that will examine alternative explanations for the observed effect (e.g., the examination of other equipment problems in the brake analysis to disprove the poor driver/poor equipment alternative theory). Such a plan will help the agency determine whether additional data are needed to support these analyses. Agency staff indicated that a preliminary analysis plan would be available to the committee early in the first quarter of 2002.

Crash Event Assessment (Alternative Analysis and Data Collection Issues)

The TCCS represents an important opportunity for causal analysis using methods other than those chosen by FMCSA. Moreover, the committee previously suggested that the agency consider conducting such analyses (for example, the "but for" analysis discussed in its March 9, 2001, letter report). The potential for such alternative analyses is directly related to the depth of the investigation conducted—how far back in time the investigator pursues each possible causal chain of events for each vehicle involved in a crash. It was clear for some of the cases reviewed by the task force, as well as those presented at previous committee meetings, that such causal chains had been thoroughly pursued. (In one case, for example, the event chain went back in time from a rear-end crash to the failure of the driver to reduce speed at the top of a hill to an incomplete or unsuccessful brake repair which the driver was aware of.) The committee urges FMCSA and NHTSA to reinforce in their instructions to investigators the need to examine these event chains thoroughly for each vehicle and driver and to include this information in the database and in the narratives.

In some cases reviewed by the task force, there appeared to be data—potentially useful for current FMCSA analysis and for future agency and independent efforts to reconstruct the crashes more completely—that could have been collected but were not. These data were related to vehicle components and vehicle dynamics of the crash and they included brake condition, measurements of skid marks, and objective estimates of precrash speeds based on physical evidence at the crash scene. Agency staff indicated that they would instruct their investigators on the need and methods for collecting such data and for analyzing the data when necessary to identify the most likely of several possible critical events.

In addition to the data currently being collected and suggested for collection, the committee believes future alternative causal analyses would be further enhanced by recording the crash investigator's assessment of whether a defensive avoidance maneuver or preventive action could reasonably have been taken by either the truck or nontruck driver to avoid the crash and what that maneuver or action might have been. This assessment could be based solely on the investigator's judgment in light of the crash data file and could be described in the narrative that is part of every crash case file. A reasonable maneuver is one that could be taken by an average driver given the roadway and roadside environment, traffic volume, and ambient weather conditions. Judgments about potential avoidance maneuvers, while subjective, provided important information in the Indiana Tri-Level study (see Appendix B); such maneuvers were judged to be possible in one-third of the cases examined. If a similar finding applied to truck crashes, it would be very important for identification and development of countermeasures, as well as for FMCSA's enforcement and licensing/relicensing programs, especially because truck drivers can be required to undergo remedial training. In addition, the existing set of uncompleted cases should be reviewed by the investigators to determine whether avoidance maneuvers can be identified for them.

Crash Data Files

As noted above, a committee task force recently reviewed five crash case files. While these files were not yet complete—some follow-up data and interview information can take several months to obtain—the review provided the task force with a unique opportunity to become more familiar with the data being collected and the analysts' interpretations of the contributing factors involved. The review led to a set of questions that was addressed by agency staff at the meeting. The discussion of these questions is reflected throughout this report. Some specific issues are addressed in the following paragraphs.

Several committee members would like to review the five crash case files once they have been completed and entered in the database; they would also like to review additional completed files, time permitting. Agency staff pointed out that data continue to be added to the files, and data edits will take approximately 4–5 months to complete. According to agency staff, approximately 15–20 complete crash files should be available by March 15, 2002. The committee would like access to these crash files, as well as the interview forms, investigator notes, and other documents pertaining to the cases so they can be reviewed in detail. A review of completed cases will inform the committee as to what final case files look like, give members another opportunity to review the data coding and critical event decisions, and allow them to check the usability of the public crash file structure. Agency staff assured the committee that this review could be arranged.

Information attesting to the truthfulness and accuracy of data is often as important as the data itself and must be included in the database. Task force members noted their concerns about data known or suspected by the crash investigators to be erroneous. When the crash investigators know or suspect a data item is false, they make written notations to that effect on the data forms. However, agency staff informed the committee that these qualifying notes—sometimes called flags—are lost when the data are extracted from the database for release to the public. The committee strongly recommends that such qualifying information be included in the electronic database because, in its absence, future independent analysts will be unaware of such potentially false data items.

The task force review of the crash files underscored the need for calculations based on physical measurements made at the crash site to verify data and information provided by drivers or others involved in or witnessing the crashes. Even basic calculations based on tire tracks or skid marks can help verify or disprove such subjective data. NHTSA staff indicated their intention to adopt simple speed-estimating procedures so that analytical methods will be used to the extent possible in future cases.

Several committee members emphasized the need, in some cases, for accurate information on roadway geometry and related topics, including shoulder and lane widths, radius of curvature, superelevation, presence and dimensions of rumble strips, sight distance, sideslope grades, and final vehicle resting position. In certain cases it is also necessary to include information about the roadway upstream from the crash site, especially if there are questions about whether sight distance was adequate or stopping distance was a factor. Currently these items are noted only on a scaled sketch included in the crash case file. However, the committee recommends that information on critical roadway geometry be tabulated for each case and included in the database. Doing so will facilitate future analyses by FHWA and other researchers interested in the relationships between highway design and safety.

The committee inquired about the extent to which previous committee member suggestions for changes to the data forms have been adopted. Agency staff indicated that nearly every suggested change has been made. Several committee members, after a brief review of selected revised data forms, noted items that still could be improved. The committee's concern is that data items must be well defined on the forms to yield data useful for analyses. Agency staff agreed to send copies of all the data forms to each of the members. At the request of agency staff, individual committee members will continue to review the forms and provide comments. Finally, agency staff agreed to change some of the terminology in the crash event assessment form so that fault will not be inferred. For example, under driver-related factors, "decision errors" should be termed "decision factors", and "performance errors" should be termed "performance factors."

Public Access to Data

An important aspect of the TCCS is that most of the data collected will be available to the public for analysis once the project is completed. However, data obtained in interviews conducted under nondisclosure agreements with interviewees may not be released. Two important issues emerged from the discussion about public access. First, the committee understands the need to protect information that might lead to the identification of specific crashes and the individuals involved. While the agency standard and capability for protecting privacy appears to be high, it appears some information thus obtained, such as length of last sleep interval, will apparently be disclosed in an aggregated form. The rules regarding nondisclosure should be explicit and adhered to consistently or the agency risks losing the voluntary cooperation of crash-involved witnesses. Accordingly, the committee urges FMCSA and NHTSA to review their nondisclosure rules and the way interviewers explain these rules to the interviewees to ensure that data sources are well protected. The agencies should also ensure that their field investigators comply with these rules and procedures.

Second, while recognizing that privacy concerns are important, the committee believes that information critical to successful analysis by others once the data have been made public should not be withheld unnecessarily. Of concern is interview information about driver hours of service, fatigue, work compensation, working conditions, and truck ownership. Agency staff stated that when such information can be obtained from secondary sources, it will become part of the public record. In addition, FMCSA plans to prepare analyses that aggregate much of this information, thereby disclosing it in a form that does not violate nondisclosure agreements. Nevertheless, the committee urges FMCSA to find secondary sources for as many of such data items as possible; doing so will increase the amount of data released to the public and their usefulness. For example, it may be possible for FMCSA inspectors to collect information on work compensation, truck ownership, and related items from truck companies and owners, thereby reducing reliance on the driver and/or company interviews by NHTSA investigators. In many cases it will be necessary for investigators to check hours of service and sleep claims independently. The committee suggests that such independent checks be standard practice for all crash case investigations.

