What Regulating Trucks through Glenwood Canyon Achieves and Does Not

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Spring 2026 Capstone

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May 1, 2026

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Executive Summary

Interstate 70 through Glenwood Canyon is a critical economic and mobility corridor for Colorado's Western Slope as well as the state's tourism and freight economy. Truck-involved crashes have intensified public and stakeholder concern, particularly among communities represented by the I-70 Coalition. In response, the Colorado Department of Transportation restricted trucks from the left lane through Glenwood Canyon beginning January 1, 2024.

The literature review found that truck lane restriction strategies (TLRS) improve safety outcomes across a variety of methods and contexts. Project methodology begins with descriptive statistics to compare crash data from a two-year "before" period (2022-2023) with a two-year "after" period (2024-2025) following implementation. Chi-Square and Poisson rate tests confirm that trucks are disproportionately involved in crashes relative to their proportion of traffic. When adjusted for traffic volume the post-TLRS reduction in truck crash rates is statistically significant. Statistical significance was insufficient to show that the TLRS reduced crashes involving trucks during the four year time period. The project looks briefly at closure data though it is not subject to a similar level of analysis. An established relationship between trucks and crashes beside parallel closure counts supports continued use of TLR as part of a broader data-driven safety strategy.

(Glenwood Canyon and Dotsero Closure photos by Author)

A lifeline of materials and tourism flow along I-70 connecting the Denver region to the entire Western Slope of Colorado through a series of mountain communities. As one of four east-west routes between Canada and Mexico, the 12.5-mile segment at the West end of the Rocky Mountains is strategically important to local economies and national supply chains. Each hour I-70 is closed, the cumulative cost to the state approaches "two million dollars" (CDOT, 2023 November 4). A 2007 study by the Metro Denver Economic Development Corporation, being updated for 2026 predicts "intensified congestion, leading to longer delays, reduced reliability" will "put a greater strain on the corridor through 2050," citing that "mountain resort region businesses conduct an average of $2.3 million in tourism-related transactions each workday hour" (Denver Metro EDC, 2026 p. 5). In response to dramatic truck crashes, closing Glenwood Canyon up to 12 hours, the I-70 Coalition joined community voices, urging the Colorado Department of Transportation address the problem (Isenberg, 2024; KJCT, 2022). The agency cited crash data to implement a lane restriction barring trucks from the left lane through the canyon (Ballard, 2023). Within months, the Colorado Legislature passed truck lane restrictions with SB24-100 into law adding penalties and expanding the restrictions to other locations (CDOT, 2025 December 3). The Research Question for this project asks, did truck lane restrictions reduce crashes, contributing to the desired outcome of fewer closures?

Problem Statement

Glenwood Canyon's constrained geometry - tight curves, tunnels, bridges, and limited shoulders resembles operating conditions of an urban complex freeway system despite the rural setting. Interstate 70 through Glenwood Canyon requires constant maintenance and vigilance to remain safe and operational for traffic. Celebrated in 1992, after 12 years of construction, costing $490 million (over $1.1 billion today), touted as "an incredible engineering project" the 13-mile segment of Interstate required erection of 40 elevated bridges, boring of 3 tunnel sections, and construction of 15 miles of retaining walls, (CDOT, 2026). Replacing historic, two-lane Highway 6 in 1992, Glenwood Canyon was the last four-lane segment of Interstate 70 completed through Colorado. Today it remains the only paved road connecting several counties through the Rocky Mountains. When a crash incident in Glenwood Canyon prompts a closure, the significance to national commerce, indispensability to local mobility and mountain-town economies is acutely demonstrated changing plans, routes and schedules for thousands of motorists. Bypass routes suitable for trucks require three to four additional hours additional travel along secondary state highways, suddenly congesting remote towns miles away.

Keeping traffic flowing safely through the canyon proved a challenge in the years immediately leading up to the truck lane restrictions. In August of 2020, the Grizzly Creek fire caused a two-week closure. The following year, frequent summer rains caused mudslides; the largest of which forced CDOT to deem the canyon "closed indefinitely" (Matthews, 2022 July 28; Minor, 2021, June 30; Sebastian, 2020 August 24). During the first five years following the Grizzly Creek Fire, Glenwood Canyon closed 1,039 times in one direction; defined as a "partial closure," and 215 times in both directions; defined as a "full closure" (CDOT, 2026). The canyon's extended closures are often due to nature, putting a policy focus on those that can be mitigated through policy. Especially heavy winter storms during the winter of 2022-2023 resulted in series of truck crashes seen in headlines; while complex extractions of truck wreckage required multiple cranes, inducing lengthy closures which animated community leaders and motivated CDOT Region 3 leadership into action (Appendix XI); Ballard, 2023 March 20; Sentinel Staff, 2023 January 31). The focus turned to trucks. Advocating in a letter to Governor Polis, The Town of Vail called for increased fines for truckers, estimating that ninety-nine full interstate closures in 2024 cost the town $300 million dollars (Blevins, 2025).

December of 2023, CDOT implemented truck lane restrictions (TLR). Installed over a few days by CDOT staff, eight-foot wide by twenty-foot-tall stencils with the classic red circle with a slash over the black image of a truck trailer were attached to the pavement in the left lane, accompanied by signage clamped to railings on inside and outside shoulders. Materials cost less than $30,000 (CDOT staff email). It was an elegant, cost-effective application to a very expensive problem, embraced immediately by policymakers as a solution elsewhere on the mountain corridor. The Research Question for this project leverages secondary data supplied by CDOT data to assess whether truck lane regulations through Glenwood Canyon achieved intended outcomes.

The Project Client

In 2004, twenty-eight local governments signed an Intergovernmental Agreement (IGA) establishing the I-70 Coalition to provide a collective voice to address a 50-year plan launched by CDOT to define the future of the I-70 corridor from Golden to Glenwood Springs. Eventually becoming a 501(c)3 non-profit organization, the group's mission "advocate(s) for improvements on the I-70 mountain corridor;" through "the implementation of joint public and private transportation management efforts" (I-70 Coalition, 2025). Meeting quarterly; the organization's strength is functioning as a convener, bringing together a diverse group of community stakeholders including representatives from CDOT, the Colorado State Patrol alongside industry, state legislators and congressional representatives to discuss upcoming projects, view data, deliberate, build consensus and make recommendations to the agency, occasionally promoting legislation as it did with SB24-100 which codified the Glenwood Canyon lane restrictions in law. The Coalition provides a unified voice for rural and resort communities that experience the benefit of proximity accessing a major interstate, and occasional severe impacts due to it being the only connection between many neighboring towns.

Based on a rise in the number of truck crashes, an increasing volume of overall traffic without a corresponding increase in truck volume, CDOT's decision to experiment with lane restrictions made sense. Based on visual evidence, operations policy directed at tractor-trailer trucks was not a difficult case to make, nor was the Coalitions' advocacy for SB24-100, expanding TLR geographically and with penalties. In January 2023, six separate, consecutive wrecks involving tractor trailer rigs closed the canyon. Images of truck crashes dominated newspaper headlines in the winter of 2022-2023 though truck crashes continued throughout that year even on dry roads (Appendix V, Ballard, 2023; Sentinel Staff, 2023; KJCT, 2022). The spike in dramatic truck crashes provided a clear narrative for public outrage. Prior to implementing the truck lane restrictions, CDOT Region 3 staff fielded comments from the I-70 Coalition and directly from local governments about closures impacting their communities. Reviewing crash data collected by the Colorado State Patrol, CDOT set about tracking closures of Glenwood Canyon and strategizing how to reduce incidents involving trucks. As the client, the I-70 Coalition approaches this project to understand where to focus policy and were to proceed to structure stakeholder discussions as convener and advocate for evidenced-based policies in its partnerships.

Literature Review

To inform the project's research question, the following literature review examines two interrelated bodies of research encompassing what is known about the study of truck lane restrictions. Modeling examines if operational interventions such as truck lane restrictions are effective at reducing potential accidents by adjusting variables across thousands of scenarios and analyzing potential conflicts to optimize interstate operations. Crash Data Analysis, assesses actual crashes, seeking causal relationships from collected data. Each approach provides a basis for wide ranging literature on the world-wide challenge of improving traffic safety, of which literature on truck lane restrictions is a distinct subset. For the sake of brevity, throughout, the shorthand "truck" is parlance in both research and practice, while recognizing that precise categorization of "truck" will come into play later.. To drivers, especially on narrow, winding roads, "truck" refers to a "semi," "tractor trailer," or "combination rig;" one of thousands of commercially owned, long-haul freight carrying vehicles with a separable trailer that are considerably longer, taller and heavier than the average personal vehicle.

The seminal 170-page study on traffic safety specific to lane restrictions performed in 2007 refers collectively to the field as Truck Lane Restriction Strategies, or TLRS (Liu, 2007). Academic literature on TLR or TLRS, as noted, generally divides into two categories, the eldest field concerning a study of *crashes*, with the newer field relying heavily on increasingly refined computer *simulation models* to optimize traffic operations (Choi, 2014 p. 74). Lane restriction research tends to focus on trucks as a prevalent policy target for reducing highway crashes or optimizing operations (Liu, 2007; Gayah, 2006; El-Tantawy, 2009; Choi, 2019; Zaranka, 2021;

Park, 2024; Gonah, 2025). This project narrows in on crash data, lending primary import to studies derived directly from a study of actual crashes while drawing upon the immense body of research and insights provided by modeling studies. This review begins with modeling studies before turning to classic crash studies which directly apply to the methodology and analysis.

