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Large Truck Crash Causation Study Analysis Series

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Methodology of the Large Truck Crash Causation Study

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Summary

The Large Truck Crash Causation Study (LTCCS) was undertaken jointly by the Federal Motor Carrier Safety Administration (FMCSA) and the National Highway Traffic Safety Administration (NHTSA). The LTCCS is based on a nationally representative sample of nearly 1,000 injury and fatal crashes involving large trucks that occurred between April 2001 and December 2003. The data collected provide a detailed description of the physical events of each crash, along with an unprecedented amount of information about all the vehicles and drivers, weather and roadway conditions, and trucking companies involved in the crashes. Because

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the goal of the study is to determine the reasons for crashes in order to develop countermeasures, the data collection was focused on pre-crash events.

The LTCCS defines "cause" as any factor that increases the risk of being involved in a crash. Many factors are commonly identified as "causes" of traffic crashes, including alcohol consumption, fatigue, and speeding. Yet those factors do not invariably, or even usually, result in crashes. It is clear, however, that such behaviors and conditions increase the risk of having a crash. Accordingly, the LTCCS study design focuses on determining the factors that increase the risk of crash involvement for large trucks.

The LTCCS methodology is based on an analysis of associations in aggregate crash data. The crash assessment coding for each crash provides information on what physically occurred in the crash, including the prior movements of each vehicle, the critical event in the crash, the reason for the critical event, and the factors associated with the crash.

Factors that increase the risk of crashes operate through physical mechanisms. For example, driver fatigue may result in a vehicle's drifting across the center line of a roadway and hitting another vehicle head-on. Because the physical way in which the crash occurred is known, statistical tests can show whether a particular "risk-increasing factor" was over-involved in the kind of crash for which a given physical mechanism—for example, head-on collision—is known. Thus, countermeasures for particular crash types or modes of involvement can be targeted by identifying associations of vehicles, drivers, and environmental characteristics with particular crash types or modes of involvement.

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Crash Causation and the Probabilistic Nature of Traffic Crashes

What is a "cause"? The Oxford English Dictionary's first definition of "cause" is "[t]hat 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, then X is said to be a cause of Y." One may also observe, however, that there is 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." A more appropriate metaphor might be a "network," in that the cause-effect system 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? The tire may have been underinflated, allowing heat to build up and making failure more likely. Is poor maintenance the cause? Alternatively, investigation may reveal that the tire was defective. Is the defect the cause of the crash? The defect in the tire may have occurred because a worker made a mistake in manufacturing the tire. Is the worker's mistake the cause? Quality control procedures may have failed to catch the defect. Is a poor system of quality control the cause? And so on.

Returning to the critical event: the tire blew, and then the driver lost control of the vehicle. Some experts believe that proper driving techniques may allow drivers safely to stop a vehicle with a blown tire. If so, is inadequate driving skill the real cause in this case? Or is it a failure of licensing procedures that do not require this skill? Or in driver instruction for not teaching it? To go back even further: the vehicle is of a particular design—for example, a particular model of sport utility vehicle. The design of the vehicle may be such that tire failures are more frequent than on other models, or the vehicle may be less controllable than other models when a tire fails. Is the vehicle design the cause of the crash?

Consider the events that follow the blowout. Does a crash necessarily follow? Sometimes an out-of-control vehicle comes safely to rest. Other times, there may happen to be some object, such as an old trash can or a small tree, in the way of the skidding vehicle. Then again, there may be times when a tire happens to blow just as a fully loaded tractor-semitrailer is passing in the other direction. The outcome of the event in each case can be dramatically different, depending on factors entirely extraneous to the deflated tire.

This simple example makes two points. First is the problem of identifying causes. After the "first cause," every other cause is the effect of some prior cause. How far to go back through the chain, or more accurately out through the network, of cause-effect is essentially a matter of judgment. Second 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 contradiction of a "cause" without an "effect." Alcohol obviously increases the risk of crash involvement, yet many intoxicated drivers navigate their vehicles safely. Running through traffic lights or stop signs is high-risk behavior, yet it does not always result in a crash. With such seemingly clear-cut, well-accepted causes of crashes, why no crash?

The examples above make it clear that the explanation lies in a number of contingencies required to produce a crash. In crashes involving more than one vehicle, both (or all) vehicles have to arrive at the same location in space and time for a collision to occur.