Study Sampling Plan

FMCSA staff noted that data collection is now under way at all 24 study sites, and while some sites are yielding crash cases at a rate within an expected range for these sites, others are falling short in this regard. Because the agency's sampling plan is critical to achieving a nationally representative sample of crashes, the committee would like to know whether the data collection effort is yielding the desired representative sample of truck crashes. Specifically, the committee would like to know how many crashes are expected each year from each site, and how these figures compare with the basic NASS sample for these sites. The committee would also like to know, from the beginning of the study and for each study site, how many truck crashes have occurred, how many crash cases are under investigation, and how many crash investigations have been completed. In addition, the committee requests that the agency categorize the crashes under investigation by type (e.g., rollover, rear end). and location (e.g., freeway, rural two-lane road, intersection). This information will provide a preliminary indication of the nature of the sample thus far and allow the crash selection methodology to be reviewed and any expected bias identified and assessed. The committee would like to have this information by January 31, 2002.

Study Report Preparations

There was considerable discussion about the potential study findings and how FMCSA plans to analyze and report them to Congress. To further ensure an adequate data collection and analysis plan, agency staff should begin preparing a strawman version of the report's expected key findings based on a coherent theoretical statement of what the possible, causal or contributing factors are and including suggested formats for tables of key data the agency expects to be able to summarize. Preparing a draft of the opening paragraphs of the executive summary for the study's final report would also be a useful exercise in this regard, since these paragraphs ultimately will provide the most important version of the study rationale and scope. Addressing these tasks now might reveal the need for additional data or analysis. As noted above, agency staff indicated that a draft analysis plan would be available for review and comment by January 31, 2002.

Future Meeting Plans

If the committee receives the completed crash case files by March 15, 2002 it plans to meet on or around June 15, 2002. This schedule will give the committee time to review the files and prepare questions for the agency. Final meeting plans will depend on when the crash case files are available.

Sincerely,

Forrest Council
Chairman
Committee for Review of the Federal Motor Carrier
Safety Administration's Truck Crash Causation Study

Enclosures

MEETING ATTENDANCE

Committee Members

Forrest Council, Chair
Michael H. Belzer
John R. Billing
Kenneth L. Campbell
James Dally (NAE)
Lindsay I. Griffin, III
Anne McCartt
Hugh W. McGee
A. James McKnight
Raymond C. Peck
Lawrence A. Shepp (NAS, IOM)
Frank R. Wilson

TRB Staff

Walter Diewald
Joseph Morris
Stephen Godwin

Liaisons and Visitors

Joseph Carra, NHTSA
Ralph Craft, FMCSA
William Gay, Volpe National Transportation Systems Center
Donald Hendricks, Veridian Engineering, Inc.
Rich Ketterer, KLD Associates, Inc.
Stephen Mavros, KLD Associates, Inc.
Michelle McMurtry, National Transportation Safety Board
James Page, Veridian Engineering, Inc.
Greg Radja, NHTSA
Richard Reed, Consultant
Terry T. Shelton, FMCSA
Seymour Stern, NHTSA
Gary Toth, NHTSA
Daniel Whitten, Transport Topics (American Trucking Association)
Robert Woodill, Veridian Engineering, Inc.

Appendix A
Review of Previous Committee Decisions

The Committee for Review of the Federal Motor Carrier Safety Administration's Truck Crash Causation Study (TCCS) was convened after FMCSA had completed the TCCS study design and just as a pilot study was beginning. [See letter report dated November 15, 2000.] Thus, before the committee became involved in the project, FMCSA had already made two key decisions about methodology that affect every committee action and recommendation. The first FMCSA decision was to team with NHTSA to utilize that agency's experience with post-crash data collection developed for the NASS (National Automotive Sampling System) program. However, NASS does not address truck crashes, the level of pre-crash data collection envisioned for the TCCS, or on-scene crash investigations that the TCCS does. Therefore, the agencies had to develop new truck-related data collection instruments, investigative processes, and record-keeping systems for the TCCS. At the committee's first meeting, agency staff encouraged committee review of the full set of TCCS data collection forms and asked for detailed suggestions from the committee regarding truck and truck operating issues. This request established an atmosphere of open discussion and interchange of ideas regarding the data collection instruments and activity that continues.

The second decision—jointly made by FMCSA and NHTSA—was to adapt the method of classifying crash data and coding crash events developed by Perchonok (see Appendix C for the agency description of the method). In the TCCS crash investigators will record the presence or absence of a wide range of data items to create individual crash data files. When a crash data file is complete, experienced crash analysts will use the Perchonok method to determine a critical event and a critical reason for the critical event, as well as the contributing factors, for each crash. While some committee members are unconvinced that the determination of the critical event is sufficiently objective, the committee has chosen to provide guidance on three specific methodological issues. First, the committee continues to review the Perchonok method in as much detail as possible and provide suggestions about data needed for its successful use in determining the critical events. Second, the committee has suggested that the agency use alternative analysis methods. Discussions about alternative methods led the agency to request the preparation of the paper by Dan Blower of the University of Michigan Transportation Research Institute included as Appendix B. The committee has also made recommendations for additional data to support alternative analysis methods. Third, the committee supports the development of a truck crash data base that will allow the use of alternative analysis methods in future analyses that will be conducted by the agency and by other researchers.

The committee has emphasized these points in open meeting discussions with agency staff and in previous letter reports. Agency staff encouraged this ongoing dialogue. Previous committee letter reports provides details on each of these points.

Appendix B

The Large Truck Crash Causation Study

Introduction

This paper will provide an explanation of the approach and methodology of the Large Truck Crash Causation Study (LTCCS). The LTCCS is a study of a nationally-representative sample of serious or fatal heavy truck crashes. The data collected will provide a detailed description of the physical events of the crash, along with an unprecedented amount of information about the vehicles, drivers, truck operators, and environment.

Roughly 5,000 medium and heavy trucks are involved in fatal traffic crashes each year; on average, 5,400 people are killed in those crashes. The purpose of the LTCCS is to advance understanding of how and why truck crashes happen in order to reduce this toll. In 1999, then-Secretary of Transportation Rodney Slater set a goal to reduce the number of fatalities in truck crashes by half within 10 years. In order to meet this ambitious goal, it will be necessary to advance on all fronts, to cast the broadest possible net for way to prevent crashes involving trucks.

The Federal Motor Carrier Safety Administration has identified four key safety areas in achieving the goal of crash reduction: commercial and passenger vehicle drivers; commercial vehicles, the roadway and environment, and motor carrier safety management practices.[1][*] The LTCCS has the potential to enhance understanding in each of the four key safety areas. The LTCCS was designed to include all elements in a traffic crash—vehicle, driver, and environment. In addition, extensive information is collected about the operator of each truck involved, including details about driver compensation, vehicle maintenance, and carrier operations.

The amount of data collected is vastly greater than any previous truck crash investigation program in the United States. The data elements were all chosen for the light they might shed on

[*] Numbers in square brackets refer to references found at the end of the paper.

factors that affect the risk of crash involvement. The objective of the analysis is not to establish culpability in each crash investigated. Ultimately, the goal of the LTCCS is to support the search for countermeasures to reduce the number of trucks involved in traffic crashes. While establishing fault in traffic crashes may point to certain solutions in preventing future crashes, countermeasures may be found everywhere. In fact, the most effective countermeasures may not be related to causes. The design of the LTCCS will support the widest possible search for countermeasures in truck crashes by providing a comprehensive set of data covering all the elements of a truck crash.

Approaches to causation: the clinical method and statistical association

To provide some background for the methodology of the LTCCS, it is useful to discuss how crash causation has been studied in the past. In this section, two general approaches to studying crash causation will be discussed to provide some context for the discussion of the LTCCS methodology. In addition, a brief discussion of the meaning of "causation" in relation to traffic crashes is offered.