Modeling Studies

Most operational TLRS studies seek to optimize *traffic flow* in urban freeway settings measuring micro variations in traffic speed, travel time and throughput as measures of effectiveness or MOEs (Gayah, 2006; Liu, 2007; Abdel-Aty, 2008; Lee, 2011). Operational modeling shows that truck crashes decrease when “large and ordinary vehicles (are) separated,” “rest breaks (are) implemented,” importantly showing that “lane separation by vehicle type” had the “greatest impact” of all other measures (Park, 2024 Section 5). Between restricting right lane, left lane or a dedicated truck lane, El-Tantawy found on a 3-lane freeway that separating trucks from the fastest lane was the most consistently effective measure for reducing conflict (El-Tantawy, 2009 p. 130). Later modeling studies shifted from MOEs to identifying “truck movements with potential for ‘conflict’ with other vehicles,” assessing various inputs to test reductions in conflict, clearly establishing that “truck crashes decreased when large and ordinary vehicles were separated,” that “there is a high correlation between the crash risk of large vehicles and driver fatigue,” and that “crash severity (involving trucks) is higher compared to ordinary vehicles” (Park, 2024 pp. 1, 11). “Potential conflict,” was first defined in 1977 by Amundsen and Hyden as “an observable situation in which two or more road users approach each other in time and space to such an extent that there is *a risk of collision* if their movements remain unchanged” (Liu, 2007 Section 2.3). Trucks inherently create variable conditions. They tend to travel at slower speeds than other vehicles which is why “one of the countermeasures to alleviate safety concerns for truck traffic" is to develop operation strategies to separate trucks from other vehicles with "differential speeds by vehicle type" (Garber, 1988; Choi, 2014 p. 74). Separation in distance as well as vehicle type are closely related to the severity of potential accidents. Severity is a distinct field of study. Differential speed is usually concerned with interactions *within* a lane, while differential posted speed limits for trucks (50 mph) from other vehicles (60 mph) as is posted in Glenwood Canyon is primarily concerned with separating vehicles by capability. These safety interventions are so established, differential posting of truck speeds is ubiquitous on interstates.

Reducing lane changes is a theme in many studies supporting truck lane restrictions. Ma cites "oscillation" and "shock waves" due to lane change, finding crucially that "vehicle following and lane changing…are two critical research hotspots in traffic flow" to the degree that that study concludes that "75% of traffic accidents stem from driver's lane change errors" (Ma, 2023 p. 2). How to operationalize findings from such studies is not always obvious. Fontaine found the effectiveness of TLRS to be volume dependent, finding models revealed a 50% reduction in truck involved crashes at low volumes under 10,000 Vehicles Per Day Per Lane (VPDPL is essentially AATD, but *per each lane*) while also finding that TLRS effectiveness *degraded* safety at higher volumes (Fontaine, 2009 p. 32). That interpretation suggests a clogged muti-lane interstate, but Glenwood Canyon is a two-lane highway throughout the canyon. To align VPDPL for an equivalent to AADT requires a doubling. Another top finding from a researcher that does not lend to obvious use in situations such as Glenwood Canyon, "higher ratio of the flow in the center lane to the flow in adjacent lanes and higher overall average flow ratio increase the likelihood of sideswipe crashes in the center lane" benefits from later translation in that study's conclusion section to "discouraging abrupt merging…can be suggested for reducing sideswipe crashes," which is a finding relevant to Glenwood Canyon though studied specific to conditions "downstream of an on-ramp" (Lee, 2011 pp. 119-120). Across studies, reducing the number of lane changes made by trucks is beneficial to overall traffic safety.

Crash data may note the road condition (wet, icy, dry) while some modeling studies factor variations in inches of rain, snow, or sight distance. Compared to crash studies in places like the canyon where the primary objective is safety during the incident when collecting "on the ground," modeling studies typically begin with considerably more inputs from surrounding conditions, such as average speed, lane changes, speed distribution, volume distribution between restricted and unrestricted lanes (Liu, 2007 Section 1.2). Modeling studies affirm that restricting trucks to one lane allows these larger vehicles additional time and space to accommodate differences in conditions and performance related to "limited maneuvering and braking capabilities due to weight, length and configuration" (Liu, 2007 Section 2.2; El-Tantawy, 2009 p.123). Insights from modeling studies support truck lane restriction as a tool to reduce hazardous interactions between vehicles with different capabilities, especially if driving in variable road conditions on road segments with unconventional geometry. Speed and differential speed are an entire area of traffic safety study.

Crash events are complex with many relevant factors including speed, speed variance, time to collision, as well as other human, environmental and road conditions factors, which microsimulations utilize as "surrogate measures of safety." In controlled study simulations, these factors are directly measurable with "a known relationship to traffic crash" potential (Abdel-Aty, 2008). Slower moving trucks may "impede" smaller vehicles "from navigating roads at their optimal speeds" such that many cars "may attempt to avoid or maneuver their way around trucks…(which) can cause speed differentials…that *increase the likelihood of crash*" (Gonah, 2025 p. 130). This, again, reinforces the benefits for separation of trucks as slower vehicles, because the reaction capabilities of trucks and truck drivers pertain directly to Glenwood Canyon since the numerous curves, bridges and tunnels punctuated with straight sections encourage speed variation (Illustration I). Implemented through lane, speed, time-of-day, or route controls, TLRS are particularly relevant in constrained or high-risk corridors *where differences in vehicle performance tend to increase crash potential* (Liu, 2007).

Crash analysts sometimes argue that the objective of optimizing flow in urban settings is not related to the potential for crashes in rural settings. Modeling researchers like Liu who ran 14,400 scenarios tend to argue that crash studies prior to modeling lacked direct correlations between lane restrictions separating trucks from other vehicle types with overall crash reduction (Liu, 2007 pp. 23, 58). Some modeling results that measure "conflict," as a proxy for traffic safety do prove instructive to understanding crash data across many contexts. For example, the benefit of limiting trucks to certain lanes increases "especially at higher volumes" is simply to lower the risk of "interactions, conflicts and crashes" (Gonah, 2025 p. 130). Truck lane restrictions appear to improve safety on freeways with volumes under 10,000 vehicles per day and are most effective when "truck percentage exceeds 15%" of traffic (El-Tantawy, 2009 p. 123; Fontaine, 2009 p. 32). Traffic counts in Glenwood Canyon have steadily risen from 18,500 Annual Average Daily Traffic (AADT) in 2007 to over 25,000 in 2025 with the percentage of trucks ranging from 13.3 to 14% per day through the four-year study period (Appendix II, Table II*; CDOT Station 000105, I-70 E/O SH82 Glenwood Springs, 2026*). That overall traffic volume through Glenwood Canyon has steady increased while the ratio of trucks as a percentage of overall traffic has fluctuated above and below a mean of 13.2% alongside a profound increase in the percentage of trucks involved in crashes in the canyon which suggests that the volume

Illustration I: CDOT Level of Service Map, Glenwood Canyon.

thresholds cited in multilane urban freeway models may not translate as well as some of the more generalized findings in those studies (Table II). Therefore, following Gonah and setting aside Fontaine's finding related to volume; as traffic volume continues to increase overall, when the percentage of truck traffic remains at current annual rates, truck lane restrictions should *"lower the risk of conflicts and crashes"* while optimizing flow. One of the benefits of isolating trucks with slower vehicles in the right lane is that they tend toward a uniformly slower speed as well as more uniform speed and following distance or "safe headway" according to Choi; directly applicable to the canyon, Choi states, "because truck lane restriction can make the traffic stream more homogeneous by separating trucks from other vehicles, the speed variation decreases," it is expected "larger safety benefits would be obtained if a truck lane restriction strategy was implemented on freeway segments that experience larger speed variations *under adverse weather conditions*, which also include downhill grades, *tunnels, and bridges*" (Choi, 2014 p. 79. Park, 2024 Section 4, emphasis added). Those characteristics align with conditions in Glenwood Canyon.

Crash Data Studies

One purpose of collecting crash data is that departments of transportation build Level of Service of Safety Maps (LOSS) upon that information. CDOT's LOSS identifies three sections of Glenwood Canyon as Level 4 constituting a "High Potential for Crash Reduction" (the highest category). Adjacent segments of the canyon are identified as Level 3, "Moderate to high potential for crash reduction," such that roughly half of the length of the canyon from the Eagle/Garfield County line to No Name just a couple miles from the Highway 82 exit fit Liu's definition of "constrained or high-risk corridor." Two of the LOSS Level 4 segments are on major curves in the canyon. Worth noting, Jason Smith, Region 3 Operations Director shared that according to agency analysis, truck crashes are "distributed randomly enough" that specific curves cannot be isolated as problematic to trucks (CDOT LOSS Map, Illustration I). Turning from operational data collected through modeling to crash studies, the problem is that "crash data is limited…and could take years to observe a sufficient number of crashes for reliable safety evaluation" (Li, 2026 p.1). This is one reason why researchers largely shifted from crash analysis through site-specific study to modeling with "surrogates which occur at a higher frequency" (Liu, 2007 Section 2.3).