In the case of the stop-sign runner who has escaped unscathed, fortunately there was no one on the crossing road contesting the right-of-way at just that instant. There easily could have been.

Thus, various bad behaviors, driving errors, poorly maintained vehicles, and dangerous road conditions do not *always* produce crashes. Rather, they *increase the risk* of crashes. A driver who runs a stop sign may not collide with crossing traffic; but the risk of a collision is much higher for a driver who runs a stop sign than for a driver who stops for it. Similarly, drunk driving is much *riskier* than sober driving.

Crash Causation Research: Clinical and Statistical Approaches

Two general approaches have been employed in the study of causation in traffic crashes. The first is referred to here as the "expert" or "clinical" method, in which experts determine the causes of particular crashes. The second is referred to as the "statistical" method, which relies on data analysis to identify associations between various factors and an increased risk of crash involvement, in either relative or absolute terms.

The "clinical method" typically involves multidisciplinary teams of experts intensively studying individual crashes, drawing on team members' expertise in crash reconstruction, vehicle dynamics, psychology, and other relevant disciplines. For each crash, team members determine primary and contributing causes according to some hierarchy of causation. The resulting data can then be analyzed by statistical means to identify associations between particular causal factors and crash types, and so on. Determinations of cause and the relative contributions of various factors, however, are based on the clinical judgment of the experts.

In the "statistical method," causation is not determined by researchers at the data collection stage, regardless of their expertise. In fact, 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 in which the crash occurred, and the vehicles and drivers involved. Analysts then search for associations between factors of interest and changes in the risk of crash involvement. In this approach, a "cause" is defined either explicitly or implicitly as a factor that increases the risk of a crash.

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

Clinical Approach: The Indiana Tri-Level Study

The best-known example of the clinical method is the Indiana Tri-Level study of the causes of traffic crashes. That study defined a cause 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" [1, p. 16]. In identifying causes, investigators applied a "but for" test: *but for* the causal factor, the crash would not have occurred. "Causes" were determined by the clinical method. The Tri-Level study employed a complex, multi-level methodology, combining police-reported data, on-scene investigation, and investigation by a multidisciplinary team of specialists using a variety of analytical techniques. The fundamental approach was to gather information about crashes and then have a panel of experts make clinical judgments in assigning a cause or causes to each crash.

With the Indiana Tri-Level 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 nonperformance errors, recognition errors, decision errors, and performance errors. At the most in-depth level of investigation, an interdisciplinary team of experts collects very detailed information about the crash and identifies the factor(s) that caused it or contributed to its severity. Although the Indiana Tri-Level approach has been considered successful, it is not often emulated, because it requires a heavy commitment of experts in a number of disciplines.

At least two observations can be made about the method of assigning causes by expert analysis of traffic crashes. First, because traffic crashes do not occur in an experimental setting, it is not possible for analysts to control all relevant factors. In a true experiment, the researcher controls relevant factors, varies a factor of interest, and observes the effect. If dependent variable Y varies with independent variable X and all other factors are held constant, then the change in X may be said to "cause" the change in Y. For practical, moral, ethical, and legal reasons, however, the experimental approach cannot be used to study traffic crashes. Instead, crashes occur, investigators sift through the events for clues, and then causes are determined. This approach is inevitably subjective, and in a sense it is biased by the fact that a crash did occur. Thus, although the resulting causal determinations can be plausible and even useful, they cannot be verified.

Second, the Indiana Tri-Level study required a significant investment in expertise for each case, including psychologists, civil and mechanical engineers, and crash reconstructionists; and over a period of four years only about 420 cases were completed at the most in-depth level. Thus, in all likelihood, a similar effort to cover a nationally representative sample of large truck crashes would be not only extremely complex but also prohibitively expensive.

Clinical Approach: National Transportation Safety Board Cases

Another example of the clinical method for studying large truck crashes is the National Transportation Safety Board (NTSB) case approach. In NTSB case studies, individual truck crashes are investigated extensively, sometimes by a team of experts, until their causes are identified. The team typically produces a lengthy report on the crash, with detailed findings and recommendations. Recent examples include an investigation of a collision between a tractor-semitrailer and a motor coach [2] and a report on a tractor-semitrailer that collided with a school bus [3].

