# THE LARGE TRUCK CRASH CAUSATION STUDY

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No motor vehicle crash databases in the United States focus on the causes of, or factors related to, large truck crashes. The Fatality Analysis Reporting System and Generals Estimates System, both operated by the National Highway Traffic Safety Administration (NHTSA), the Trucks Involved in Fatal Accidents database from the University of Michigan Transportation Research Institute (UMTRI), and the Motor Carrier Management Information System Crash File all collect descriptive data.

Two limited truck causation studies were conducted by the US National Transportation Safety Board. "Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes" (NTSB, 1990) examined 186 large trucks involved in crashes. "Factors that Affect Fatigue in Heavy Truck Accidents" (NTSB, 1995) analyzed 107 single-vehicle heavy truck crashes. Both studies focused narrowly on truck driver condition factors.

**Data Collection**

The Large Truck Crash Causation Study (LTCCS) was designed to be a national representative sample of large truck crashes. Data was collected at 24 data collection sites in 17 States by researchers from NHTSA's National Automotive Sampling System (NASS) and State truck inspectors. Crash data were coded in two NASS Zone Centers and reviewed by FMCSA and NHTSA personnel and national truck crash experts.

Each crash involved at least one large truck with a gross vehicle weight rating of more than 10,000 pounds, and resulted in at least one fatality or one incapacitating or non-incapacitating injury. Data were collected on up to 1,000 elements in each crash. To get the highest quality data, onsite investigations began as soon as possible after the crash occurred.

Researchers collected data at the scene through driver, passenger, and witness interviews, and drew crash scene diagrams. The truck driver interview form covered areas such as crash scene description; vehicle rollover, fire, jackknife, and cargo shift; vehicle mechanical problems; driver credentials, history, and method of wage payment; driver physical condition, including fatigue; driver errors including inattention/distraction, perception, and decisions; and trip information including intended start time, purpose, length, and route familiarity. Passenger vehicle drivers were asked the same questions, with the exception of factors that would apply only to truck drivers.

State truck inspectors conducted North American Standard Level 1 inspections. These inspections covered thirteen critical truck areas such as brakes, exhaust systems, frames, cargo securement, tires, wheels and rims, and fuel systems. The driver inspections collected data on licenses, medical cards, duty status, and log books.

After leaving the crash scene, researchers collected additional interview data by telephone from motor carriers responsible for the trucks, and surrogate drivers of trucks and other vehicles when the actual drivers could not be interviewed as a result of a fatal or serious injury. Researchers also reviewed police crash reports, hospitals records, and coroners' reports. In addition, researchers often revisited the crash scene to make more accurate scene diagrams and search for additional data.

**LTCCS Case Characteristics**

This LTCCS report includes information on 963 total crashes which included 1,123 large trucks, 959 non-truck motor vehicles, 251 fatalities, and 1,408 injuries. The LTCCS cases included 221 in which there was at least one fatality, 277 cases with at least one incapacitating injury, and 465 in which there was at least one non-incapacitating injury. Data was also collected on an additional 107 crashes, but these were excluded from the final database because they were practice cases, fell outside the parameters for inclusion, or were crashes for which researchers were not able to collect sufficient data.

One-fourth (241) of the cases involved only one truck including those that rolled over, struck an object, hit a pedestrian, or collided with a non-motorized vehicle such as a bicycle. Three-fourths of the crashes involved a collision between a least one truck and at least one other motor vehicle. Of these 488 involved two vehicles, and 234 involved more than two vehicles.

Sixty-two percent of the 1,123 trucks involved in the LTCCS crashes were tractors pulling a single semi-trailer. Single-unit or straight trucks accounted for 25 percent of the trucks, and other combination unit trucks accounted for the other 13 percent.