In broad terms, there are two primary approaches to studying causation in traffic crashes. The first can be roughly described as the "expert" or clinical method in which experts determine the causes of particular crashes; the second method—the "statistical" approach—relies on data analysis to search for associations between various factors and increased risk of crash involvement, either in relative or absolute terms. In the clinical method, typically, multidisciplinary teams of experts study individual crashes in great detail, drawing on team members' expertise in crash reconstruction, vehicle dynamics, psychology, and other relevant disciplines. For each crash, the team members determine primary and contributing causes according to some hierarchy of causation. The resulting data can then be analyzed by statistical means to examine the association between particular causal factors and crash types and so on. But a determination of cause and relative contribution of various factors is made for each crash by the clinical judgment of the experts.

In contrast, in the "statistical" approach, "causation" is not determined at the data collection stage by researchers, however expert. The "causes" of specific crashes are not determined or assigned at any point. Instead, crash cause is defined in terms of changes in risk. Researchers attempt to collect objective data describing the crash, the environment of the crash, and the vehicles, and drivers involved. Then analysts search for associations between factors of interest and changes in the risk of crash involvement. In the "statistical" approach, cause is defined, either explicitly or implicitly, as a factor that increases crash risk.

"Risk" in this case can be measured in either absolute or relative terms. Sometimes appropriate measures of exposure are available, so absolute crash risks can be calculated. For example, travel estimates for tractor-semitrailers and tractors pulling two trailers might be available, allowing absolute rates to be calculated and the crash risks per mile traveled of the two combinations to be compared. In other cases, exposure information is not available, and the crash data is analyzed to provide conditional or relative risks.

Indiana expert approach

The best-known example of the clinical method is the Indiana Tri-level study of the causes of traffic crashes. In that study, a cause was defined as "a factor necessary or sufficient for the occurrence of the crash; had the factor not been present in the crash sequence, the crash would not have occurred." [2, page 16.] In identifying causes, the investigators applied a "but-for" test: "but for" the causal factor, the crash would not have occurred. The method of determining these "causes" was the clinical method. The Tri-level study employed an elaborate, multi-level methodology, combining police-reported data, on-scene investigation, and investigation by a multidisciplinary team of specialists. They employed a variety of analytical techniques. But the fundamental approach was to gather information about the crash and then make a clinical judgment, by a panel of experts, assigning the cause or causes of each crash.

In the Indiana approach, a framework of causes is defined. At the top level, the causes cover vehicles, drivers, and the environment. Within each of those areas, a variety of causes are defined. For example, human direct causal factors are subdivided into critical non-performance, recognition errors, decision errors, and performance errors. At the most in-depth level of investigation, an interdisciplinary team of experts collected very detailed information about the crash and identified the factor(s) that caused the crash and those that contributed to its severity. In the end, about 420 traffic crashes in one county of Indiana were investigated at the "third" or most detailed level. While the Indiana tri-level approach has been considered successful, it is not often emulated because of the heavy commitment of experts in a number of disciplines required.

At least two observations may be made about the method of assigning causes by expert analysis of traffic crashes. Since traffic crashes do not occur in an experimental setting, it is impossible for the analyst to control all relevant factors. In an experiment, the researcher can control relevant factors and then vary the factor of interest and observe the effect. If dependent variable Y varies with independent variable X and all other factors are held constant, then X may be said to “cause” Y. But the experimental approach cannot be used in studying traffic crashes for moral, ethical, and legal reasons. Instead, crashes occur, investigators sift the events for clues, and then causes are determined. But this approach is inevitably subjective, biased by the fact that a crash did occur. While the causal determinations can be extremely plausible, they cannot be verified.

The second observation to be made is that the approach requires a heavy investment in expertise for each case. Psychologists, civil and mechanical engineers, and crash reconstructionists were all employed. Only about 420 cases over four years were completed at the most in-depth level. A similar effort to cover a nationally-representative sample of heavy truck crashes would be very difficult and prohibitively expensive to execute.

National Transportation Safety Board case approach

Another approach to studying heavy truck crashes is the National Transportation Safety Board (NTSB) case approach. In these studies, individual truck crashes are investigated extensively, sometimes by a team of experts. The team typically produces a lengthy crash report, detailing the findings. In some cases, a number of similar crashes will be studied together, as for example a study of truck crashes related to tire failure a number of years ago. Essentially the methodology is for the team of experts to study the crash intensively until the reason for the crash is discovered.

While this approach results in a thorough understanding of particular crashes, it is less useful in understanding truck crashes as a general traffic safety problem. First, the selection of particular crashes to study is the not the product of systematic sampling, but is a matter of convenience or on some other ground. However selected, there is no context in which to put the NTSB-investigated crashes. If low inflation pressures are identified as the cause of the blowout that led to the crash, without a systematic sampling scheme one has no idea if this is a widespread problem, or unique to the crash investigated.

The second problem with the NTSB method is that it does not appear that investigators approach each crash with a systematic framework that is applied to all crashes. There appears to be no common set of data elements that is collected for all crashes investigated, no set of rules that guides the effort. This may be appropriate since each investigation essentially stands alone, but the lack of a systematic selection of crashes or a consistent investigative approach makes generalizing from the findings impossible. No database accumulates the results—each is unique.

The LTCCS approach

The LTCCS relies on a statistical approach to "causation," defining cause in terms of relative risk. A statistical view of causation has two elements, both of which are necessary. The first element is a statistical association between crash types and factors of interest. One analytical technique will be to show that certain factors are over-represented in certain crash types. Association is not causation, however. Statistical association itself does not indicate the direction of the causal arrows, as it were. The second element necessary to establishing a "causal" relationship is some plausible mechanism to explain how the factor relates to the crash. By providing detailed information about the physical events of a crash, data in the LTCCS will establish the necessary link between the statistical association and the physical mechanism that explains the association.

The methodology of the LTCCS collects some of the same types of data as the Indiana tri-level study, but takes an alternative approach to determining "causation." Rather than crash experts assigning causes to each crash, the LTCCS approach is based on statistical associations in the aggregate data. The crash assessment data provides information on what physically happened in the crash, including prior movements of each vehicle, the critical event in the crash, and the reason for the critical event. Basically all of the other data in the LTCCS provide the context, by providing a detailed description of the environment (road type, time of day, weather, road conditions, etc.), vehicle (weights, lengths, cargo, truck inspection, etc.), and driver (experience, driving record, fatigue, hours of service, etc.). "Causes" can be determined through the analysis of this information, by identifying associations between vehicle, driver, and environmental characteristics, and particular crash types or modes of involvement.

This approach will produce a great deal of information about what happens in truck crashes. There are many hypotheses about how various factors increase the crash risk. Many “risk increasing factors” work through physical mechanisms. Since the way the crash physically occurred is known, statistical tests can show if a particular “risk increasing factor” was overinvolved in the kind of crash where the physical mechanism could be expressed. For example, the LTCCS data will provide information about the condition of the trucks’ braking system. Crash type coding can be used to distinguish rear-end crashes in which the truck was the striking vehicle from those in which the truck was struck. Hypothesis: trucks with poor braking are overinvolved in rear-end crashes in which the truck was the striking vehicle. Using the LTCCS data, this hypothesis can be tested and the conditional probability estimated of rear-end crash involvement of poorly-braked trucks.

So did poor brakes cause these crashes? This raises directly the meaning of the word cause” in a non-experimental context. What is a “cause?” In the Oxford English Dictionary, the first definition of “cause” is “That which produces an effect; that which gives rise to any action, phenomenon, or condition.” This definition implies something like, “if a change in X produces a change in Y, X is said to be a cause of Y.”