That said, studying data collected from an actual crashes persists as the ideal for certain purposes. No modeling studies have been performed in Glenwood Canyon or were found that reflected the canyon's conditions and geometry. "Traffic crash statistics have been considered the 'gold standard' in traffic safety evaluation, since they are directly correlated to fatality, injury, property damage, and other related factors" (Li, 2026 p. 1). They are place specific.

CDOT crash data has value in building LOSS standards from actual events tracked to specific locations rather than perceived risk or data from generalized models. Another benefit of this data is that crash statistic procedures are updated infrequently, meaning they remain relatively consistent across states, jurisdictions and conditions. Federal Highway Administration published guidelines in the 1980s for studying safety using the "the traffic conflict technique" which is based on "manually observed" conflicts largely still in use (Li, 2026 p.1). That is the general framework for collecting crash data on site as it has been collected in Glenwood Canyon since 2007, "on the ground" by Colorado State Patrol and CDOT employees with the caveat that minor modifications were made to collection procedures in 2020 (Cater, 2025 pp. 21, 73, 113). Crash studies and modeling studies remain in tension without canceling mutual relevance. Some modelers point to a lack of consistency in crash data collection reducing external validity, including un-reported (no data) or underreported accidents (limited data) which is why some current preference is for automated data collection tools (Skaug, 2025 p. 2, 6, 7).

Literature supports application of truck lane restrictions in the study area. Many past traffic safety studies focused on relating crash rate (DV) to operational independent variables in regression models. That approach is limited due to the statistical limitations of calibrating variables to a specific local site due to the relative infrequency of crashes and random occurrence (Liu, 2007 Section 2.3). Sophisticated analytical techniques have since been developed utilizing crash data including variations on Empirical Bayesian regression analysis also employed by CDOT as well as many researchers in the literature (Hauer 2002; Fontaine 2009; Lee 2011; Choi 2019; Park 2024; Skaug 2025). When utilizing classic crash data, early studies warned that "accident counts that are older than 2-3 years may not represent current conditions" (Hauer, 2002 p. 127). More recently, before-and-after ratios for each of the countermeasures were a standard utilized by Choi with an analysis period of three years before the installation of a countermeasure and three years after (Choi, 2019 Section 2). The three years prior to treatment would be used, save for the symmetry of two years before and two years after.

Methodology

This research focuses on a four year range when 482 crashes occurred overall with trucks involved in 114, straddling the implementation of truck lane restrictions January 1, 2024, with two years of “before” providing a natural control group (2022-2023) and two years following the treatment providing the test group (2024-2025). The data is what CDOT utilized in their decision-making process when implementing the TLRS as secondary data for this project, the before-after structure provides a natural, quasi-experimental framework. The first level of analysis (Table I), establishes simple baseline count. Recognizing that the small population of crashes over the range provides descriptive statistics (averages and percent of totals) and basic comparative analysis (separating trucks) with limited statistical power. The second level of introduces traffic counts. The third level boosts the statistical accuracy by establishing rates (crashes to traffic volume) establishing rates. To each of these three levels, inferential statistics are then applied using null and alternative hypothesis created for each run through a Chi Square tests (A, B and C). These use the frequency of crashes prior to TLRS to test if actual truck crashes post treatment meet an indicated expected frequency in the post TLRS period. To utilize the Chi-Square tests, three null and alternative hypotheses are constructed to test the three levels. A Poisson test is then applied to test Chi-Square test C.

Each crash is a single entry in the data with site and conditions recorded as well as data related to each vehicle in an incident which are listed as Vehicle 1, Vehicle 2, and so forth. When Table I notes “non truck crashes” that means crashes that did not involve a truck as any of the numerated vehicles in that crash. In Tables II (count) and III (rate), the total of all vehicles is calculated against the truck count. A key variable throughout for the study involves vehicle type, "Trucks over 10k/busses over 15 passengers," as noted in crash data; for simplicity, shortened to "trucks." Closure data identifies CMV as a truck. CDOT emailed crash data from 2007 through 2025 to the researcher on two different occasions; first through 6 months of 2025 in January, then later the entirety of 2025. Minor changes made to data prior to 2025 in the second data pull raised a question about completeness and filtering to which CDOT staff responded that data is continually being reviewed and refined (CDOT staff email). This study distinguishes data prior

Table I

CDOT Annual Crash Event Summary - Glenwood Canyon, CO

Year	Total Crashes	Non-Truck Crashes	Truck/Bus Crashes	Truck/Bus % of Total Crashes
2025	108	78	30	27.8%
2024	111	91	20	18.0%
2023	148	109	39	26.4%
2022	115	90	25	21.7%
2024-2025	219	169	50	22.8%
2022-2023	263	199	64	24.3%
All Years (2022-2025)	482	368	114	23.7%

Raw Data Courtesy of Colorado Department of Transportation via email April 3, 2026

Each crash counts once no matter how many vehicles are involved.

to 2020 for context, reinforcing this by placing tables with the entire historic range from 2007 in Appendices, while study period data and analysis is reflected in Tables in the body of the document. Crash data is in yellow to blue-shaded tables. Closure data in green-shaded tables. The methodology progresses through four levels.

First Level: Crash Count Data. The first level of descriptive analysis involves simple comparison of crash count data pulled directly from CDOT. Shown in Table I, Crash Event Summary, the unit of measure for this level is *crashes per year* with year as the independent variable. Dependent variables include total crashes, other vehicle crashes, truck/bus crashes, and truck/bus as percent of total crashes derived from the previous two variables. This level then calculates a two-year average for each period to be analyzed. Appendix I contains corresponding count data back to 2007.

Second Level: CDOT Traffic Data Summary. The second level of analysis shown in Table II, introduces traffic counts from sensor numbered 000105 located at the west end of Glenwood Canyon. This data is framed in Table II with basic descriptive statistics, comparing trucks to overall traffic. Traffic count data was pulled directly from the CDOT website. Table II

Table II

CDOT Traffic Data Summary - Station 000105

I-70 E/O SH 82, Glenwood Springs

Year	AADT (Total)	Truck % of AADT	Truck AADT	Annual Volume	Truck Annual Volume
2025	25,800	13.3	3,431	9,417,000	1,252,315
2024	25,200	13.5	3,402	9,198,000	1,241,730
2023	24,500	13.8	3,381	8,942,500	1,234,065
2022	23,800	14.0	3,332	8,687,000	1,216,180

Source: CDOT Online Transportation Information System (OTIS)

AADT: Average Annual Daily Traffic

takes an average annual volume (AADT) to separate trucks as a percentage of the total volume of traffic. Appendix II contains corresponding data from 2007.

That data for the First and Second Levels, crashes and traffic volume derive from different sources is part of the reasoning for introducing inferential statistical methods. Crash rates in the third level of analysis are calculated (numerator- crashes, denominator – MVMT) to create an annual rate of crashes to traffic. Each of the two independent data sources have internal rigor. Combing them, it should be recognized that they utilize different collection tools and therefore not fully aligned classification of "truck," introducing an imprecision with a potential for systematic bias. AADT is an annual average that smooths out variations of season, time of day and other factors, while crashes are discreet events which may cluster around

Table III

Crash Rate Summary (per MVMT)

Canyon Segment Length: 12.5 miles (I-70 Glenwood Canyon)

Year	Total Crash Rate	Truck Crash Rate	% Difference
2025	0.92	1.92	108.9%
2024	0.97	1.29	33.5%
2023	1.32	2.53	91.0%
2022	1.06	1.64	55.3%
2024-2025	0.94	1.60	70.4%
2022-2023	1.19	2.09	75.1%
All Years (2022-2025)	1.06	1.84	73.4%

AADT = Annual Average Dail Traffic, MVMT = Million Vehicle Miles Traveled

Crash Rate = Crashes / (AADT × 365 days × 12.5 miles / 1,000,000)

Traffic data: CDOT OTIS Station 000105; Crash data: CDOT via email April 3, 2026 specific times, or conditions. To drill down with the limited crash data by month, which this project does not do might prove more accurate, if statistically weaker due to sample size. Because AADT is not a direct count, but an estimate extended across the entire canyon, the basic comparative analysis will inherently contain the potential for measurement error bias, which the next level of analysis Chi-Square tests is introduced to quantify.

Third Level: Crash Rate Summary. The third level of analysis shown in Table III, builds upon the first two levels to compare the crash rate of trucks to the crash rate of all other vehicles. Annual traffic counts are measured in Annual Average Daily Trips (AADT) to produce a crash rate per Million Vehicle Miles Traveled (MVMT), then calculated as Crash Rate = Crashes / (AADT × 365 × 12.5) / 1,000,000. Appendix II contains the corresponding crash rate data back to 2007.

Parsing the relatively small total crash population (N=482) into the subset of truck crashes or observed frequency (n=114) across 4 years introduces the challenge to statistical power. To counter this weakness, three Chi-Square "goodness of fit" tests were performed on a hypothesis created for each level of analysis. For each Chi-Square test, the pre-period rate is a base for an expected frequency that is compared to post-period observations. A weakness of the Chi-Square method is that pre-test rate is not particularly more accurate than the post data. Therefore, as a cross-check, a Poisson rate test was also performed, specifically for the instance when one Chi-Squared test failed to disprove the null hypothesis.