Although the NTSB clinical approach results in a thorough understanding of specific crashes, it is less useful for understanding truck crashes as a general traffic safety problem. First, the selection of specific crashes for study by the NTSB is not the product of systematic sampling but rather a matter of current interest or some other criterion, and thus it is difficult to provide a context for the crashes that are investigated. For example, if low tire pressure is identified as the cause of a blowout that led to a crash, without a systematic sampling scheme it is difficult to determine whether the problem is widespread or unique to the crash that was investigated.

Second, NTSB investigators may not apply a systematic and consistent framework to all the crashes they study. There appear to be no common set of data elements collected for all the crashes investigated and no set of rules guiding the effort. This may be appropriate, because each investigation essentially stands alone; but the lack of a systematic selection process and a consistent investigative approach makes generalizing from the findings impossible. Each case is unique, and no database accumulates the results.

Statistical Approach: Large Truck Crash Causation Study

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

The LTCCS methodology provides for collecting some of the same types of data as the Indiana Tri-Level study, but it takes an alternative approach to determining "causation." Rather than relying on experts to assign causes to each crash, the LTCCS approach is based on statistical associations in the aggregate data. The crash assessment data provide information on what physically happened in the crash, including the prior movements of each vehicle, the critical event in the crash, and the reason for the critical event. Basically, all the other data in the LTCCS provide the context, by presenting detailed descriptions of the environment (road type, time of day, weather, road conditions, etc.); vehicle (weight, length, type of cargo, date of inspection, etc.); and driver (experience, driving record, fatigue, hours of service, etc.). Risk factors can be determined through an analysis of the information that identifies associations between vehicle, driver, and environmental characteristics and a particular crash type or mode of involvement.

Many factors are hypothesized to increase crash risk. Each hypothesis is based on a mechanism that explains why the factor would increase risk. Because the way in which the crash physically occurred is known, statistical tests using the LTCCS data can show whether a particular "risk-increasing factor" was over-involved in the kind of crash where the physical mechanism could be implicated. For example, the LTCCS data provide information about the condition of the trucks' braking systems. 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. The hypothesis may be that trucks with poor braking capability are over-involved 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 for the involvement of poorly braked trucks in rear-end crashes can be estimated.

The LTCCS approach is consistent with the probabilistic nature of traffic crashes, as described above. The data are analyzed by searching for associations between the various descriptive variables and involvements in particular types of crashes. The broad range of factors included permits a wide range of hypotheses to be tested. Further, the methodology avoids the problem of determining causes for each crash. Such a determination is unavoidably subjective, as acknowledged by the authors of the Indiana Tri-Level study, who further point out that there is a bias in evaluating whether a factor was "necessary" to the crash, because the crash did in fact occur [1, p. 20].

The observations offered here about the Indiana Tri-Level study should not be taken as criticism. The study of traffic crashes is complex, and the Indiana Tri-Level study is in many ways a model of methodological transparency. Indeed, the study's system of driver factors has been adapted to the LTCCS. It should be recalled, however, that the Indiana Tri-Level study was criticized even in its own time, both for logical problems with its definition of "cause" and for the tautological nature of some of the causes assigned [4, pp. 44-45].

There is, in fact, no single methodology appropriate for all questions. The LTCCS employs an alternative method, which has its own strengths and limitations.

The LTCCS Methodology

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

The decision as to what data to collect was guided by the desire to reflect the wide variety of factors that are associated with truck crashes. Accordingly, a wide range of data were collected. 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 operation; and the environment at the scene of the crash. Similar and appropriate data on other vehicles and nonmotorists involved in the crashes to be studied are also collected. A deliberate attempt was made to include sufficient information about the vehicle, driver, and environment, so that the contribution of each could be legitimately assessed.

The focus of the LTCCS data collection is on pre-crash rather than post-crash events. Data on injuries and damage are collected, but the purpose of those data is primarily to characterize the nature of large truck crashes and put them in context, rather than to support, for example, a search for injury mitigation methods. Cases for investigation are selected by a multistage, random selection procedure to produce a nationally representative sample of large trucks involved in traffic crashes that resulted in serious or fatal injuries.