One can observe that there is also a W that caused X, a V that caused W, a U that caused V, and so on. Every cause is itself the result of some prior cause or causes. There is no such thing as an absolute cause for an event, the identification of which satisfies and completes all inquiry. The alphabetic example just given implies a “causal chain,” but a more appropriate metaphor might be a network, since the system of cause-effect can have multiple dimensions.

Take, for example, a case that seems relatively clear-cut and simple: A tire blows out and a vehicle swerves into oncoming traffic where it collides with another vehicle. Is the blowout the cause of the resulting crash? Investigation reveals that the tire was defective. Is the defect the cause of this crash? The tire was under-inflated, allowing heat to build up and making failure more likely. Is maintenance the cause? The defect occurred because a worker made a mistake in manufacturing the tire. Is the worker the cause? Quality-control procedures failed to catch the defect. Is a poor system of quality-control the cause? And so on. But let us return to the critical event. The tire blew and then the driver lost control of his vehicle. Some experts believe that proper driving techniques may allow drivers to safely stop a vehicle with a blown tire. So is inadequate driving skill the real cause here? Or the failure in licensing procedures for not requiring this skill? In driver instruction for not teaching it? But let's back up again. The vehicle is of a particular design, for example, a particular model sport utility vehicle. The design of the vehicle is such that tire failures are more frequent or the vehicle is less controllable than others if a tire fails. So is the cause of this crash vehicle design?

Let us now move in the other temporal direction, the events that follow the blowout. We've described a network of influences that produces a vehicle, out of control, with a deflated tire. Does a crash follow? Sometimes out-of-control vehicles come safely to rest. Other times there happens to be an old trash can or a small tree in the way of the skidding vehicle. And then again, there are times when the tire happens to blow just as a fully loaded tractor-semitrailer is passing in the other direction. In each case, the outcome of the event can be dramatically different, depending on factors entirely extraneous to the deflated tire, and may even result in no crash at all.

This seemingly simple example makes two points. First is the loaded problem of identifying causes. After the First Cause, every cause is the effect of some prior cause. How far to go back through the chain, or more accurately, out through the net of cause-effect is essentially an arbitrary decision.

The second point is the inherently probabilistic nature of traffic crashes. Some of the most obvious "causes" of crashes do not invariably produce crashes, thus presenting the logical problem of a "cause" without an "effect." Alcohol obviously increases the risk of crash involvement, yet many intoxicated drivers safely navigate home every Saturday night. Running through traffic lights or stop signs are high risk behaviors, yet most do not result in a crash. These are examples of "causes" without "effects."

With such clear-cut, well-accepted causes of crashes, why no crash? The reason is the myriad of other contingencies required to produce a crash. For crashes involving more than one vehicle, something has to get another vehicle to that same bit of the space-time continuum for a collision to occur. In the case of a stop-sign runner who escaped unscathed, fortunately there was no one on the crossing road exercising his right of way at just that instant. There easily could have been. But it just so happened that no one ten minutes before (not 10 minutes and one second or nine minutes and 59 seconds, but exactly ten minutes) had to run out for a gallon of milk, or had a class to get to, or decided on a whim to go out for a ride and was feeling somewhat distracted.

So the various bad behaviors, driving errors, poorly maintained vehicles, and dangerous road conditions do not *cause* crashes, but they do *increase the risk* of crashes. A driver who ran a stop sign may not have collided with crossing traffic, but a collision is certainly much more likely running a sign rather than stopping for it. Similarly, drunk driving is much riskier than sober, even if most trips are completed safely.

The approach of the LTCCS is consistent with the probabilistic nature of traffic crashes. Analysis of the data will proceed by searching for associations between the various descriptive variables and involvements in particular types of crashes. The broad range of factors included will permit a wide range of hypotheses to be tested.

The methodology of the LTCCS also avoids the problem of determining causes for each crash. This is inherently subjective, as the authors of the Indiana study acknowledge. They also point out that there is a bias in evaluating whether a factor was "necessary" to the crash, since the crash did in fact occur. [2, page 20] This should not be take as undue criticism of the Indiana study. The area is a very difficult one. The Indiana study has been very useful in the development of the LTCCS. Their system of driver factors has been adapted for the LTCCS. However, the Indiana study has been criticized both for logical problems with the definition of "cause" employed and for the somewhat tautological nature of some of the causes assigned. [3, pages 44-45.] The representativeness of the study area is also problematic. The LTCCS is an alternative method, also with strengths and limitations. There is no single methodology that is appropriate for all questions.

Methodology

The LTCCS is essentially a *collision-avoidance* or *crash-prevention* study. The study is focused on pre-collision events rather than injury consequences. The purpose is to increase knowledge of the factors associated with heavy truck crashes. With greater understanding of the events and conditions that lead to crashes, it should be possible to devise strategies to decrease the frequency of heavy truck crashes.

The choice of data to collect was guided by the assumption that a wide variety of factors are associated with truck crashes. Accordingly, the net was cast broadly. Data collected include a detailed description of the vehicle and its condition, driver condition and experience, information about the motor carrier and type of trucking operations, and the environment at the scene of the crash. Similar and appropriate data is collected also about the non-truck vehicles and nonmotorists involved in the crash. A deliberate attempt was made to include sufficient information about vehicle, driver, and the environment so that the contribution of each could be legitimately assessed.

The focus of the data collection is on pre-crash events, rather than post-crash. Data is collected about injuries and damage, but the purpose of these data is primarily to characterize the nature of heavy truck crashes and put them in context, rather than to support, for example, a search for injury-mitigation methods.

Cases for investigation will be selected by a multistage, random selection procedure that will produce a nationally-representative sample of trucks involved in traffic crashes with serious or fatal injuries.

The approach to both data collection and analysis is structured around the view of traffic crashes as probabilistic events. The heart of the approach is to provide a good description of the physical events that lead to crashes. In this, the LTCCS adapts the method of coding accident events outlined by Kenneth Perchonok [4]. The critical event, defined as the event that immediately precipitated the crash, is determined. The immediate failure that led to that critical event, the critical reason, is also determined. A wide variety of descriptive factors is also collected on the vehicles, drivers, and environment. At this stage, no determination is made as to whether the factors are related to the events. The data collected is purely descriptive. The factors are either present (present in a certain quantity), or not. In fact, at no point in the coding of an individual cases will the relationship between a certain factor and a particular crash be determined. Instead, later statistical analysis of aggregate data will show the relationship, if any, between particular factors and particular types of crashes.

Critical Event

The "critical event" is the starting point for the data collection, as it is for the analysis. All the other data essentially builds out from the critical event. One and only one critical event is determined for each crash. The critical event is defined as the event that immediately led to the crash. It is the action or event that put the vehicles on a course such that the collision was unavoidable given reasonable driving skills and vehicle handling. [4, pp. 7, 11-13]

Examples:

- A car veers into the opposing lane and collides head-on with a truck. The critical event is the car's movement into the truck's lane. Veering into the truck's lane of travel put the vehicles on a collision course.

- A truck turns across the path of an oncoming car at an intersection. The critical event is the truck's turn across the path of the other vehicle.

- A truck fails to slow down for slower or stopped traffic. The critical event is the failure of the truck to slow down for the traffic. (If, on the contrary, a vehicle in front of the truck suddenly slammed on its brakes and the attentive truck driver could not react in time, the critical event is the sudden braking by the lead vehicle.)