Ch-Square methodology was conducted as follows. First, Chi-Square Test A compares observed frequencies in the pre-period to expected frequencies in the post period to test if trucks *by count* were *equally* involved in crashes relative to their share of AADT traffic during the study period (null hypothesis) vs an alternative hypothesis that the number of trucks crashes were *disproportionate* to their ratio of overall traffic (Appendix VI). This question of trucks disproportionately represented in crashes is essentially the entry point for the research question. If they are not, then the framework of logic from the truck crashes to treatment to closures fails.

Second, another Chi-Square Test, Test B was performed comparing frequencies from the pre-period to expected frequencies from the post treatment to test if the 1.5% difference in crash count for trucks against total crash count was statistically significant. This is the core question of the research: is the difference measurable and statistically valid from before to after treatment? This establishes (or nullifies) the intended benefit of TLR in reducing truck-related crashes. The null hypothesis posed that this minor difference was due to chance. The alternative stated that it was not due to chance.

Finally, the third Chi-Square Test, Test C hypothesized the null, that the *crash rate* of trucks was the same as the crash rate of overall traffic and the alternate hypothesizing that it was not. Results from this were mixed. To weigh those mixed results, a Poisson Rate Test was also performed to test if crash counts were occurring at a rate proportional to MVMT. That produced a confidence level. The null hypothesis for Poisson Rate Test posed that the truck crash rate per MVMT is the same for both pre and post periods. A rate ratio of 1.0 with the alternative hypothesis, compares to a difference from pre and post periods with a rate ratio not equal to 1.0.

Caveats to the methodology: data collection techniques are of note. The CDOT Annual Crash Event Summary contains data collected “manually,” as it has been since 2007, by a Colorado State Patrol Officer in-person, on-site following each crash event. That officer notates each descriptive crash factor rigorously, which consists of 82 categories and 73 unique variables including eleven vehicle types,15 movement types and 5 injury levels among a trove of other collected data listed for reference in a Codebook which was not directly used in analysis but is instructive (Appendix VI). Table II contains traffic count data collected in the standard form of Average Annual Trips per Day (AADT) which is accessible to the public on the CDOT Website on OTIS, the Online Transportation Information System page under Traffic Data Explorer. By choosing a location on the webpage map the corresponding location is highlighted in a spreadsheet. The Traffic Count Sensor (TCS) for Glenwood Canyon is just east of the Glenwood Springs entrance. That TCS station also isolates "trucks," although the method with which it does so is not equivalent to "trucks over 10,000lbs/busses over 15 passengers" as the State Patrol identifies "trucks" in the crash data introducing a classification consistency issue. The sensor also counts other FWHA Vehicle Category Classifications (Appendix IV). Variations in the category "truck" between Annual Crash Event Summary data (Table I) and the Traffic Data Summary (Table II) mean that Crash Rate Summary data (Tables III and IV) introduces a classification inconsistency between the count and volume. All that said, rate is shown to be an instructive, and statistically valid tool.

Data decay is a concern related to time as well as, accuracy, relevance and completeness; CDOT's 2025 Strategic Highway Plan directly flags changes in collection prior to 2021 as well as underreporting as limitations of its own statewide crash data (Cater, 2025 p. 16, 74, 80). That caveat extends to this project which will confine data prior to 2021 to contextual use. Under-reported incidents are not a notable concern for Glenwood Canyon, which is monitored by 128 cameras observed 24-hours per day at the Hanging Lake Tunnel Operations Center.

Analysis

The literature firmly establishes that Truck Lane Restrictions (TLR) reduce crashes by separating vehicle types, mitigating speed differentials, and reducing lane-change conflicts, especially in high-risk corridors (Liu, 2007; Park, 2024; Gonah, 2024; Choi, 2014; Skaug, 2025;

El-Tantawy, 2009; Abdel-Aty, 2025). Trucks have an outsize impact on crashes which explains their prominence in the literature on traffic safety. As for the Glenwood Canyon crash data, there is a high confidence in accuracy, and completeness due to source and collection standards. Therefore, *crash* observations Glenwood Canyon are representative of actual incidents, reinforcing the reliability and internal validity of the data, particularly when comparing truck-involved crashes against total crashes. According to CDOT, it is unlikely the low frequency of crashes in the data set is a result of a crash incident going unreported or of reporting being inaccurate within a State Patrol report (Blanchette, 2025 May 16).

During the four-year study period, despite comprising only 13.7% of traffic, trucks were involved in 23.7% of all crashes (*Table I*). In the canyon, the number of crashes increased dramatically across the 15 years leading up to the study period and an upward trend of truck participation as the total percentage of crashes (Appendix I and II). The strength of this trend as context overcomes data decay and a minor caveat about an update to collection standards in 2020 cited by CDOT as discussed in the methodology section (Cater, 2025). Trucks are disproportionately represented in crashes in recent years, with the *number* of truck crashes to other *number* of vehicle crashes from 2007 to 2021 hovering around 16% (Appendix I) the study period saw a rise to 23.7% (Table I). By ratio across all years from 2007 to 2021 truck crashes are greater than total crashes by 35.3% (Appendix II) compared to the 73.4% during the study period (Table III), and roughly four times the 17.7% percent of truck crashes to overall crashes in the six years *prior* to the study period (Appendix II). In other words, trucks represented a higher percentage of total accidents until dropping in half in the six years before the study period, then quadrupling from that average. No wonder it suddenly appeared to local observers that trucks crashes were increasing dramatically through the canyon.

The crash count indicates TLR to have been effective during the study period. Put to the question, are trucks in Glenwood Canyon disproportionately involved in crashes relative to their share of the traffic, the difference is both apparent at face value (Table I), and of statistical significance (Appendix X). Chi-Squared Test A reveals a statistic of 46.893, far exceeding the critical value of 9.488; with a p-value <.001 indicating an extremely low probability that the disproportion is due to chance. Therefore, Chi-Square Test A shows that across the four study years, it is statistically established that trucks are involved in crashes at a rate disproportionate to their share of the traffic through Glenwood Canyon. This, combined with strong peer-reviewed literature provide reason enough for CDOT focus on safety strategies related to reducing the disproportionate involvement of trucks in crashes, including imposition of lane restrictions. Beyond this point, in testing if the TLR that was applied has yet proven statistically significant, the data is less conclusive.

Chi-Square Test B analysis was formulated directly to a key research question: did these truck lane restrictions reduce in this place and time during the study period reduce truck crashes? This provided a more nuanced result. The null hypothesis tested that TLR had no effect in the difference in crash counts involving trucks from before to after the treatment vs the alternate hypothesis that TLR made a difference in the crash count involving trucks. The null hypothesis could not be disproven since the Chi Square Test B statistic of .269 does not exceed the critical value or 2.81, nor is the p-value of .604 above the significance threshold (<.5%), meaning that the proportional difference of TRL after the treatment to before the implementation of TLR is "not statistically significant." Total crashes also dropped after the treatment, specifically in 2024 as shown at the bottom of Appendix VI in Section 4, which likely impacted significance. A Chi-Square test observes one frequency period creating what it would expect in another period. The pre-restriction crash rate would have expected over 65 truck crashes in the post period of 2024—2025 though only 50 occurred. That might be the final word, except that when the Chi-Square Test C was applied to *crash rate adjusted for traffic volume*, the results proved significant with a p-value of .025, well below the significance threshold (<.5%). Adjusted for traffic volume, the rate of truck crashes vs all crashes proved statistically significant. One of the weaknesses of a Chi-Squared test is that it assumes one periods expected values are fixed and known while a Poisson test recognizes that both the pre and post-test rates are derived from limited data (64 truck crashes in pre period to 50 in the post period (Appendix IX) and pools both periods to establish an expected frequency for the post period reducing the expected number to 57.5 truck crashes and a rate ratio at .76, which meets the 95% confidence threshold of < 1.0 required, but also produces a confidence level range with a lower end of .53 and an upper end of 1.11, meaning that it straddles the threshold and therefore is not statistically significant.

That these two approaches fall on either side of statistical significance reveals a challenge in putting the research question to a small data set. These significance tests imply that additional years of data collection in Glenwood Canyon may show TLR to meet statistical analysis thresholds, while underscoring that for the four years of the study period, there simply were not enough crashes to draw nuanced conclusions between types.

With that analysis in mind, looking back at Table I, it is evident that enough oscillation exists in the near-term data to give pause to making definitive, long-term conclusions. Although the years 2022, 2023 and 2025 met the Chi-Squared test for significance in the difference between truck related to overall crashes, 2024 falls short individually. Another confounding anomaly in the data, the highest year for truck overrepresentation is 2025 when trucks represented only 13.3% of traffic (Table II), while being involved in 27.8% of crashes; that the second year *after* TLR treatment which should be expected to show increased improvement instead shows an increase raises questions about the presence of outside factors (Table I). Left unanswered is the counterfactual question, “would the post treatment numbers be even higher without truck lane restrictions?” Given evidence of effectiveness and the absence of alternative explanations for the post-TLR reduction, the relatively low cost of implementing—or reversing—TLR through Glenwood Canyon supports continued deployment of Truck Lane Restriction Strategies (and ongoing tracking of data). Crashes reduced by number in Glenwood Canyon from the pre to the post TLR period, though it cannot be established that TLR was the driving factor *by count*. Without subjecting a small portion to further mincing there is a larger question that this study leaves for another day. This analysis of crashes related to trucks does not address a central concern of the I-70 Coalition to the overall question, did TRLS reduce canyon *closures*?