**National Estimates from the LTCCS data**

The remaining data in this paper present national estimates based on weighted data. During the two-year and nine-month study period of the project, NHTSA estimated that there were approximately 141,000 large trucks involved in fatal, incapacitating, and non-incapacitating injury crashes. Each of the 963 LTCCS study cases was assigned a sampling weight (based on the probability of selection into the sample for the site associated with the case) that allows for national estimates of total truck crashes, broken down by various characteristics for these 141,000 trucks.

The estimates presented may differ from true values because they are based on a probability sample of crashes and not a census of all crashes. The size of these differences may vary depending on which sample of the crashes is the focus of each particular table and analysis. A discussion of standard errors associated with estimates drawn from the LTCCS database is included in the Users Manual which is available on the FMCSA website.

Almost one-fourth (23 percent) of the crashes involved a truck hitting another vehicle in the rear or being hit by another vehicle in the rear. Eighteen percent of the crash types were crashes where a vehicle ran off the road or out of its traffic lane. Other common crashes involving other vehicles included sideswipes (15 percent), turning across the path of another vehicle (8 percent), and colliding straight

into another vehicle at an intersecting point (6 percent). Rollovers were the most common single vehicle crash type (9 percent).

## Descriptive Data Analysis

The coding of the events surrounding the crash begins with the "critical event," "critical reason" for the critical event, and "associated factors". Crashes are the probabilistic result of a range of factors. This study was designed to permit consideration of a broad range of factors that could be used to guide development of crash countermeasures. A thorough discussion of these and other issues is included in the Analysis Brief "Methodology of the Large Truck Crash Causation Study", Daniel Blower and Kenneth L. Campbell (FMCSA, 2005). To understand the analysis presented in this report, a brief review of key terms and an example follows:

- Critical Event – the event that immediately led to the crash. The critical event is the action or event which put the vehicle or vehicles on a course that made the collision unavoidable. For this paper only one vehicle in each crash is coded with a critical event.
- Critical Reason – the immediate reason for the critical event; the failure leading to the critical event. Possible critical reasons include driver errors; vehicle failures; and environmental conditions (weather and roadway). Only one critical reason is coded for each crash and it is always assigned to the vehicle with the critical event.
- Associated Factors – any condition or circumstance present at the time of the crash is coded. The factors coded are selected from a broad range of factors thought to contribute to crash risk. No judgment is made as to whether any factor is related to the particular crash, just whether it was present.

Other information on the crash events include pre-event maneuver, right of way, crash avoidance maneuvers and results, and a listing of each collision event for each vehicle in the crash. The coded factors and narrative descriptions provide enough information about the crash to describe it completely. Critical events, critical reasons, and associated factors, in and of themselves, do not describe "cause," but when considered together give a good picture of crash causation.

**Trucks in All Crashes**

While this section covers the estimated 141,000 large trucks involved in fatal and injury crashes during the course of the study, an estimated 64,000 trucks were not assigned the critical reason for their crashes. Numbers and percentages in the next two tables focus on the estimated 77,000 trucks that were coded with the crash critical reason during the 33-month study period.

Critical Events

**Table 1 – Estimated Number of Trucks in All Crashes by Critical Events where Truck was coded with the Critical Reason**

| **Events** | **Number*** | **%**** |
|---|---|---|
| Over the Lane Line or Off the Road | 25,000 | 32% |
| Control loss (Too Fast for Conditions, other) | 22,000 | 28% |
| Other Motor Vehicle in Travel Lane | 17,000 | 22% |
| Turning, Crossing an Intersection | 8,000 | 10% |
| Pedestrian/Other Non-motorist in Roadway | 2,000 | 3% |
| Other Vehicle Encroaching into Travel Lane | 1,000 | 2% |
| Other | 2,000 | 2% |
| Not Involved in First Harmful Event | *** | 1% |
| Large Trucks Coded with Critical Reason | 77,000 | 100% |
| Large Trucks Not Coded with Critical Reason | 64,000 | |
| Large Trucks Involved in All Crashes | 141,000 | |

Notes: * Estimates are rounded to the nearest 1,000.
** Percents are calculated on unrounded weighted numbers.
*** Weighted numbers lower than 500 are rounded to zero.