The critical event is coded without regard to legal fault or culpability. Right of way is captured separately. The critical event is determined to the extent possible from the physical movement of the vehicles. Critical event can be difficult to assess in some crash configurations. For example, in the case of same direction collisions, such as rear-ends, if the striking vehicle is always coded with the critical event, then the critical event adds no more information beyond that the crash was a rear-end collision. The definition of critical event has two primary components: 1) it is the action that put the vehicles on a collision course; and 2) the collision could not be avoided by normal driving skills or vehicle handling properties. But there can be difficulty in determining whether the following vehicle had time to stop or evade, or whether the following vehicle was following too closely to respond safely to the actions of other road users.

Note that the critical event is not the "cause" of the crash.

Critical Reason

The critical reason is the immediate reason for the critical event. It is the failure that led to the critical event. [4, pp. 8, 13-17] The list of critical reasons covers driver decisions and conditions; vehicle failures; and environment conditions, including weather, roadway condition, and even highway design features. The list of critical reasons was constructed deliberately to permit the choice of any of the three primary categories of contributors—vehicle, driver, or environment.

Examples:

- A car drifts into the opposing lane and collides head-on with a truck. The critical event is the car's movement into the truck's lane. The car driver was fatigued and had fallen asleep. The critical reason is "sleep, that is, actually asleep."

- A truck turns across the path of an oncoming car at an intersection. The critical event is the truck's turn across the path of the other vehicle. The truck had the turn arrow and observed the on-coming vehicle, which he assumed would stop. The critical reason is "false assumption of other road user's actions."

- A truck fails to slow down for slower or stopped traffic. The critical event is the failure of the truck to slow down for the traffic. Most of the truck's brakes were out of adjustment and when the driver attempted to stop, his brakes failed. The critical reason is "brakes failed." If instead, the truck was following so closely it could not stop safely even with properly functioning brakes, the critical reason would be "following too closely to respond to the actions of other road users."

The critical reason is not intended to establish the "cause" of the crash, though many of the code levels look like causes. But that is not the intent of the variable, and using the variable in that way both misconstrues the variable and can mask the range of contributing factors. In the second example above, it would be clearly inadequate to say that the cause of the crash was the truck driver's exercising his right-of-way. More plausible interventions can be suggested by factors relating to the other driver. Right-of-way is captured in the data, so this avenue can be explored. And while in the last case, "brake failure" seems like a satisfying "cause" of the crash, the design of the LTCCS methodology permits more remote factors relating to the brake problem to be evaluated. For example, brake problems might be associated with responsibility for maintenance or carrier type or vehicle type. Those factors may in turn suggest targeted interventions to reduce the incidence of brake failures and associated crashes.

In other words, analysis of the data is not completed by an enumeration of the critical reasons assigned. Instead, the critical reason should be used as another bit of evidence of what happened in the crash. For example, in the case of the truck driver who exercised his right of way and turned in front of approaching traffic, the critical reason "false assumption" indicates that the driver saw the on-coming traffic and did not verify that the vehicle was going to stop.

Some researchers specifically object to "causes" such as "false assumption," in part because most of the time the assumption is warranted. [3, p. 45] But this difficulty can be resolved in how the variable is used. The critical reason is not the "cause" of the crash. It is the immediate failure that led to the critical event. The critical event is determined independently, to the extent possible, of the legal system. In the example given, the critical event is the turn, since that act put the vehicles on an unavoidable collision course. The critical reason is the explanation for the turn. If the driver saw on-coming traffic and thought it was going to stop, then "false assumption" is the logical explanation for the turn. The error is not in selecting the code, but in interpreting the selection as answering the "causal" question.

Associated Factors

A wide range of data is collected on a variety of factors. No judgment is made as to whether the factor is related to the crash. Investigators objectively record the presence or absence of the various items.

The list of factors was intended to serve two functions. The first is to provide enough information about the crash to describe it completely, permitting the range of crashes in the

LTCCS to be put in the context of other crash files and allowing the selection of meaningful subsets of cases for analysis. This can be as simple as selecting crashes by maximum injury severity in the crash or testing the representativeness of the distribution of involvements in the LTCCS against other national files.

The second function of the list of associated factors is to provide information on a wide range of factors that have been thought to be related to crash risk. For example, it has been suggested that different types of motor carrier operations may have different risks of involvement in fatigue-related crashes. Much more detail on motor carrier operations is collected in the LTCCS than is available in any other crash file. Data in the LTCCS can be used to test if, for example, truck-load carriers are overrepresented in fatigue-related crash involvements.

Analysis of the data

The LTCCS will provide much more information about truck crashes than is now available elsewhere. The events of the crash will be described in much richer detail than in any other crash data file. The LTCCS will supply unprecedented detail about the types of motor carriers, methods of payment to drivers, incidence of fatigue, recent sleep schedule, mechanical condition of vehicles, and so on for a nationally representative sample of trucks in traffic crashes. What can these data be used for? What kind of analyses can they support? These data can be used for several different types of analyses, including descriptive statistics and conditional probability calculations.

Some of these uses will be illustrated here using similar data collected by the Michigan State Police. The Motor Carrier Division (MCD) has a continuing program to collect data on fatal commercial motor vehicle (CMV) crashes in Michigan, called the Fatal Crash Complaint Team (FACT) program. The approach is similar to that of the LTCCS, though there are important differences. Since the MCD has primary responsibility for enforcement of CMV regulations, the FACT program focuses on trucks rather than passenger vehicles. Accordingly, relatively little data is collected on non-truck vehicles in the crashes. Crash type and critical event variables are similar to those in the LTCCS, but critical reason is not coded. The LTCCS collects data on the associated factors in greater depth. The FACT program also is restricted to traffic crashes in which at least one fatality occurred. However, some of the results from the FACT file can shed light on the range of analyses that the approach can support.

Distributions of events and factors

Table 1 shows recent results from the FACT data on trucks involved in fatal crashes. Just as in the LTCCS, each truck is subject to a North American Standard level 1 inspection by a CVSA-trained inspector. These inspection data are much more thorough and reliable than the vehicle defect data in virtually any other crash file. Inspectors record the condition of the vehicle prior to the crash, to the extent that can be determined. Crash damage is excluded. As an item, note that over one-third of the trucks involved in a fatal crash in Michigan would have been placed out of service if they had been inspected prior to the crash. Some type of brake problem was found in over 31% of the trucks, and violations of the light/marker/signal regulations were found in almost 25% of the trucks. Brake-related inspection items are aggregated here; more detail is available about the nature of the violation and the unit of the combination where the violation occurred.

Table 1 Inspection results: All trucks that were inspected
MSP FACT data

Inspection item	%
All log violations	13.0
All hours-of-service	3.0
All other driver violations	18.1
All brake problems	31.4
All lights/markers/etc	24.2
All air pressure/hose problems	9.4
All tire problems	14.2
All steering axle problems, including brakes	13.9
All suspension problems	10.0
All violations	65.9
All OOS items	33.8

Table 2 shows the prevalence in the FACT data of several factors that have been identified as risk factors in heavy truck crashes. The LTCCS data will provide national estimates of these and other factors that will be, at least for items like fatigue, substantially better than any currently available data.

Table 2 Factor present for the driver MSP FACT data

Condition	%
Alcohol	0.97%
Illegal drugs	1.93%
Fatigue	2.90%
Unfamiliar with area	1.21%
Driver inexperience	2.66%

It has been hypothesized that truckload carriers, at least small truckload carriers, have a higher incidence of fatigue-related crashes because of their irregular and unpredictable schedule of operation. Currently, the only crash database available that records carrier type is the Michigan FACT data. Table 3 shows the distribution of carrier type in the FACT data. Note that over 41% of motor carriers in a FACT crash were for-hire, truckload carriers, while only 7.1% were less-than-truckload.

