FMCSA Safety Program Effectiveness Measurement: Carrier Intervention Effectiveness Model (CIEM), Version 1.3 Report for Fiscal Year 2021 Interventions

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

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FOREWORD

The Federal Motor Carrier Safety Administration (FMCSA), in cooperation with the John A. Volpe National Transportation Systems Center (Volpe), uses a quantitative model called the Carrier Intervention Effectiveness Model (CIEM) to measure the effectiveness of motor carrier interventions in terms of estimated crashes prevented, injuries prevented, and lives saved. This model provides FMCSA management with information needed to address the requirements of the Government Performance and Results Act of 1993 (GPRA), which requires Federal agencies to measure the effectiveness of their programs as part of the budget cycle process. This report documents the results of the CIEM for fiscal years 2019–2021.

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16. Abstract

The Federal Motor Carrier Safety Administration (FMCSA), in cooperation with the John A. Volpe National Transportation Systems Center (Volpe), uses a quantitative model called the Carrier Intervention Effectiveness Model (CIEM) to measure the effectiveness of motor carrier interventions in terms of estimated crashes prevented, injuries prevented, and lives saved. This model provides FMCSA management with information needed to address the requirements of the Government Performance and Results Act of 1993 (GPRA), which requires Federal agencies to measure the effectiveness of their programs as part of the budget cycle process. This report documents the results of the CIEM for fiscal year 2021.

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SI* (MODERN METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	Acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume (volumes greater than 1,000L shall be shown in m^3)		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		Temperature (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	pound-force	4.45	newtons	N
lbf/in^2	pound-force per square inch	6.89	kilopascals	kPa

Approximate Conversions from SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		Temperature (exact degrees)		
°C	Celsius	1.8c+32	Fahrenheit	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force and Pressure or Stress		
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

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ACRONYMS

Acronym	Definition
ATET	average treatment effect on the treated
CIEM	Carrier Intervention Effectiveness Model
CMV	commercial motor vehicle
CR	compliance review
CREM	Compliance Review Effectiveness Model
CSA	Compliance, Safety, Accountability
FMCSA	Federal Motor Carrier Safety Administration
FY	fiscal year
GPRA	Government Performance and Results Act of 1993
HM	hazardous materials
MCMIS	Motor Carrier Management Information System
MCSAP	Motor Carrier Safety Assistance Program
PRISM	Performance and Registration Information Systems Management
PU	power unit (commercial motor vehicle)
USDOT	U.S. Department of Transportation
Volpe	John A. Volpe National Transportation Systems Center

EXECUTIVE SUMMARY

In 2010, following an operational model test in select States, the Federal Motor Carrier Safety Administration (FMCSA) began a phased implementation of its Compliance, Safety, Accountability (CSA) program, representing a redesign of the Agency's existing enforcement model. The CSA enforcement model includes an array of carrier intervention types in place of the one-size-fits-all compliance review (CR) which formed the basis of the prior enforcement model. The new enforcement model was designed to improve safety in the operation of commercial motor vehicles (CMVs).

The Carrier Intervention Effectiveness Model (CIEM) provides FMCSA with a tool for measuring the safety benefits associated with Agency interventions. The model incorporates both comprehensive reviews (similar to the original CRs), as well as newer intervention types (i.e., warning letters, offsite investigations, onsite focused investigations, and other non-ratable reviews) when assessing these benefits.

The CIEM produces national-level measurements for the effectiveness of FMCSA's carrier intervention program, measured in terms of crashes and injuries prevented, and lives saved. It is designed to be implemented on an annual basis, focusing on carriers receiving both State- and Federal-conducted interventions in a given fiscal year (FY).

This approach yields national-level measurements of the effectiveness of FMCSA's current carrier interventions. The CIEM model shows that in FY 2021, carrier interventions resulted in an estimated 11,305 crashes prevented, 5,599 injuries prevented, and 370 lives saved.