Source: LTCCS Database, September 2005: weighted data

Critical Reason

When the critical reason was assigned to a large truck, it was assigned to the driver in a large majority of the cases. The LTCCS codes four types of driver errors. Some examples of the specific errors:

- Non-Performance – Driver fell asleep, was disabled by a heart attack or seizure, or was physically impaired for another reason;
- Recognition – Driver did not recognize the situation as a result of inattention, distraction from inside or outside the vehicle, or failure to adequately observe the situation;
- Decision – Driver drove too fast for conditions, misjudged other vehicle speed, followed other vehicles too closely, or made false assumptions about other driver's actions; and
- Performance – Driver froze, overcompensated, or exercised poor directional control.

Table 2 presents weighted data on the critical reasons assigned to the large truck in the 963 study cases. Non-truck motor vehicles were coded with the critical reason in almost all other crashes, but the critical reason was assigned to pedestrians in a few crashes.

**Table 2 – Estimated Number of Trucks in All Crashes by Critical Reasons**

| **Reasons** | **Total*** | **%**** |
|---|---|---|
| *Driver* | | |
| Non-Performance | 9,000 | 12% |
| Recognition | 22,000 | 28% |
| Decision | 29,000 | 38% |
| Performance | 7,000 | 9% |
| *Driver Total* | 67,000 | 87% |
| *Vehicle* | 8,000 | 10% |
| *Environment* – Roadway, Weather | 2,000 | 2% |
| Unknown | *** | 0% |
| Large Trucks Coded with Critical Reason | 77,000 | 100% |
| Large Trucks Not Coded with Critical Reason | 64,000 | |
| Large Trucks Involved in All Crashes | 141,000 | |

Notes: *Estimates are rounded to the nearest 1,000.
** Percents are calculated on unrounded weighted numbers.
*** Weighted numbers lower than 500 are rounded to zero.

Source: LTCCS Database, September 2005: weighted data

A wide range of vehicle factors were coded in the study, but these factors were coded as being the critical reason for only 10 percent of the trucks in the study assigned a critical reason. The critical reasons for large trucks were concentrated in three areas: brakes, tires or wheels, and cargo shift.

Associated Factors

Approximately 1,000 associated factors were coded during the LTCCS. Table 3 presents the top 20 most coded factors, and 6 other factors of interest. Some factors listed are composites of a group of factors. For example, the brake factor includes everything from failed brakes to brakes out of adjustment. Other factors, such as driver fatigue and driving too fast for conditions, are single variable factors.

**Table 3 – Estimated Number of Trucks in All Crashes by Associated Factor**

| Top 20 Factors | Number of Trucks* | Percent** |
|---|---|---|
| ***Drivers*** | | |
| Prescription Drug Use | 37,000 | 27% |
| Traveling Too Fast For Conditions | 33,000 | 23% |
| Unfamiliar with Roadway (less than 6 times in 6 months) | 31,000 | 22% |
| Over-the-Counter Drug Use | 25,000 | 17% |
| Inadequate Surveillance | 20,000 | 13% |
| Fatigue | 18,000 | 13% |
| Under Work-Related Pressure | 13,000 | 9% |
| Illegal Maneuver | 13,000 | 9% |
| Inattention | 12,000 | 9% |
| External Distraction Factors | 11,000 | 8% |
| Inadequate Evasive Action | 9,000 | 7% |
| Aggressive Driving Behavior (tailgating, weaving, other) | 9,000 | 7% |