The LTCCS 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. To do this, the LTCCS has adapted the method of coding crash events outlined by Kenneth Perchonok [5]. A critical event, defined as the event that immediately precipitated the crash, is determined. The immediate failure that led to that critical event, termed the critical reason, is also determined, and a wide variety of descriptive factors for the vehicles, drivers, and environment are also obtained. At the data collection stage, no determination is made as to whether the factors produced the events. The data collected are purely descriptive; the factors are either present (or present in a certain quantity) or absent. In fact, at no point in the coding of an individual case is the relationship between a certain factor and a particular crash determined. Instead, later statistical analysis of aggregate data will show the relationship, if any, between specific factors and specific types of crashes.

Critical Event

The "critical event" is the starting point for the LTCCS data collection, as it is for the analysis. All the other data essentially build out from the critical event. The critical event is defined as the event that immediately led to the crash. One and only one critical event is determined for each crash. It is the action or event that put the vehicles on a course that made the collision unavoidable, given reasonable driving skills and vehicle handling [5, pp. 7, 11-13].

Examples:

- A car veers into the opposing lane and collides head-on with a truck, such that the truck is unable to avoid the collision. The critical event is the car's movement into the truck's lane. Veering into the truck's lane of travel puts the vehicles on a collision course.

- A truck turns across the path of an oncoming car at an intersection, and the car is unable to avoid the collision. 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, even though there is sufficient sight distance and time to permit a safe stop. The critical event is the failure of the truck to slow down for the traffic. (If, on the other hand, a vehicle in front of the truck abruptly brakes and the attentive truck driver cannot 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. It is simply the action or inaction that made the collision unavoidable. Right-of-way is captured separately. The critical event is determined to the extent possible from the physical movement of the vehicles. In many cases it will be consistent with right-of-way, but there can be some crash configurations in which the critical event is assigned to the vehicle that had the right-of-way. The critical event is not the "cause" of the crash. It is the last event in the chain leading to the collision.

The critical event can be difficult to assess in some crash configurations. For example, in the case of same-direction collisions, such as rear-end collisions, if the critical event is required to be assigned to the striking vehicle, then the critical event adds no information beyond the fact that the crash was a rear-end collision. Accordingly, the definition of critical event has two primary components: (1) it is the action that put the vehicles on a collision course; and (2) given that action, the collision could not be avoided by normal driving skills or vehicle handling properties. Clearly, it can be difficult in particular cases to determine whether the vehicle following behind another vehicle had time to stop or evade, or whether the vehicle was following too closely to respond safely to the actions of other road users.

Critical Reason

The critical reason is the immediate reason for the critical event. It describes why the critical event occurred [5, pp. 8, 13-17]. Possible critical reasons include driver decisions and conditions; vehicle failures; and environmental conditions, including weather and roadway conditions and even highway design features. The list of potential 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 "driver 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, because the critical event is assigned to the vehicle movement that made the collision inevitable. The truck had the turn arrow, observed the oncoming vehicle, and assumed that the oncoming vehicle would stop, which proved to be incorrect. (Right-of-way, which is captured separately, does not necessarily determine the critical event, because the collision may still be avoidable.) The critical reason is "false assumption of other road user's actions."

- A truck fails to slow down for traffic that is slowed or stopped. 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, the brakes failed. The critical reason is "brakes failed." If instead, the truck was following so closely that it could not stop safely even with properly functioning brakes, the critical reason is "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, although many of the code levels look like causes and could be taken as proximate causes. However, use of the critical reason variable as capturing "the cause" both misconstrues the variable and masks the range of contributing factors. Again, the ultimate purpose of the LTCCS is to establish countermeasures that will reduce the number and severity of large truck crashes. Focusing the search only on cases of legal fault would unnecessarily limit the scope of possible countermeasures.

In the second example above, it would be inadequate to say that the cause of the crash was the truck driver's exercising his or her right-of-way. More plausible interventions can be suggested by factors related to the actions of the other driver. Because right-of-way is captured in the data, this avenue can be explored. On the other hand, if truck conspicuity played a role in the driver's failure to stop, interventions to improve conspicuity could address the crash type, even though the car driver, not the truck driver, was legally at fault. In the third example, although brake failure may seem to be a sufficient cause of the crash, the LTCCS methodology permits evaluation of other, more remote factors related to the brake problem. For example, brake problems might be associated with carrier size, vehicle operations, or responsibility for maintenance. Those factors may in turn suggest targeted interventions to reduce the incidence of brake failures and associated crashes.