Table 3 Carrier type FACT data

Carrier type	%
LTL	7.1
truck load	41.5
private	38.7
other	5.3
unknown	7.4
total	100.0

In only about 3% of truck drivers in the FACT data was there evidence of fatigue, but fatigued drivers were distributed unequally across carrier types. No driver for a private carrier in the FACT data was fatigued, and fewer than 4% of the drivers for truckload carriers were judged to be fatigued at the time of the crash. But fatigue was recorded for almost 15% of drivers for LTL firms in the FACT data. The data are too sparse to draw conclusions with respect to carrier type and fatigue, but they are not consistent with the hypothesis. Some measure of exposure would be ideal, but merely the distribution is interesting and even suggestive. The LTCCS will provide a much more detailed description of the truck crash population than is available anywhere else.

Finally, the FACT data records a critical event that is very similar to the approach taken in the LTCCS. Figure 1 shows a distribution of broad categories of critical events recorded for fatal truck involvements investigated by the FACT team. Again, these descriptive statistics are valuable, purely for the insight they provide into the problem of heavy truck safety. At least as a first cut, the figure gives a general guide to where to look for countermeasures to reduce the incidence of truck crashes.

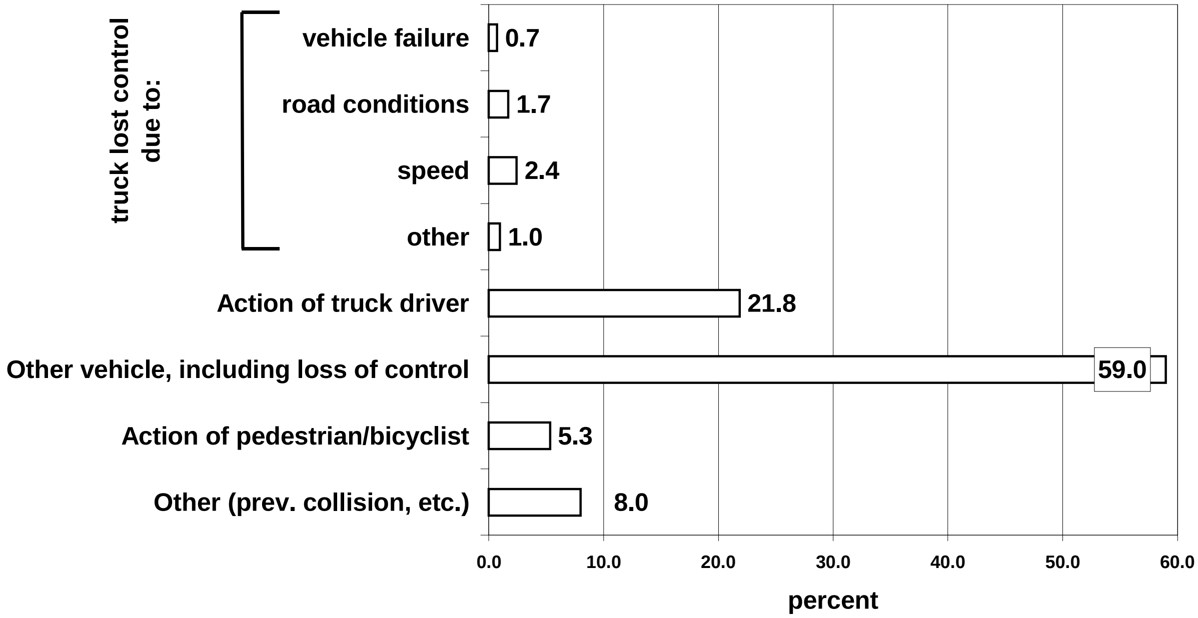

Figure 1 Critical Event
FACT data

Relative risk: involvement ratios

The most interesting way these data can be used is in testing hypotheses through conditional probability calculations. A primary component of the LTCCS methodology is to establish a relatively detailed picture of what physically happened in the crash. By incorporating this detail into the analysis, it is possible to test hypotheses that certain factors are associated with increased risk. Most of the factors of interest operate through particular mechanisms. Thus, they are more likely to be found in some crash types than others. Using the LTCCS data, one can essentially calculate conditional probabilities to measure the relative risk of involvement of driver or vehicles with certain properties in crashes where those properties should pose additional risks as compared to other vehicles/drivers without those properties.

Take, for example, hours of service (HOS) violations. HOS violations themselves do not cause crashes, just as night does not cause crashes or even excessive alcohol use. Each factor operates through a mechanism. The LTCCS will provide detail about what happened in the crash. Appropriately designed analyses can then test for over-involvement of HOS violations in that part of the crash population where they are expected. And we would not expect to find HOS violations (or not as many) in the part of the crash population where they should not be part of the causal mechanism.

If crash-involved truck drivers with HOS violations were all in vehicles stopped at a red light, rear-ended by another vehicle, there could be an overinvolvement of drivers with HOS violations, but our knowledge of the details of the crashes would make the overinvolvement appear to be spurious. On the other hand, if 30% of drivers in single vehicle crashes at night had HOS violations, compared with 20% for multiple-vehicle crashes at night, that would be consistent with the notion that HOS violations played a role in the crashes.

The FACT data provides a useful example of a relative risk calculation. To test for the association between brake violations and crashes, crashes were identified in which braking is likely critical. These crashes include rear-end crashes and crashes where the vehicles were on intersecting paths or changing trafficways (basically intersection crashes where the vehicles were on different roadways or one was turning onto a different roadway). The role of braking in rear-end crashes is clear. Intersection crashes are included because of the observation made while reviewing cases that in some crashes the truck driver decided to go through a light on yellow (or red) because he knew he didn't have enough braking to stop for the light. This led to the idea that the effect of poor brakes can include the decision not to use them at all, as well as increased stopping distances. Braking is the primary collision-avoidance method at intersections just as it is in rear-ends.

Currently, the "brake-related" crash type includes 135 involvements in the FACT data. In table 4 below, cases are divided into those where the truck violated the right-of-way (striking vehicle in a rear-end or went through the light/stop sign in the intersecting paths crashes), and those where the truck did not. In the cases where the truck had the right of way, brake condition is not immediately connected to the crash. Where the truck did not have the right-of-way, brake condition is relevant to the crash. The top half of the table shows frequencies, the bottom column percentages.

Table 4 Brake violations and braking-critical crashes MSP FACT data			
brake violations	**other braking critical**	**truck braking critical**	**total**
none	68	24	92
one or more	23	20	43
total	91	44	135
none	74.3%	54.5%	68.2%
one or more	25.7%	45.5%	31.2%
total	100.0%	100.0%	100.0%

Chi-square=5.56, 1df, prob=0.018.

Cases where the braking capacity of the truck was critical in the crash were 1.8 times more likely to have a brake violation. Roughly half had brake violations, compared with 26% of trucks involved in the same crash type but where their braking was not relevant.

One explanation for this result could be that "at-fault" trucks are poorly operated and maintained and therefore the association of brakes and "at-fault" in the crashes reflects poor operations rather than the mechanical association that is hypothesized. The relationship of each of inspection categories listed in table 1 above was tested against violating the right-of-way in "brake-related" crashes. None of the items showed any statistically significant association. Log violations showed a similar magnitude of effect, but there are insufficient cases for the association to be significant. There could be an effect for lights, but the effect is the opposite as for brakes (trucks with light/marker violations are more likely to be the vehicle with the right-of-way), the effect is not significant, and the likely causal mechanism there is conspicuity.

Thus, the analysis shows that brake violations are statistically associated with being the "at-fault" vehicle in crashes where braking is important. The association is statistically significant, of significant magnitude, and supported by a physical mechanism. This demonstrates a link between vehicle condition and crashes in trucks. The FACT data is the first data where this is possible. NTSB has done special investigations showing the link in specific crashes, but those findings are not generalizable to the crash population, while these are. The LTCCS will support precisely this type of analysis.