| **Top 20 Factors** | **Num. of Trucks*** | **Percent**** |
|---|---|---|
| Unfamiliar with Vehicle (less than 6 times in 6 months) | 9,000 | 7% |
| Following Too Closely | 7,000 | 5% |
| False Assumption of Other Road Users Actions | 7,000 | 5% |
| ***Vehicle*** | | |
| Brake Failure, out of adjustment, etc | 37.000 | 27% |
| ***Environment*** | | |
| Traffic Flow Interruption (previous crash, congestion, other) | 40,000 | 28% |
| Roadway Related Factors | 29,000 | 21% |
| Driver Required To Stop Before Crash (traffic control device, other) | 28,000 | 20% |
| Weather Related Factors | 20,000 | 14% |
| **Other Factors** | | |
| Cargo Shift | 6,000 | 4% |
| Driver Pressured to Operate Even though Fatigued | 5,000 | 3% |
| Cargo Securement | 4,000 | 3% |
| Illness | 4,000 | 3% |
| Illegal Drug Use | 3,000 | 2% |
| Alcohol Use | 1,000 | 1% |
| Notes: * Estimates are rounded to nearest 1,000.<br>** Percents are calculated on unrounded weighted numbers. | | |
| Source: LTCCS Database, September 2005; weighted data | | |

## Relative Risk Data Analysis

The remainder of this paper will discuss findings derived from relative risk analysis of the data collected. Relative risk analysis for this study is described by Blower and Campbell in their analysis brief referenced above (FMCSA, 2005) and in another analysis brief: "Using LTCCS Data for Statistical Analyses of Crash Risk", James Hedlund and Daniel Blower (FMCSA, 2006).

### Defining Causation

Motor vehicle crashes are complex events, usually involving two or more vehicles. Elements that influence the occurrence of a crash may take place hours, days, or months before the crash. They include driver training and experience, vehicle design and manufacture, highway condition and traffic signaling, and weather conditions. Other elements may take place immediately before a crash, such as a decision to turn in traffic, a tire blowout, or snow. Crash reconstruction experts rarely conclude that crashes are the result of a single factor.

Fatigue, drinking alcohol, and speeding are major factors in motor vehicle crashes. Although their presence does not always result in a crash, these three factors, as well as other driver, vehicle, and environmental factors, can increase the risk that a crash will occur. In the LTCCS, "causation" is defined in terms of the factors that are most likely to increase the risk that large trucks will be involved in serious crashes.

### Relative Risk

Relative risk analysis of the data on associated factors, using the critical event and critical reason coding, allows the sorting out of factors into those merely present at the time of the crash and those that increase the risk of having a crash. The trucks involved in LTCCS crashes can be divided into two groups: those that were assigned the critical reason and those that were not. When the presence of associated factors coded to the two groups is compared,

the relative risk of each factor can be assessed, as the following examples illustrate:

- If 30 percent of the trucks assigned the critical reason for a crash were coded with the driver associated factor "traveling too fast for conditions," while only 5 percent of the trucks that were *not* assigned the critical reason were coded with the same associated factor, it can be concluded that speed is a factor that increases the risk of being involved in a crash by a factor of six (30 divided by 5). Six would be the relative risk ratio.
- If 30 percent of the trucks assigned the critical reason for a crash were coded with the driver associated factor "prescription drug use," while 30 percent of the trucks that were *not* assigned the critical reason were also coded with the same associated factor, it can be concluded that prescription drug use is not a factor that increases the risk of being involved in a crash (30 divided by 30). The relative risk ratio of 1.0 would indicate no increased risk associated with prescription drug use.

Table 4 shows 20 associated factors that were coded most frequently for large trucks in the LTCCS, *where there was a statistically significant association between the factor and the assignment of the critical reason*. The order of the factors in the table is based on the number and percentage of trucks assessed with each factor. The relative risk number is a ratio of the critical reason coding for trucks coded with the factor, compared with trucks not coded with the factor. Thus, Table 2 shows that a truck with brake problems was 170 percent more likely to be coded with the critical reason for a crash than a truck that was not coded with the brake problems associated factor.