Canyon Closures

Canyon closures are of more direct concern to the project client than crashes (or TLRS for that matter), which is why closures were initially intended to be central to the research. Weaknesses in the closure data became readily apparent when assessing its use for project. First, a lack of literature on road closures indicated that closures *per se* are not apparently a subject of academic study. Then when the closure data was presented to the researcher a month after the initial crash data, it became readily apparent that collection, classification and tabulation methodologies differed greatly between the two. To focus on a singular treatment on a specific date, specifically intended to reduce incidents involving trucks made for a more coherent project scope.

Table IV

Glenwood Canyon Incident Closure Summary *Data Source: CDOT Raw Partial and Full Closures (1,101 incidents, 2022-2025) via CDOT staff email February 26, 2026*						
Incidents by Year and Closure Type						
Year	Full Closure	CMV (Full)	Partial Closure	CMV (Partial)	Total	CMV (Total)
2025	54	15	252	43	306	58
2024	44	16	269	36	313	52
2023	48	16	141	17	189	33
2022	47	9	246	25	293	34
Total	**193**	**56**	**908**	**121**	**1,101**	**177**
Post-Treatment (2024-2025)	**98**	**31**	**521**	**79**	**619**	**110**
Pre-Treatment (2022-2023)	**95**	**25**	**387**	**42**	**482**	**67**

The lack of alignment between two sources- crash data and closure data is worth explicating for the sake of future research. CDOT's closure data tracks Commercial Motor Vehicles (CMV), which are not a precise overlay to "trucks over 10,000 lbs./buses over 15 passengers" or any of the 13 FHWA Vehicle Classification Categories for that matter. Eight of FHWA classification categories contain vehicles often used for commercial purposes (CMV), though only four could be considered tractor trailers as depicted in Appendix V. Tractor trailers are often greater than 10,000 GVW. Worth noting, SB24-100 defines “trucks” as vehicles over 16,000 gross vehicle weight (GVW), which more precisely tracks to the 4 classifications of trucks resembling tractor trailers. Two different weight thresholds, a descriptive classification- commercial vehicles (CMV) and a set of both weight and depictive classifications in FWHA

Table V

Glenwood Canyon CMV Involvement by Incident Category

Data Source: CDOT Raw Partial and Full Closures (1,101 incidents, 2022-2025)

via CDOT staff email February 26, 2026

Category	Full Closure	CMV (Full)	Partial Closure	CMV (Partial)	Total	CMV (Total)
Traffic	45	9	593	85	617	88
Crash	93	38	188	30	241	54
Environmental	21	2	177	2	184	2
Incident Closures	23	3	5	2	27	5
Outside Agency Activity	11	4	26	2	32	4
Total	**193**	**56**	**989**	**121**	**1,101**	**153**

make for a complicated array of definitions for which "trucks" are being restricted by TLR, and which are counted in CSP crash data, traffic count sensors, or CDOT's closure data.

Second, CDOT categorizes closure incidents by type—traffic, crash, environmental, incident closure, and outside agency (Table V). CMV (trucks) appear across all five categories, not only the crash category. Incidents by category during the study period showed Traffic incidents involving a CMV at 56% of the total, Crash incidents as 21.9% of the total, with Environmental closures – for instance fires, mudslides or rockfall contributing to 16.7% of incidents by category the other 5.4% are "Incident and Outside Agency" closures. An example of categorical challenge is, for instance a disabled CMV, a HAZMAT spill, or a slide-off each triggers a closure independent of whether a crash occurs. Linking individual closure records to individual crash records would require granular case-by-case alignment, which is why CDOT went to the roadside camera data when building the closure data. Third, the literature linking truck lane restrictions specifically to closures is not evident; research on TLR focuses on crash reduction and traffic flow, not on closure frequency or duration. The crash data does not vindicate trucks from the issue of closures. The main challenge was the eventual determination that the closure data, though it looks in descriptive statistical Tables IV and V to be very similar to crash data in Tables I, II and III, it is not known if it can withstand the same inferential tests applied to crash data.

All that aside, descriptive analysis of the closure data is contextually instructive and roughly aligns with crash data. Across the four study years (2022–2025), CDOT recorded 1,101 closure incidents in Glenwood Canyon, of which 177 involved a CMV (16.1%). CMV constitute approximately 13.7% of corridor traffic (Table II), placing their share of closure incidents modestly above their share of traffic. Within the crash-category subset—the 281 closures most analogous to the crash data analyzed above—68 involved CMV (24.2%), a proportion consistent with the disproportionate truck crash involvement identified in Chi-Square Test A.

Comparing pre-TLR (2022–2023) and post-TLR (2024–2025) periods, total closure incidents rose from 482 to 619, and CMV-involved closures rose from 67 to 110. The CMV share of all closures increased from 13.9% to 17.8%. In the crash-category subset, CMV involvement held roughly steady at 23.8% pre-TLR versus 24.5% post-TLR. These figures do not support the conclusion that TLR reduced CMV-involved closures in absolute or proportional terms, though the increase in total closures crosses all categories The closure data then corroborates crash analysis in one respect: CMV appear to be disproportionately involved in incidents relative to their traffic share. It diverges in another: the pre/post TLR trend in closures does not mirror the modest improvement seen in crash rates. This divergence likely reflects the broader scope of the closure data, which captures non-crash events (disabled vehicles, debris, environmental incidents) that TLR would not be expected to address. Future research could improve on this analysis by developing a crosswalk between CDOT's CMV closure categories and CSP's crash vehicle classifications, enabling direct linkage of closure duration to specific crash events. If CMV were to be accepted as a precise equivalent to "trucks," the closure tables indicate that these vehicles involvement in closures by one means or another at 153 of the total of 1,101 closures would be significant. This study is cautious about making conclusions about closures.

Conclusions

Truck lane restrictions are a low-cost intervention with measurable safety value. CDOT should maintain truck lane restrictions and incorporate them into a broader safety strategy for reducing hazardous interactions between trucks and other vehicles. The closure problem and the crash problem cannot be addressed in isolation since structural re-engineering of the canyon or expensive infrastructure are unlikely given cost-benefit constraints, making operational and data-driven interventions the more viable path. The relative low frequency of crashes in the canyon limits generalizability and the strength of causal claims, reinforcing the need for improved data collection methods as they become available. Emerging technologies monitored in vehicle that can be tracked by nearby infrastructure—including Time-to-Collision (TTC), Space Headway (SHW), and Shockwave Speed (SWV) metrics gathered through instruments such as adaptive cruise control—are beginning to transform safety monitoring and will be especially valuable on high-risk, constrained segments like Glenwood Canyon (Barhoumi, 2024, p. 607). The camera and fiber infrastructure in the canyon also makes it a good candidate for infrastructure-to-vehicle hazard monitoring in real time. The commercial freight industry—driven by consumer demand and shaped by industry policy—should also be considered as a partner in safety strategy, given that large commercial haulers operate CMV, tractor trailer trucks. Building upon their role, the client in this project, the I-70 Coalition could become an independent source for ongoing data analysis, supporting CDOT in an evidence-based approach to improved operations. Then, when the Coalition advocates for legislative measures, such as SB24-100, and potentially extending similar interventions to other corridors with different characteristics and challenges, that advocacy would bear greater statistical weight.

Disclosure

The policy actors that had a role in pushing for safety interventions for trucks in Glenwood Canyon include local news, community leaders and the I-70 Coalition itself, which at the point of decision included the client, Jonathan Godes, who is the project client as Executive Director of the I-70 Coalition. Godes served as Mayor of the City of Glenwood Springs and was quoted in local news stories advocating restrictions on trucks during the year leading up to the lane restrictions (Ballard, February 3, 2023). The I-70 Coalition originated within the author's organization long ago. In May of 2004, the jurisdictions that signed the IGA forming the I-70 Coalition sought support from Northwest Colorado Council of Governments (NWCCOG) to organize and administer the organization before it became an independent 501(c)(3). The author of this report is the current Executive Director of NWCCOG. The idea behind this research arose at the January 8th, 2026 Quarterly meeting of the I-70 Coalition when Jason Smith, Region 3 Transportation Director for CDOT kindly agreed to provide access to the data. The researcher is grateful for the support of the Coalition an CDOT staff including Drewe Lee, CDOT Region 3 PE I, Traffic who provided Crash Data, and Trevor Allen, Supervisor for Labor Trades and Craft at CDOT who supplied the closure data.