Limitations to the LTCCS approach

Though the purpose of this note is to argue for the usefulness of the LTCCS approach, it is important to recognize its limitations and to contrast the LTCCS approach with other methods. Each has particular strengths and weaknesses. Each can answer certain types of questions and is not suited to others.

<u>Absolute risk using VMT or some measure of exposure</u>

An analytically attractive approach is to calculate risks in terms of crash rates for factors of interest using appropriate measures of exposure. Exposure provides an explicit control, and allows absolute rates to be calculated, not risks relative to something else or conditional on crash involvement. The most common measure of exposure is vehicle miles traveled or VMT, though other metrics are in some cases more appropriate. With the appropriate measure of exposure, one could calculate the number of crash involvements per the unit of exposure, and compare the resulting rates for the factors of interest. In theory, virtually any factor could be evaluated by this means, as long as an appropriate unit of exposure could be determined and measured.

One of the weaknesses of the LTCCS approach is that it cannot evaluate factors that operate to raise crash probabilities across all subsets. For example, it is known from other work that Interstate highways have the lowest fatal involvement rates in the highway system, while rates on major arterial roads are considerably higher. While differences in collision types will be readily identifiable, the higher overall crash risk on some road types cannot be detected using crash data alone.

Exposure data, however, can be very difficult and expensive to collect, often much more so than the crash data they are used with. In a study as broad-ranging as the LTCCS, it is hard to imagine a single exposure survey that could provide appropriate data for all the different components. The LTCCS includes data on vehicle configuration, vehicle, weather, driver and road conditions, company type and size, and so on. An exposure study that can simultaneously handle all those factors, and more, would be a mammoth undertaking. And what is the proper unit of exposure for a driver operating under pressure? However, the LTCCS will provide an accurate and detailed numerator for any exposure data that becomes available.

Alternative approaches with LTCCS data

Finally, it should be noted that the data produced by the LTCCS can support other methods of assessing "causation." The approach of the LTCCS is to collect and preserve extensive objective information about pre-crash events and detailed information about all parties in the crash. This information will be available for review by experts. For example, the Indiana tri-level "but-for" test could be applied after the fact, and "causes" assigned based on that approach to causation. Other methods of assessment of causality or countermeasures could also be supported. A strength of the LTCCS approach is to preserve accurate detailed information that does not foreclose subsequent reinterpretation.

Justification: Why take this approach rather than some other?

There are two fundamental justifications for taking the proposed approach. The first is that it is the appropriate approach for a very broad study given the current state of knowledge about truck crashes. Compared with passenger vehicles, heavy truck crash research has been neglected. For example, there is no good estimate of the number of truck drivers in the country. The best estimates for the number of trucks and trailers comes from the Vehicle Inventory and Use Survey, (formerly the Truck Inventory and Use Survey) which is conducted only every five years by the Bureau of the Census. Estimates of vehicle miles traveled are limited to those published in Federal Highway Administration's *Highway Statistics*, which breaks down truck travel by only two truck configurations and roadway function class. In terms of crash statistics, trucks were dropped from the National Automotive Sampling System Crashworthiness Data System (NASS CDS) sample in 1986. The NASS General Estimates System (NASS GES) has since increased its sample of trucks, but includes only data generally available from police reports. The accuracy of its identification of trucks is unknown. The Trucks Involved in Fatal Accidents file from the University of Michigan Transportation Research Institute (UMTRI) provides a good identification and description of trucks, but the file covers only fatal crash involvements.

When completed, the LTCCS will provide a good description of the landscape of serious heavy truck crash involvements. It will provide vastly more detail in virtually every area than is now available about truck crashes. We will know much more about the types of motor carrier operations represented in traffic crashes, the mechanical condition of the trucks, the status of the drivers, and the types of crashes they are involved in. This will provide a good roadmap to further research, in some cases using the case materials collected for the LTCCS. For example, in the crash types in which brake condition was found to contribute, all those cases could be examined to determine the nature of the braking problem, whether slack adjustment, maintenance, air pressure, or some other factor.

As another example, the LTCCS will provide context and perspective on fatigue studies, measuring the size of the fatigue contribution for both truck drivers and non-truck drivers. There may be associations with types of trucking operations, maybe even associations between recent sleep schedules and types of crashes/crash precursors. This information would then provide the background for a more in-depth study of the role of fatigue.

The second justification for the approach taken in the LTCCS is feasibility. The experience of the Michigan State Police FACT team shows that this type of data can be collected with reasonable quality and at a reasonable cost. The FACT program is not perfect, the LTCCS will be more comprehensive, but the FACT data has already provided valuable insights into the problem of heavy truck crashes.

The primary next step beyond the LTCCS is to add an exposure component. But providing some measure of exposure for all the factors covered in the LTCCS is almost impossible to conceive, much less finance and execute. However, the data produced by the LTCCS may provide its own impetus for the collection of selective exposure data. This will happen in two ways. The first is that the "roadmap" to heavy truck crashes generated by the LTCCS will provide guidance as to the type of exposure information that is necessary. If vehicle condition is shown to be a considerable factor, then an appropriately randomized truck inspection study might be useful. On the other hand, if less-than-truckload drivers are much more likely to be involved in fatigue-related crashes, then exposure data of a different sort is called for.

Secondly, some results of the LTCCS will just cry out for exposure data, and thus provide a needed stimulus for its collection. With the great increase in detail about the type of trucking operations involved in traffic crashes, there could be a movement to increase the data available about population of truck operators. Some of this additional information could be readily added to at least a sample of the MCMIS carrier file and thus provide exposure data for the LTCCS.

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Appendix C

FMCSA Statement of Approach for Coding In-depth Accident Investigation Reports

The conceptual model for the in-depth accident database is taken from Kenneth Perchonok in *Accident Cause Analysis*. Perchonok describes traffic accidents as the product of causal chains, where events are linked to one another in a cause-effect relationship. Each effect serves as a cause for the next link in the chain.

Crash Event Chains

Consider a simple rear-end collision (this example is modeled on an actual fatal crash involving a heavy truck). The lead vehicle slowed to turn left into a driveway of a store's parking lot. There was no turning flare or center-left lane, so the car was slowing in the through-traffic lane. The truck driver of the following vehicle noticed some construction to his right in a mall and a sign advertising a two-for-one special at a fast food restaurant. He did not recognize that the lead vehicle was slowing until he was too close to stop safely. He braked, but couldn't stop in time and struck the lead vehicle in the rear. Cause-effect chains can be illustrated for the driver of the lead car, the driver of the following truck, and the following car itself in the table below. The arrows show the causal direction:

Lead car driver	Following truck driver	Condition of following truck
	Mall construction and eye-catching signage	failure to follow program of preventive maintenance
	activity attracts driver's attention	brakes worn
	Fails to notice slowing vehicle in time	increased stopping distance
	Brakes sharply	fails to stop in time
	Collision	

Each cause is itself the effect of some other cause. And the cause-effect chain could be extended indefinitely for each of the three factors. But all of the factors listed above had to come together to produce this particular crash. If the truck's brakes had been in better shape, it may have stopped in time or at least not hit as hard. If the trucker had been paying more attention to the roadway ahead, he would have noticed the car in front slowing. If there had been no lead car, there would have been nothing for the distracted driver to crash into. If there had been a turn lane, the car would have been out of the line of traffic. If the lead driver hadn't decided to shop at that particular store, he wouldn't have gotten into the other driver's way. And so on. Some of the examples are trivial, but the point is that traffic accidents are complex events and many things have to be present at the same time for a crash to occur.