Of the top 10 associated factors coded for large trucks, 3 do not appear in Table 3. For those three associated factors—traffic flow interruption, prescription drug use, and required to stop before crash—there was no significant difference in the frequency at which trucks with and without the factors were coded with the critical reason for a crash.

| Table 4 – Associated Factors Coded in Large Truck Crashes and their Relative Risk Ratio | | | |
|---|---|---|---|
| **Factor Category and Factors** | **Number of Trucks** | **Percent of Total** | **Relative Risk Ratio** |
| ***Drivers*** | | | |
| Traveling too fast | 32,000 | 23% | 7.7 |
| Unfamiliar with roadway | 31,000 | 22% | 2.0 |
| OTC drug use | 25,000 | 17% | 1.3 |
| Inadequate surveillance | 20,000 | 14% | 9.3 |
| Fatigue | 18,000 | 13% | 8.0 |
| Felt under work pressure from carrier | 16,000 | 10% | 4.7 |
| Made illegal maneuver | 13,000 | 9% | 26.4 |
| Driver: inattention | 12,000 | 9% | 17.1 |
| External distraction | 11,000 | 8% | 5.1 |
| Following too close | 7,000 | 5% | 22.6 |
| Jackknife | 7,000 | 5% | 4.7 |
| Illness | 4,000 | 3% | 34.0 |
| Internal Distraction | 3,000 | 2% | 5.8 |
| Illegal Drugs | 3,000 | 2% | 1.8 |
| Alcohol | 1,000 | 1% | 5.3 |
| ***Vehicle*** | | | |
| Brake problems | 41,000 | 29% | 2.7 |
| Tire problems | 8,000 | 6% | 2.5 |
| Overweight | 7,000 | 5% | 6.3 |
| Cargo shift | 6,000 | 4% | 56.3 |
| ***Weather*** | | | |
| Roadway problems | 29,000 | 20% | 1.5 |

Source: LTCCS Database, September 2005; weighted data

The 15 driver in Table 4 factors can be divided into two major groups. One group reflects the condition of the driver before the crash such as fatigue, illness, and drug use (both legal and illegal). The other group reflects driving mistakes such as excessive speed,

inadequate surveillance, illegal maneuver, inattention, distraction (outside the truck and inside the truck), and following too close.

It is important to note both the number of times an associated factor is coded and its relative risk ratio. For example, the brake problems associated factor is the most frequently coded, but it has a lower relative risk ratio than those for 13 other factors. Pre-crash cargo shift, with the highest relative risk ratio (56.3), was reported for only four percent of the large trucks involved in LTCCS crashes.

One crude way to estimate the relative importance of the factors would be to multiply the percent of times they appear in crashes and the relative risk ratio. Using the data above the five most important factors that raise the risk of truck involvement in fatal and injury crashes are cargo shift, driver illness, making an illegal maneuver, following too close, and not paying attention.

**Large Truck – Passenger Vehicle Crashes**

Half of the crashes in the LTCCS involved at least one large truck and one passenger vehicle. For Table 5, a two-vehicle large truck-passenger vehicle crash will include the following two categories of crashes:

- crashes which involve a single truck and a single passenger vehicle, and
- crashes involving more than two vehicles where the *first two vehicles* that collide are a truck and a passenger vehicle.

For both large trucks and passenger vehicles, there was a statistically significant link between the following 14 of the 25 associated factors in Table 5, but there are some important differences. Six factors were linked to the critical reason for large trucks, but not passenger vehicles: Traffic flow interrupted, roadway problems, felt under work pressure, false assumption of other driver's action, tire problems, and following too close. Three factors were significant for trucks, but not applicable to passenger vehicles: overweight, jackknife, and cargo shift.