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Appendix I

CDOT Annual Crash Event Summary - Glenwood Canyon, CO (2007-2025)

Year	Total Crashes	Other Vehicle Crashes	Truck/Bus Crashes	Truck/Bus % of Total Crashes
2025	108	78	30	27.8%
2024	111	91	20	18.0%
2023	148	109	39	26.4%
2022	115	90	25	21.7%
2021	126	100	26	20.6%
2020	106	88	18	17.0%
2019	118	97	21	17.8%
2018	102	91	11	10.8%
2017	104	86	18	17.3%
2016	73	62	11	15.1%
2015	79	67	12	15.2%
2014	141	111	30	21.3%
2013	137	109	28	20.4%
2012	152	128	24	15.8%
2011	88	75	13	14.8%
2010	133	108	25	18.8%
2009	128	112	16	12.5%
2008	158	139	19	12.0%
2007	123	102	21	17.1%
2022-2025	482	368	114	23.7%
2015-2021	708	591	117	16.5%
2007-2014	1060	884	176	16.6%
All Years (2007-2025)	2250	1843	407	18.1%

Raw Data Courtesy of Colorado Department of Transportation

via email April 3, 2026

Appendix II

CDOT Traffic Data Summary - Station 000105

I-70 E/O SH 82, Glenwood Springs, Mile Marker 118

Year	Annual Volume All Vehicles	AADT All Vehicles	Annual Truck Volume	AADT Trucks Only	Truck % of All Vehicles AADT	Truck % Over/(Under) Mean
2025	9,417,000	25,800	1,252,315	3,431	13.3	(0.0)
2024	9,198,000	25,200	1,241,730	3,402	13.5	0.2
2023	8,942,500	24,500	1,234,065	3,381	13.8	0.5
2022	8,687,000	23,800	1,216,180	3,332	14.0	0.7
2021	8,030,000	22,000	1,164,350	3,190	14.5	1.2
2020	7,117,500	19,500	1,067,625	2,925	15.0	1.7
2019	8,431,500	23,100	1,197,200	3,280	14.2	0.9
2018	8,176,000	22,400	1,144,640	3,136	14.0	0.7
2017	7,957,000	21,800	1,097,920	3,008	13.8	0.5
2016	7,738,000	21,200	1,028,935	2,819	13.3	(0.0)
2015	7,592,000	20,800	1,024,920	2,808	13.5	0.2
2014	7,373,000	20,200	973,090	2,666	13.2	(0.1)
2013	7,227,000	19,800	939,510	2,574	13.0	(0.3)
2012	7,008,000	19,200	896,805	2,457	12.8	(0.5)
2011	6,789,000	18,600	828,185	2,269	12.2	(1.1)
2010	6,643,000	18,200	797,160	2,184	12.0	(1.3)
2009	6,533,500	17,900	751,170	2,058	11.5	(1.8)
2008	6,862,000	18,800	878,190	2,406	12.8	(0.5)
2007	6,752,500	18,500	843,880	2,312	12.5	(0.8)
Mean	**7,709,184**	**21,121**	**1,030,414**	**2,823**	**13.3**	

Study period "after" dark yellow, "before" light yellow, context years alternating blue/white.

VPD (Vehicles Per Day) differs from AADT (Annual Average Daily Traffic)

Data from CDOT, Online Transportation Information System (OTIS), Traffic Data Explorer

https://dtdapps.coloradodot.info/otis/trafficdata#ui/2/0/0/station/000105/criteria/000105/

Appendix III

Crash Rate Summary (per MVMT) — All Years (2007-2025)
Canyon Segment Length: 12.5 miles (I-70 Glenwood Canyon)

Year	Total Crash Rate	Truck Crash Rate	% Difference
2025	0.92	1.92	108.9%
2024	0.97	1.29	33.5%
2023	1.32	2.53	91.0%
2022	1.06	1.64	55.3%
2021	1.26	1.79	42.3%
2020	1.19	1.35	13.2%
2019	1.12	1.40	25.3%
2018	1.00	0.77	-23.0%
2017	1.05	1.31	25.4%
2016	0.75	0.86	13.3%
2015	0.83	0.94	12.5%
2014	1.53	2.47	61.2%
2013	1.52	2.38	57.2%
2012	1.74	2.14	23.4%
2011	1.04	1.26	21.1%
2010	1.60	2.51	56.6%
2009	1.57	1.70	8.7%
2008	1.84	1.73	-6.0%
2007	1.46	1.99	36.6%
2022-2025	1.06	1.84	73.4%
2015-2021	1.03	1.21	17.7%
2007-2014	1.54	2.04	32.6%
All Years (2007-2025)	1.23	1.66	35.3%

AADT = Annual Average Daily Traffic, MVMT = Million Vehicle Miles Traveled

Crash Rate = Crashes / (AADT × 365 days × 12.5 miles / 1,000,000)
Traffic data: CDOT OTIS Station 000105; Crash data: CDOT via email April 3, 2026

Appendix IV

I - 70 MP 118 - 131; Glenwood Canyon

Codebook for Crash Data Workbook

Variable Name	Column #	Description	.evel of Measuremen	Values Measured	Dich
Road System	A	Type of road system	Nominal	Interstate; Frontage Road (State Highway)	No
Route Num	B	Route number identifier	Nominal	Interstate 70	No
Route Section	C	Section of the route	Nominal	A (CDOT segment designating Glenwood Canyon)	No
Milepost	D	Milepost location of crash	Ratio	(Milepost number)	No
Date	E	Date of the crash	Ratio	(Date)	No
Time of Day	F	Time of day the crash occurred	Ratio	(Time of day)	No
Severity	G	Overall crash severity level	Ordinal	No Injury (PDO); Possible/Complaint of Injury (C); Evide	No
Uninjured	H	Number of uninjured persons	Ratio	(Count)	No
Level C Injuries	I	Number of Level C (possible) injuries	Ratio	(Count)	No
Level B Injuries	J	Number of Level B (non-incapacitating) injur	Ratio	(Count)	No
Level A Injuries	K	Number of Level A (incapacitating) injuries	Ratio	(Count)	No
Fatalities	L	Number of fatalities	Ratio	(Count)	No
Crash Location	M	General location of crash relative to road	Nominal	On Road; Off Road Right; Off Road Left	No
Road Description	N	Type of roadway location	Nominal	Non-Intersection; Ramp; Intersection Related; Parking	No
Vehicles	O	Number of vehicles involved	Ratio	(Count)	No
Road Contour	P	Road contour/alignment at crash site	Nominal	Straight On Grade; Straight On Level; Curve On Level;	No
Road Cond	Q	Road surface condition	Nominal	Snowy; Dry; Icy; Slushy; Wet; Foreign Material; Snowy	No
Lighting Cond	R	Lighting conditions at crash time	Nominal	Daylight; Dark Un-Lighted; Dark Lighted; Dawn or Dusk	No
Weather	S	Weather conditions at crash time	Nominal	None; Snow/Sleet/Hail; Rain	No
Veh1 Speed Limit	T	Posted speed limit for Vehicle 1	Ratio	(Speed in mph)	No
Veh2 Speed Limit	U	Posted speed limit for Vehicle 2	Ratio	(Speed in mph)	No
Veh3 Speed Limit	V	Posted speed limit for Vehicle 3	Ratio	(Speed in mph)	No
Ramp Id	W	Ramp identifier letter	Nominal	B; D; E; O; T	No
Crash Type	X	Type of crash	Nominal	Guard Rail; Concrete Barrier; Rear End; Sideswipe Sam	No
Fixed Object	Y	Whether a fixed object was struck	Nominal	FO:Yes; FO:No	Yes
Event1	Z	Sequence of events - Event 1	Nominal	Guard Rail; Concrete Barrier; Rear End; Sideswipe Sam	No
Event2	AA	Sequence of events - Event 2	Nominal	Guard Rail; Concrete Barrier; Rear End; Sideswipe Sam	No
Event3	AB	Sequence of events - Event 3	Nominal	Guard Rail; Concrete Barrier; Rear End; Sideswipe Sam	No
Mhe	AC	Most harmful event	Nominal	Guard Rail; Concrete Barrier; Rear End; Sideswipe Sam	No
Animal Species	AD	Species of animal involved in crash	Nominal	Deer; Elk	No
Veh1 Dir	AE	Direction of travel for Vehicle 1	Nominal	East; West; North; South	No
Veh1 Type	AF	Type of Vehicle 1	Nominal	See Footnote 1	No
Veh1 Speed	AG	Speed of Vehicle 1 at time of crash	Ratio	(Speed in mph)	No
Veh1 Movement	AH	Movement of Vehicle 1 prior to crash	Nominal	See Footnote 2	No
Driver1 State	AI	State of license for Driver 1	Nominal	(U.S. state abbreviation)	No
Veh1 HAZMAT	AJ	Whether Vehicle 1 carried hazardous materi	Nominal	Yes; No	Yes
Driver1 Belt	AK	Seatbelt use by Driver 1	Nominal	Yes; No	Yes
Veh1 Cycle Prot	AL	Motorcycle protection for Vehicle 1 occupan	Nominal	None; Helmet and Eye Protection; Unknown	No
Driver1 Inj Level	AM	Injury level of Driver 1	Ordinal	See Footnote 3	No
Veh2 Dir	AN	Direction of travel for Vehicle 2	Nominal	East; West; North; South	No
Veh2 Type	AO	Type of Vehicle 2	Nominal	See Footnote 1	No
Veh2 Speed	AP	Speed of Vehicle 2 at time of crash	Ratio	(Speed in mph)	No
Veh2 Movement	AQ	Movement of Vehicle 2 prior to crash	Nominal	See Footnote 2	No
Driver2 State	AR	State of license for Driver 2	Nominal	(U.S. state abbreviation)	No
Veh2 HAZMAT	AS	Whether Vehicle 2 carried hazardous materi	Nominal	Yes; No	Yes
Driver2 Belt	AT	Seatbelt use by Driver 2	Nominal	Yes; No	Yes
Veh2 Cycle Prot	AU	Motorcycle protection for Vehicle 2 occupan	Nominal	None; Helmet and Eye Protection; Unknown	No
Driver2 Inj Level	AV	Injury level of Driver 2	Ordinal	See Footnote 3	No
Veh3 Dir	AW	Direction of travel for Vehicle 3	Nominal	East; West; North; South	No
Veh3 Type	AX	Type of Vehicle 3	Nominal	See Footnote 1	No
Veh3 Speed	AY	Speed of Vehicle 3 at time of crash	Ratio	(Speed in mph)	No
Veh3 Movement	AZ	Movement of Vehicle 3 prior to crash	Nominal	See Footnote 2	No
Driver3 State	BA	State of license for Driver 3	Nominal	(U.S. state abbreviation)	No
Veh3 HAZMAT	BB	Whether Vehicle 3 carried hazardous materi	Nominal	Yes; No	Yes
Driver3 Belt	BC	Seatbelt use by Driver 3	Nominal	Yes; No	Yes
Veh3 Cycle Prot	BD	Motorcycle protection for Vehicle 3 occupan	Nominal	None; Helmet and Eye Protection; Unknown	No
Driver3 Inj Level	BE	Injury level of Driver 3	Ordinal	See Footnote 3	No
Location 1	BF	Road name/location identifier	Nominal	(Road name text)	No
City	BG	City where crash occurred	Nominal	GLENWOOD SPRINGS; (blank if unincorporated)	No
County	BH	County where crash occurred	Nominal	GARFIELD; EAGLE	No
Const Zone	BI	Whether crash occurred in a construction zc	Nominal	Yes; No	Yes
Bridge	BJ	Whether crash occurred on or near a bridge	Nominal	Yes; No	Yes
Interchange	BK	Whether crash occurred at an interchange	Nominal	Yes; No	Yes
Latitude	BL	Latitude coordinate of crash	Ratio	(Latitude)	No
Longitude	BM	Longitude coordinate of crash	Ratio	(Longitude)	No