MODEL APPROACH

The model computes combined carrier crash rates—defined in terms of crashes per power unit (PU)—for carriers receiving interventions within a size group. The model calculates crash rates for different size groups to control for systemic differences in crash rates between small and large carriers, and to control for how these carriers may respond to interventions. The difference between the carriers' pre- and post-intervention crash rates within each size group measures how much the safety performance of the size group improved during this timeframe.

To help remove the effect of external factors from calculated changes in safety performance, the difference between the aggregated pre- and post-intervention crash rates is adjusted by the change in crash rates experienced by carriers not receiving interventions during the same timeframe. In addition, a set of carefully designed filters is used to identify and remove carriers with missing and outlier data from the calculations. Beginning with version 1.3 of the model, this adjustment is performed separately for carriers receiving an intervention in a given month. That is, the initial pre- to post-intervention crash rate changes for carriers in the size group receiving interventions in a given month are adjusted, based on the crash rate change in the general (non-intervened upon) carrier population from the 12-month period prior to the intervention month to the 12-month period subsequent to the intervention month.

The model assesses the effectiveness of carrier interventions by estimating three safety outcomes: crashes prevented, injuries prevented, and lives saved. To estimate these outcomes, the model calculates changes in the combined carrier crash rates for each size group. Once calculated, these crash rates changes are translated into estimates of the safety outcomes, which are then extrapolated to account for carriers that received an intervention but were not included in the initial model because of missing or inaccurate data. Only statistically significant reductions in crash rates are used for these extrapolations.

MODEL FINDINGS

All Carriers Receiving Interventions

The model was implemented for carriers receiving interventions in FY 2021, based on Version 1.3 of model. Total carriers receiving interventions in FY 2021 increased by about 10 percent, from 33,344 in FY 2020 to 36,619 in FY 2021 (see Table 2). Statistically significant crash rate reductions occurred for carriers in all four size groups considered by the model. These reductions are estimated to have resulted in the safety benefits shown in Table 1.

Table 1. Safety benefits: All interventions.

Fiscal Year	Crashes Prevented	Injuries Prevented	Lives Saved
2019	8,379	4,519	246
2020	6,819	3,461	217
2021	11,305	5,599	370

Additional Analyses

The model was also run with the exclusion of warning letters. Because the issuance of such a letter does not involve any investigative work on the part of the Agency, removing carriers that received only a warning letter from the model helps to identify safety benefits specifically linked to safety investigator and program analyst hours dedicated to Agency investigations. This analysis showed that carriers whose first intervention was not a warning letter also exhibited statistically significant crash rate reductions in all carrier size groups. Benefits from this subset of interventions are estimated to be 2,953 crashes prevented, 1,462 injuries prevented, and 97 lives saved for FY 2021.

The CIEM also estimates safety benefits associated with individual intervention types. Carriers receiving more than one type of intervention during the fiscal year are assigned an intervention type based on the nature of the first intervention it received during that year. Benefits associated with each intervention type are presented in Table 2.

Table 2. Estimated crashes and injuries prevented, and lives saved, by first intervention type, FYs 2019–2021.*

Intervention Type	All Carriers Receiving Interventions: Number of Carriers			Crashes Prevented			Injuries Prevented			Lives Saved		
	FY 19	FY 20	FY 21	FY 19	FY 20	FY 21	FY 19	FY 20	FY 21	FY 19	FY 20	FY 21
Onsite Focused	5,668	3,591	4,360	955	666	1,922	515	338	952	28	21	63
Onsite Comprehensive	5,130	2,793	1,899	809	410	178	436	208	88	24	13	6
Offsite Focused	891	4,640	4,423	6	377	490	3	192	243	0	12	16
Other Non-ratable Review	891	116	61	0	0	0	0	0	0	0	0	0
Warning Letter	25,574	22,204	25,876	6,245	5,363	8,344	3,369	2,722	4,132	183	171	273

*Due to model calculations being performed at finer levels of granularity for these estimates, estimated safety benefits associated with each intervention type do not add up to the totals shown in Table 1. Much of this disparity can be explained by smaller sample sizes in the size groups, which potentially impacts the statistical significance of the results obtained in each size group.