| Table 5 – Associated Factors Coded in Large Truck - Passenger Vehicle Crashes and their Relative Risk | | | | |
|---|---|---|---|---|
| | Large Trucks | | Passenger Vehicles | |
| **Factor Category and Factors** | **Percent of Total** | **Relative Risk Ratio** | **Percent of Total** | **Relative Risk Ratio** |
| ***Drivers*** | | | | |
| Unfamiliar with roadway | 19% | 1.6 | 10% | 3.0 |
| Inadequate surveillance | 16% | 13.5 | 14% | 5.1 |
| Traveling too fast | 15% | 6.6 | 11% | 5.2 |
| Illegal maneuver | 12% | 19.4 | 18% | 17.6 |
| Felt under work pressure | 10% | 4.5 | 3% | NS* |
| Inattention | 9% | 10.1 | 9% | 10.1 |
| External distraction | 8% | 8.0 | 6% | 1.3 |
| Fatigue | 7% | 2.9 | 15% | 11.0 |
| False assumption of other's action | 6% | 3.1 | 3% | NS* |
| Following too close | 5% | 16.0 | 1% | NS* |
| Aggressive driving | 5% | 8.9 | 9% | 3.6 |
| Misjudgment of gap or speed | 4% | 21.0 | 4% | 48.9 |
| Jackknife | 4% | 3.8 | NA* | NA* |
| In hurry | 2% | 65.5 | 4% | 9.0 |
| Internal distraction | 2% | 7.2 | 5% | 15.9 |
| Upset | 2% | 3.8 | 5% | Inf.* |
| Illness | 1% | 13% | 8% | 15.8 |
| Illegal drugs | 0.4% | NS* | 7% | 10.6 |
| Alcohol | 0.3% | NS* | 9% | 18.6 |

| Factor Category and Factors | Large Trucks | | Passenger Vehicles | |
|---|---|---|---|---|
| | Percent of Total | Relative Risk Ratio | Percent of Total | Relative Risk Ratio |
| ***Vehicle*** | | | | |
| Brake problems | 27% | 2.0 | 2% | Inf.* |
| Tire problems | 6% | 1.9 | 3% | NS* |
| Overweight | 5% | 55.5 | NA* | NA* |
| Cargo shift | 0.6% | 6.7 | NA* | NA* |
| ***Environment*** | | | | |
| Traffic Flow Interrupted | 25% | 2.2 | 25% | NS* |
| Roadway problems | 16% | 1.6 | 16% | NS* |

Notes*:

Inf. – Infinite: All of the passenger vehicle coded with brake problems and the driver being upset prior to the crash were also coded with the crash critical reason, so relative risk ratios could not be calculated.

NS - No statistically significant relationship exists between the factor and coding of the crash critical reason

NA – Factor not applicable to passenger vehicle drivers.

Source: LTCCS Database, September 2005: weighted data

Two factors were significant for the passenger vehicles, but not the large trucks: illegal drugs and alcohol. These two plus the much higher rate of fatigue mean passenger vehicle drivers carry more physical condition problems to the crash scene than truck drivers.

Multiplying the percent of a factors appearance in large truck-passenger vehicle crashes by the relative risk ratios is a crude way to reveal the most important crash risk raising factors for large trucks. In descending order the top five factors are being overweight, making an illegal maneuver, inadequate surveillance, in a hurry prior to the crash, and traveling too fast for conditions.

The mathematical calculation of relative risk ratios makes it impossible to develop a complete list of the most dangerous factors for passenger vehicles, since every passenger vehicle with brake problems or the driver coded as being upset prior to the crash were also coded with the critical reason. Among the factors were the relative risk can be calculated the five most important are making an illegal maneuver, misjudging a gap or another vehicle's speed, consuming alcohol, being fatigued, and being ill.

## Concluding Comments

More information on the LTCCS including the report to Congress, and three analysis briefs can be accessed at the study's home page: http://ai.fmcsa.dot.gov/ltccs/default.asp. In addition from the website researchers can download the public database, a users manual, and a codebook. In 2008 an XML database with individual crash files from the database will be available. Each crash case will include coded data, narrative descriptions of the crash, and over 100 pictures.

## REFERENCES

National Transportation Safety Board, *Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes*, (NTSB #SS-90/02, Washington, DC).

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