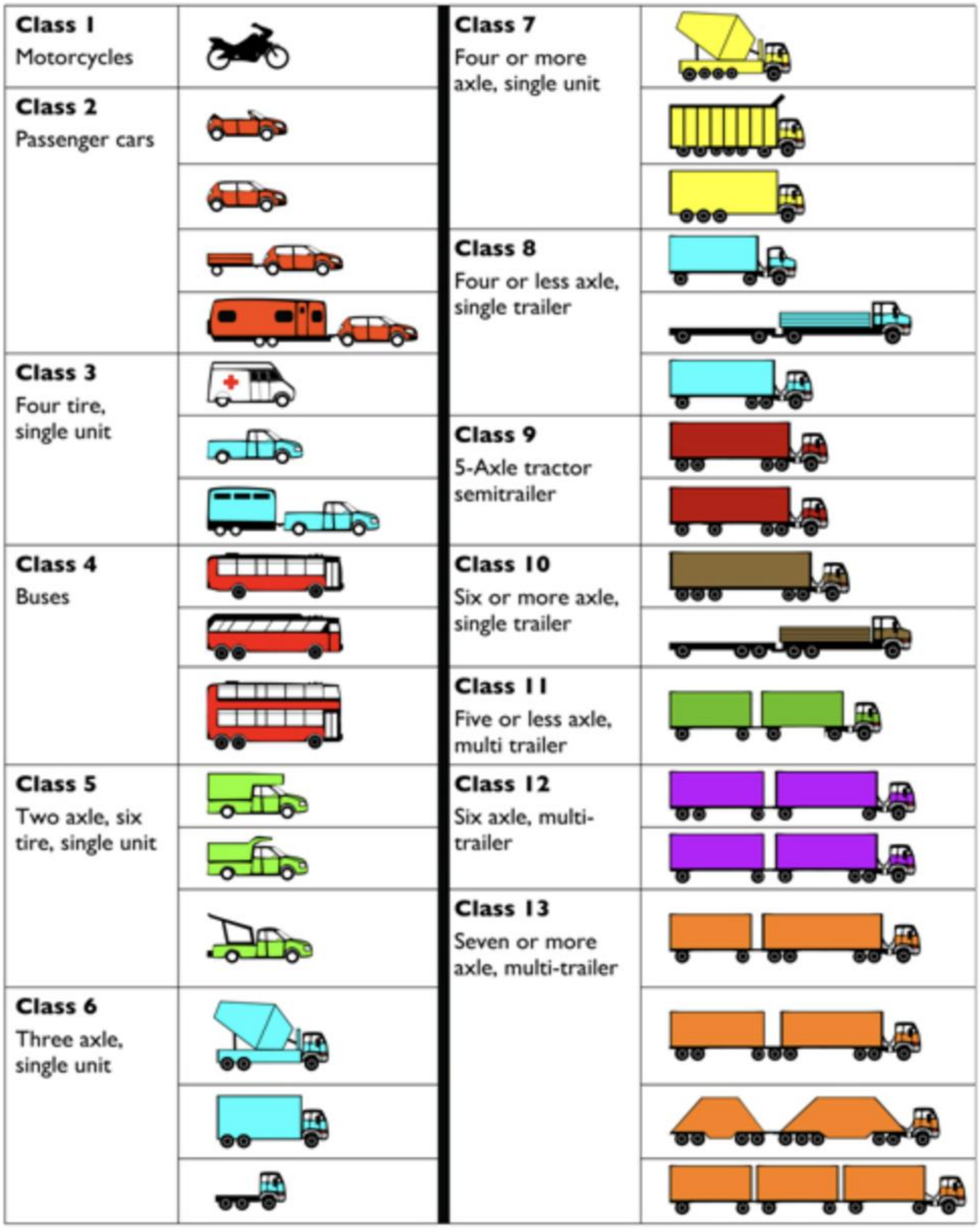
FOOTNOTES

Footnote 1 - Vehicle Types (11):	Footnote 2 - Movements (15):		Footnote 3 - Injury Levels (5):
1. Passenger Car/Van	1. Going Straight	12. Backing	1. No Injury (PDO)
2. Pickup Truck/Utility Van	2. Other	13. Entering/Leaving Par	2. Possible/Complaint of Injury (C)
3. SUV	3. Weaving	14. Parked	3. Evident Non-Incapacitating (B)
4. Trucks over 10k/Busses over 15 Pas	4. Making Left Turn	15. Drove Wrong Way	4. Evident, Incapacitating (A)
5. Hit and Run - Unknown	5. Slowing		5. Fatal (K)
6. Motorcycle	6. Stopped in Traffic		
7. Pickup Truck/Utility Van w/Trailer	7. Changing Lanes		
8. Passenger Car/Van w/Trailer	8. Passing		
9. SUV w/Trailer	9. Avoiding Object/Vehicle in Roadway		
10. Non-School Bus < 15 People	10. Making Right Turn		
11. Other	11. Making U-Turn		

Numerical values for Vehicle Type, not yet sorted by weight in Footnotes.

Appendix V

FIGURE C-1 FHWA 13 VEHICLE CATEGORY CLASSIFICATION



Source: Federal Highway Administration

U.S. DOT FHWA (2016) *Traffic Monitoring Guide*. Fhwa.dot.gov.

https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm

Appendix VI

Test A - Chi-Square Goodness-of-Fit Test

Are trucks/buses disproportionately involved in crashes relative to their share of traffic?

Null Hypothesis (H_0): The proportion of truck/bus crashes equals the proportion of truck/bus traffic (AADT)

Alternative Hypothesis (H_1): The proportion of truck/bus crashes differs from the proportion of truck/bus traffic

Significance Level (α): 0.05

Section 1: Observed vs. Expected Crash Counts by Year

Year	Total Crashes	Truck % of AADT	Expected Truck Crashes	Observed Truck Crashes	Expected Other Crashes	Observed Other Crashes
2025	108	13.3%	14.4	30	93.6	78
2024	111	13.5%	15.0	20	96.0	91
2023	148	13.8%	20.4	39	127.6	109
2022	115	14.0%	16.1	25	98.9	90
Total	**482**	**13.7%**	**65.9**	**114**	**416.1**	**368**

Section 2: Chi-Square Component Calculations

$\chi^2 = \Sigma [(Observed - Expected)^2 / Expected]$

Year	Truck χ^2 Component	Other Vehicle χ^2 Component	Year Total χ^2
2025	17.021	2.611	19.632
2024	1.678	0.262	1.940
2023	16.895	2.705	19.600
2022	4.920	0.801	5.721
Total	**40.514**	**6.379**	**46.893**

Section 3: Test Results

Chi-Square Statistic (χ^2):	**46.893**
Degrees of Freedom (df):	4
p-value:	**0.000000**
Significance Level (α):	0.05
Critical Value (χ^2 at α):	9.488
Result:	**REJECT H_0 — Statistically Significant**

Section 4: Individual Year Chi-Square Tests (df = 1 each)

Year	χ^2 Statistic	p-value	Significant at α = 0.05?
2025	19.632	0.000009	**Yes ✓**
2024	1.940	0.163636	**No**
2023	19.600	0.000010	**Yes ✓**
2022	5.721	0.016765	**Yes ✓**

Appendix VII

Test B -Chi-Square: Did Truck Lane Restrictions Reduce Truck Crashes?