In other words, analysis of the LTCCS data is not completed by assigning a critical reason for a crash. The critical reason is used as one piece of evidence about what happened in the crash. For example, in the case of the truck driver who exercised right-of-way and turned in front of approaching traffic, the critical reason "false assumption" indicates that the driver saw the oncoming traffic but did not verify that the traffic was going to stop. Some researchers specifically object to critical reasons such as "false assumption," in part because many times the assumption is warranted [4, p. 45]. This difficulty can be resolved, however, in the way the variable is used. The critical reason is not the "cause" of the crash as a whole. It is the reason for the critical event. To the extent possible, the critical event is determined independently of the legal system. In this example, the critical event is the turn, because that action put the vehicles on an unavoidable collision course. The critical reason is the explanation for the turn. If the driver saw oncoming 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 question of causation.

Associated Factors

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

The list of factors is 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 or testing the representation of the distribution of involvements in the LTCCS against other national files. The second function is to provide information on a variety of factors 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. Details on motor carrier operations are collected in the LTCCS precisely to permit examination of such questions. Data in the LTCCS can be used to test, for instance, whether truckload carriers are overrepresented in fatigue-related crash involvements.

Analysis of the Data

The LTCCS provides substantially more information about truck crashes than is available elsewhere, and the events are described in greater detail than in any other crash data file. Unprecedented detail is provided about the types of motor carriers, methods of payment to drivers, incidences of fatigue, recent sleep schedules, mechanical condition of vehicles, and so on, for a nationally representative sample of large trucks involved in traffic crashes. The data can be used for several types of analyses, including descriptive statistics and conditional probability calculations.

The first step in problem identification is to find the candidate contributing factors that occur most frequently. Risk factors that occur more frequently merit further analysis to assess their contribution to collisions. Conversely, candidate risk factors that occur infrequently probably do not merit further attention, because the limited frequency will prohibit most countermeasures from being cost-effective. A significant strength of the LTCCS is that nationally representative estimates of the frequency of a wide range of candidate risk factors will be produced.

Having identified the candidate contributing factors that occur with sufficient frequency, the next step is to assess their influence on collision risk. Hypothesized relationships between candidate risk factors and collision events can be measured using conditional probability. A primary component of the LTCCS methodology is to establish a detailed picture of what occurred physically in each crash. With this detail incorporated into the analysis, it is possible to test hypotheses that associate certain factors with increased risk. Most of the factors operate through particular mechanisms; thus, they are more likely to be found in some types of crashes than in others.

The LTCCS data can be used to calculate conditional probabilities and measure the relative risks of involvement in crashes for drivers or vehicles with characteristics that are expected to pose high risk. An example is hours of service (HOS) violations. HOS violations do not in themselves cause crashes, just as night driving and excessive alcohol use do not inevitably cause crashes. Each factor, instead, operates through a mechanism to increase risk. The LTCCS can provide detail about what happened in a crash, and appropriately designed analyses can then test for over-involvement of HOS violations in certain types of crashes. One might hypothesize, for example, that truck drivers in violation of the HOS regulations are more likely to experience a critical event for which the critical reason is an action or inaction on the part of the driver rather than a vehicle failure or environmental condition. To test the hypothesis, the crash population can be divided accordingly, and the incidence of HOS violations in the two groups can be tested. If the difference is statistically significant, the hypothesis is supported. Although this is a simple example, the LTCCS data provide much additional information that will allow more complex models to be tested, including the possible effects of driver pay, carrier size, pressure from the carrier to operate, and driver fatigue, among other factors.

In addition, the data produced by the LTCCS could support clinical methods of assessing "causation." The LTCCS collects and preserves extensive objective information about pre-crash events and detailed information about all parties in the crash. This information does not foreclose subsequent reinterpretation, and it is available for review by experts. For example, the Indiana Tri-Level "but for" test could be applied after the fact, and "causes" could be assigned on the basis of that approach to crash analysis. Other methods of assessment of causality or countermeasures could also be supported.

Finally, case materials can support the collection of additional information to study particular issues. 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.