Thinking about traffic crashes in terms of multiple cause-effect chains has two principal advantages:

First, it corresponds with our intuitive understanding of traffic accidents as complex events, in which many factors can play a role. We are not trying to find a single "cause" of a traffic accident. To use the rear-end collision above again: What is the cause of this accident? Inattentiveness by the driver of the following vehicle? Following too closely? Insufficient braking capacity? Poor maintenance? Insufficient friction from the roadway? Roadway design not up to the increased flow of traffic because of the development of the mall? Poor driving technique since he didn't attempt to steer around the stopped vehicle? Slow reaction time? The distracting signs? Many factors *contributed* to the occurrence of the accident. Which one is the *cause*? Identifying the range of factors that contributed to the crash better captures what happened than simply listing "driver inattention" or "brakes out of adjustment" as the cause.

Second, approaching traffic crashes as the product of multiple chains of events gives us a broader perspective on crash prevention. Once you start thinking about crashes as the product of many factors, you can more easily identify a variety of different ways to prevent the crash or to lessen its severity. In the example above, a better brake maintenance program might by helped lessen the severity of the crash. A forward obstacle detection system might have alerted the driver in time. Defensive driving training might have improved the drivers response. Better roadway design might have moved turning traffic into a dedicate lane, improving traffic flow.

The Critical Event

Perchonok used the concept of the *critical event* to organize the coding of accidents. He defined the critical event as the event after which the collision was unavoidable. The critical event is the action or failure to act that puts the vehicles on a course so that the collision cannot be avoided given the proximity and relative velocities of the vehicles. Turning in front of oncoming traffic can be a critical event, if there wasn't time to stop or steer around the turning vehicle. Pulling out in front of a vehicle can be a critical event, if there was no time to stop. The critical event "causes" the accident in a physical sense because, given the mechanical properties of the vehicle and roadway, there was no chance to avoid the crash after the critical event occurred.

The critical event essentially gives the researcher a place to start in analyzing a traffic accident. The idea is to start with the event after which the accident was inevitable and then build the description and related factors from that point.

The *critical reason* is the reason for the critical event. It is the "cause" of which the critical event is the result. The critical reason is the failure in the vehicle, driver, or environment that explains the critical event. For example, a driver falls asleep and runs off the road. The critical event is running off the road. The critical reason is falling asleep.

While the critical reason may be conceived of as the immediate cause of the accident, a number of other factors may be important. It is easy to imagine that for any particular critical reason, a variety of factors are related, and for each of those factors, there is another set of factors. Accordingly, a wide variety of factors are considered for in-depth accident reports.

On the other hand, it is true that the chains of events could be extended indefinitely. There is no point in the chain at which, purely from logic, all factors that conceivable could be related have been covered. So, while the list of related factors is intended to be comprehensive, it covers the current understanding of risk factors for truck crashes and the range of interventions currently considered feasible.

Sources and Variables used for the Critical Event and Critical Reason

The proposed in-depth accident database is composed of ideas and variables taken from a variety of sources. The overall concept of accident event chains is taken from Perchonok, and following him, from a methodology described by James Fell. The actual code levels for the critical event are borrowed from the National Highway Traffic Safety Administration's General Estimates System (GES). GES includes five related variables that describe the action of the vehicle prior to the critical event; the critical event; corrective action taken; vehicle control after the corrective action, and the vehicle's path after the corrective action. The GES code levels are comprehensive. Using these variables will allow comparisons with results from GES.

Coding for the critical reason essentially follows the framework of the Indiana *Tri-Level Study of the Causes of Traffic Accidents.* The *Tri-Level Study* groups related factors into driver, vehicle, and environment. For our purposes, the most important set of factors taken from the *Tri-Level Study* are those for the driver. The four primary categories of driver critical reasons are "critical non-performance," recognition errors, decision errors, and performance errors.

Critical non-performance is a "catastrophic interruption in the driver's performance," such as blacking out, falling asleep, or a heart attack, that removes the driver from any further active participation in the accident. Recognition errors include various failures to perceive or comprehend available information in a timely fashion. Decision errors are conscious decisions on vehicle control that put the driver into a situation that he could not recover from. Some of these codes have the potential to be circular. For example, "following too closely" is another way of saying "struck lead vehicle in the rear." But here the intent is to capture situations where a steady following distance had been established prior to the critical event, but the following distance was so short that an unexpected action of the lead vehicle immediately created a critical event. The final category, performance errors, refers to inadequate skills in controlling the vehicle.

Note that the critical reason is coded for both the truck and truck driver as well as the other vehicle and other vehicle's driver.

The critical event refers only to the physical movement of the vehicles involved, not which vehicle had the right-of-way at the time of the accident. There will be cases where a vehicle is assigned the critical event, yet had the right-of-way at the time of the crash. For example, a vehicle turning left on a green arrow in front of on-coming traffic had the right-of-way, but also committed the critical event in that the turn put the vehicles on a collision course. In order to address these cases as well as to sort out an important element of traffic crashes, an additional variable has been added. The variable simply records which vehicle had the right-of-way at the time of the accident. Perchonok addresses the issue with the concept of "culpability." A driver is "culpable" if he violates the expectations of a normal driver. This is reformulated here in terms of right-of-way, which can generally be determined at the scene, either from the physical configuration of the accident and its location, or established by witnesses.

Related Factors

Following the critical event and critical reason variables is a long list of "related factors." These related factors capture important characteristics of the driver, vehicle, and environment. The items on the list are taken from previous studies of accident causation and they have either been shown to increase crash risk or there are good theoretical reasons to think that they may increase crash risk. The point here is to consider all parts of the crash, i.e.,, the driver, vehicle, and environment and record the presence of any of the factors.

It is important to understand that, in this section, we are recording all factors present, *regardless of whether they contributed to this specific crash or not.* In practical terms, it is often not possible to determine all factors that contributed to a particular crash. The resources required are not available or the effect of the factor itself cannot be determined after the fact. For example, fatigue can have effects far beyond just falling asleep and running off the road. It can slow perception and reaction time, or cloud judgment. In a particular accident, fatigue *may* cause a driver to misjudge his speed or slow his perception of the movements of traffic ahead, but the evidence in a particular case is often not strong enough for the investigator to identify fatigue as causal in the crash.

At the same time, coding factors where the connection to a particular accident might not be immediately apparent allows statistical associations to be drawn. If we comprehensively collect the incidence of a factor among drivers involved in a crash, we can measure statistically whether and how much that factor increases the risk of crash involvement. We may not know that fatigue "caused" this or that crash, but we will be able to determine that fatigue raises the risk of accidents by a certain amount.

To give another example: it is clear that poor braking can contribute to traffic crashes. Some cases are very clear, as when a truck loses all braking. But there are other cases where the brakes are just out of adjustment and diminished braking capacity may or may not have contributed. It is likely that many truck drivers are aware when their truck's brakes are not fully adjusted and compensate for the longer stopping distances. A study a few years ago by the National Transportation Safety Board showed that about 45% of the trucks on the road had misadjusted brakes at that time, yet the overwhelming majority of trucks made it to their destination safely. So, does brake adjustment affect accident risk? By collecting brake adjustment data on all trucks involved in a crash, regardless of whether braking had anything to do with the crash or the role of the truck in it, it is possible to measure the effect of brake adjustment on particular types of crashes. If trucks that are rear-ended while stopped (where their own braking capacity had nothing to do with the crash) have a lower percentage of brakes out of adjustment than trucks that are rear-ending other vehicles, that is evidence that brake out-of-adjustment increases the risk of accident involvement and we can calculate the amount of the increased risk.

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