Pre/Post Comparison: 2022–2023 (pre-restriction) vs. 2024–2025 (post-restriction)

Null Hypothesis (H_0):
TLR had no effect — the proportion of truck crashes post is the same as pre

Alternative Hypothesis (H_1):
The proportion of truck crashes changed after truck lane restrictions were implemented

Significance Level (α): 0.05

Section 1: Baseline Period Data (2022–2023, pre-restriction)

Period	Total Crashes	Truck/Bus Crashes	Other Vehicle Crashes	Truck % of Crashes
2022–2023 (Pre)	263	64	199	24.3%
2024–2025 (Post)	219	50	169	22.8%
Combined	**482**	**114**	**368**	**23.7%**

Section 2: Expected vs. Observed Crashes in Post-Restriction Period (2024–2025)

Expected values use the pre-restriction (2022–2023) truck crash proportion applied to post-period total crashes.

Category	Observed (2024–2025)	Expected (based on 2022–2023 rate)	O − E	(O − E)² / E
Truck/Bus Crashes	50	53.3	-3.3	0.203
Other Vehicle Crashes	169	165.7	3.3	0.065
Total	**219**	**219.0**	**0.0**	**0.269**

Section 3: Test Results

Chi-Square Statistic (χ^2):	**0.269**
Degrees of Freedom (df):	1
p-value:	**0.604084**
Significance Level (α):	0.05
Critical Value (χ^2 at α):	3.841

Result: **FAIL TO REJECT H_0 — Not Significant**

Appendix VIII

Test C - Chi-Square: Is the Crash Rate of trucks the same as overall traffic?

This section compares truck crash rates per MVMT,
controlling for changes in truck traffic volume between periods.

Metric	2022–2023 (Pre)	2024–2025 (Post)	Change
Avg. Truck AADT	3,357	3,417	+1.8%
Truck MVMT (2-year)	30.63	31.18	+1.8%
Truck/Bus Crashes	64	50	-21.9%
Truck Crash Rate (per MVMT)	**2.09**	**1.60**	**-23.2%**
Expected Post Truck Crashes (at Pre rate)		65.1	

Rate-Adjusted Chi-Square Test (using MVMT-based expected values):

Category	Observed (Post)	Expected (at Pre rate)	$(O - E)^2 / E$
Truck/Bus Crashes	50	65.1	3.521
Other Vehicle Crashes	169	153.9	1.491
Total	**219**	**219.0**	**5.011**

χ^2 Statistic (rate-adjusted): **5.011**

p-value (rate-adjusted): **0.025184**

Result (rate-adjusted): **REJECT H_0 — Statistically Significant**

Appendix IX

Poisson Rate Test: Did Truck Lane Restrictions Reduce Truck Crash Rates?

Comparing truck crash rates per MVMT: pre-restriction (2022–2023) vs. post-restriction (2024–2025)

	Truck Crash Rate is:
Null Hypothesis (H_0):	the same in both periods (Rate Ratio = 1.0)
Alternative Hypothesis (H_1):	differs between pre- and post-periods (Rate Ratio ≠ 1.0)
Significance Level (α):	0.05

Section 1: Input Data

Metric	Pre-Restriction (2022–2023)	Post-Restriction (2024–2025)
Truck/Bus Crashes (count)	64	50
Avg. Truck AADT	3,357	3,417
Period Length (years)	2	2
Segment Length (miles)	12.5	12.5
Truck MVMT (exposure)	**30.628**	**31.176**
Truck Crash Rate (per MVMT)	**2.090**	**1.604**

Section 2: Rate Ratio and 95% Confidence Interval

The Rate Ratio (RR) compares post-restriction rate to pre-restriction rate. RR < 1 indicates a reduction.

Rate Ratio (RR) = Post Rate / Pre Rate:	**0.7675**
ln(RR):	-0.2646
SE[ln(RR)]:	0.1887
Z-critical (95%):	1.9600
95% CI for ln(RR):	
Lower bound:	-0.6345
Upper bound:	0.1054
95% CI for Rate Ratio:	
Lower bound:	**0.5302**
Upper bound:	**1.1111**
CI includes 1.0?	**Yes — NOT Significant**

Appendix X

Section 3: Hypothesis Test (Poisson Exact / Wald Test)

Method A — Wald Z-Test (based on ln(RR)):

Z-statistic: **-1.402**

p-value (two-tailed): **0.160984**

Method B — Poisson Conditional Exact Test:

Under H_0, given total crashes = n_pre + n_post, the number of post-period crashes follows a Binomial distribution with p_0 = post_MVMT / (pre_MVMT + post_MVMT). This is the exact conditional test.

Total truck crashes (n_pre + n_post):	114
Expected proportion under H_0 (p_0):	0.504429
Observed post crashes:	50
Expected post crashes under H_0:	57.50
Exact p-value (two-tailed, Binomial):	**0.189290**

Result: **FAIL TO REJECT H_0 — Not Significant**

Section 4: Cross-Validation with Chi-Square Test B

Chi-Square Test B (from Chi Test sheet) also compared pre vs. post truck crashes adjusted for traffic volume.

Metric	Chi-Square Test B	Poisson Rate Test (Wald)	Poisson Rate Test (Exact)
Test Statistic	5.011	-1.402	Exact (Binomial)
p-value	**0.025184**	**0.160984**	**0.189290**
Significant at α = 0.05?	**Yes ✓**	**No**	**No**
Observed truck crashes (post)	50	50	50
Expected truck crashes (post)	65.1	57.5	57.5
Rate Ratio (RR)	N/A	0.768	0.768
95% CI	N/A	0.530 – 1.111	0.530 – 1.111

The Chi-Square Test B found significance (p = 0.025) while the Poisson Rate Test did not (p = 0.161).

Appendix XI

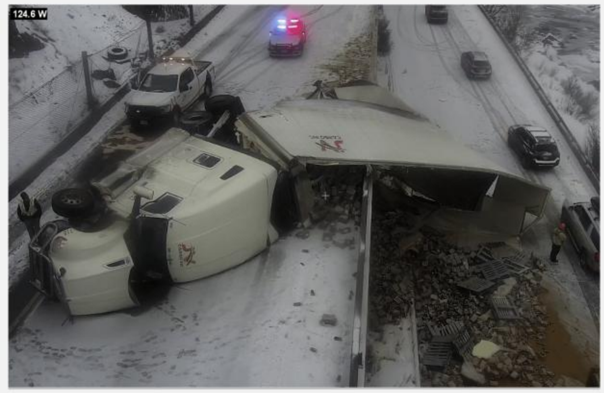
CDOT working to remove wreck on I-70 near exit 119

Motorists should expect work to continue into the early evening

A singed semi-truck straddles the median of I-70 after an accident. (Hannah Hickman)

By KJCT Staff

Updated: Oct. 13, 2022 at 3:40 PM MDT



A semi-truck straddles the two sides of Interstate 70 in Glenwood Canyon after crashing and dumping aluminum cans all over the road.

CDOT/Courtesy photo

LOCAL NEWS

I-70 WB reopens after tanker spills 3,000 gallons of fuel near Glenwood Canyon

by: Dara Bitler
Posted: Jan 17, 2023 / 09:16 AM MST
Updated: Jan 17, 2023 / 07:18 PM MST

3,000 gallons of gasoline were spilled after this crash in Glenwood Canyon on Jan. 17, 2023. (Credit: Colorado Department of Transportation) (Colorado Department of Transportation)

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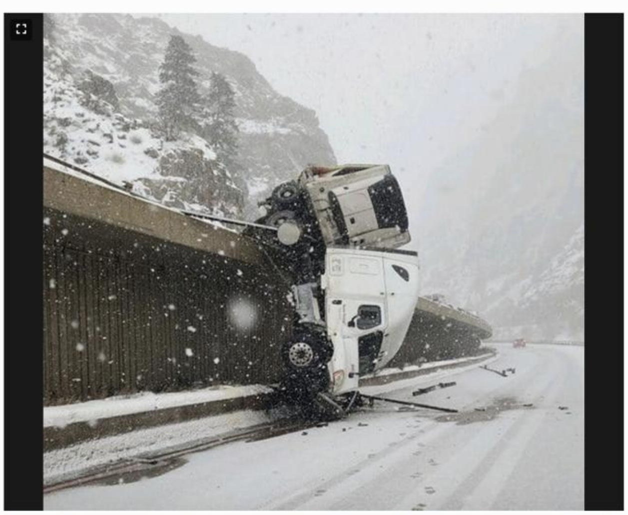
SENTINEL STAFF Jan 31, 2023 Updated Mar 7, 2024



A semitractor trailer straddles the barrier between the westbound and eastbound lanes on westbound Interstate 70 after sliding out of control in Glenwood Canyon in this 2023 file photo. A proposed new bill being considered in the Colorado Legislature would expand the state's mandatory chain requirements on commercial vehicles into Glenwood Canyon. The trucking industry is opposed to the bill.

Colorado Department of Transportation

Another massive crash closed Glenwood Canyo Monday

By SENTINEL STAFF Jan 4, 2022 Updated Feb 8, 2023

COLORADO STATE PATROL PHOTO

An icy Interstate 70 through Glenwood Canyon was the scene of a 17-vehicle crash Monday.