Limitations of the LTCCS Approach

One weakness of the LTCCS approach is that it is not suited for evaluating factors that operate to increase crash probabilities across all subsets of traffic crashes. For example, it is known from other analyses that fatal involvement rates on Interstate highways are lower than on major arterial roads. Although differences in the types of collisions that occur most frequently on different roadway types will be readily identifiable, the higher overall risk of crashes on some road types cannot be detected from crash data alone.

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, rather than risks that are relative to something else or conditioned on crash involvement. The most common measure of exposure is vehicle miles traveled, but other metrics are more appropriate in some cases. With the appropriate measure of exposure, one could calculate the number of crash involvements per unit of exposure and compare the resulting rates for the factors of interest. In theory, virtually any factor could be evaluated in this way, as long as an appropriate unit of exposure could be determined and measured.

Exposure data, however, can be difficult and expensive to collect—often much more so than the crash data with which they are used. In a study as broad-ranging as the LTCCS, a survey that would provide appropriate data for all the relevant components of exposure is implausible. The LTCCS includes data on vehicle type and configuration; driver, weather, and road conditions; company type and size; and so on. An exposure study that could simultaneously evaluate all those factors, and more, would be an enormous undertaking. (For example, what is the proper unit of exposure for a driver operating under pressure?) The LTCCS can, however, provide an accurate and detailed numerator for any exposure data that become available.

Conclusion

When completed, the LTCCS will provide a good description of the conditions surrounding large truck crash involvements. It will provide significantly more detail than is now available in virtually every area of truck safety. 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 in which they are involved. The results will provide a thorough foundation for further research, in some instances using the case materials collected for the LTCCS.

For example, the LTCCS will provide context and perspective on fatigue studies, measuring the extent of fatigue's contribution to crashes for both truck drivers and drivers of other vehicles. There may be statistically significant associations with certain types of trucking operations, perhaps even associations between recent sleep schedules and types of crashes or crash precursors. Such information could provide the background for a more in-depth study of the role of fatigue.

The LTCCS provides a statistically valid sample of serious crash involvements for large trucks. It provides the most comprehensive data on factors thought to be related to crash risk, which can be used to identify and evaluate a wide variety of factors believed to increase crash risk. The comprehensiveness of the data will permit the evaluation of factors remote from the immediate events of the crash and thus will support the assessment of a wide variety of countermeasures. The LTCCS should also serve as a landmark study that will help to guide future research.

Finally, the LTCCS data could also support clinical studies of 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. The information will be made available for review by experts. For example, the Indiana Tri-Level study's "but for" test could be applied after the fact, and an assignment of "causes" could be based on that approach to crash analysis. Other methods of assessing causality or countermeasures could also be supported. One of the strengths of the LTCCS approach is that it will preserve accurate, detailed information that does not foreclose subsequent reinterpretation.

1. J.R. Treat et al., *Tri-Level Study of the Causes of Traffic Crashes: Final Report, Volume I: Causal Factor Tabulations and Assessments* (Institute for Research in Public Safety, Indiana University, May 1979).

2. National Transportation Safety Board, *Collision of a Greyhound Lines, Inc. Motorcoach and Delcar Trucking Truck Tractor-Semitrailer, Loraine, Texas, June 9, 2002*, Highway Accident Report NTSB/HAR-03/01 (Washington, DC, February 26, 2003).

3. National Transportation Safety Board, *Collision Between Truck-Tractor Semitrailer and School Bus Near Mountainburg, Arkansas on May 31, 2001*, Highway Accident Report NTSB/HAR-02/03 (Washington, DC, September 4, 2002).

4. F. Haight, H. Joksch, J. O'Day, P. Waller, J. Stutts, and D. Reinfurt, *Review of Methods for Studying Pre-Crash Factors* (Highway Safety Research Center, University of North Carolina, October 1976).

5. K. Perchonok, *Accident Cause Analysis* (Cornell Aeronautical Laboratory, Inc., July 1972).

Office of Information Management

The goal of the Federal Motor Carrier Safety Administration (FMCSA) is to reduce the number and severity of large truck- and bus-involved crashes through more commercial motor vehicle and operator inspections and compliance reviews, stronger enforcement measures against violators, expedited completion of rulemaking proceedings, scientifically sound research, and effective CDL testing, recordkeeping, and sanctions.

The Office of Information Management develops and maintains systems for collecting and analyzing motor carrier data, and disseminates information on the motor carrier industry.

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