1. INTRODUCTION

1.1 BACKGROUND

During the 1980s, Congress passed a series of legislative acts intended to strengthen motor carrier safety regulations. These measures led to the implementation of safety-oriented programs at both the Federal and State levels. The Surface Transportation Assistance Act of 1982 established the Motor Carrier Safety Assistance Program (MCSAP), a grants-in-aid program to States for conducting roadside inspection and traffic enforcement programs aimed at commercial motor vehicles (CMVs). The Motor Carrier Safety Act of 1984 directed the U.S. Department of Transportation (USDOT) to establish safety fitness standards for carriers. The USDOT, in conjunction with the States, implemented MCSAP to fund roadside inspection and traffic enforcement programs and a commercial motor carrier safety rating system based on onsite safety audits called compliance reviews (CRs).

The Safety Program Effectiveness Measurement Project was established to identify major functions and operations (programs) associated with the Federal Motor Carrier Safety Administration's (FMCSA's) mission and develop results-oriented performance measures for the Agency's functions and operations, as called for in the Government Performance and Results Act of 1993 (GPRA). From 2002 through 2009, the benefits of CR activities were assessed using the Compliance Review Effectiveness Model (CREM).[1] In 2010, following an operational model test in select States, FMCSA began a phased implementation of its Compliance, Safety, Accountability (CSA) program, a redesign of the Agency's existing enforcement model. The CSA enforcement model includes an array of new carrier intervention types, as well as the previously existing CR intervention type developed under the Agency's previous enforcement model (renamed to Onsite Comprehensive Investigation, under CSA).

1.2 PROJECT SCOPE

The Carrier Intervention Effectiveness Model (CIEM) measures the safety benefits of carrier interventions. The model incorporates both onsite comprehensive investigations and additional interventions, including but not limited to warning letters, onsite focused investigations, and offsite investigations. The model measures the benefits of the program in terms of crashes prevented, lives saved, and injuries prevented. These measurements can be used to assess the effectiveness of FMCSA's carrier intervention program.

This report presents the results of the CIEM's implementation for carrier interventions conducted during fiscal year (FY) 2021, and describes the methodology used by the model.

[1] Reports documenting these results are available at http://ai.fmcsa.dot.gov/pe/home.aspx.

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2. FMCSA CARRIER INTERVENTION EFFECTIVENESS MODEL

FMCSA employs a data-driven approach to oversee and enforce commercial motor carrier safety. This approach uses a variety of data sources to assign safety risks to motor carriers; the assigned safety risks are then used to prioritize carriers for interventions. The CSA enforcement approach uses a broad set of carrier interventions, giving safety investigators the flexibility to address safety problems more efficiently. This set of interventions includes less labor-intensive alternatives to an onsite comprehensive investigation, which focus on each motor carrier's specific safety problems. As a result, the CSA program enables FMCSA to reach a larger number of carriers. The CIEM measures the safety benefits from carrier interventions currently used by the Agency (including intervention types developed prior to the CSA program that the Agency continues to use), in terms of crashes prevented, injuries prevented, and lives saved.

2.1 MODEL STRUCTURE

The CIEM is a statistical impact evaluation model that uses historical data to compare the safety performance of carriers that have received FMCSA interventions to their safety performance prior to receiving interventions. This comparison is used to establish the extent of safety improvement that can be attributed to interventions. The model is designed to be implemented on an annual basis, focusing on carriers receiving interventions in a given fiscal year.

The model computes crash rates—defined as crashes per power unit (PU)—for carriers receiving interventions, for time intervals corresponding to periods occurring both before and after the interventions.(2) The difference between these pre- and post-intervention crash rates, once adjusted for exogenous factors measured by a comparison group, represents the change in the safety performance for these carriers during this timeframe. To control for potential systemic differences in crash rates between small and large carriers, and in how these carriers may respond to interventions, these calculations are performed for various carrier size groupings (based on carrier PU counts) and then aggregated.(3)

To reduce the effect of exogenous factors impacting the calculated change in safety performance, the difference between pre- and post-intervention crash rates is adjusted by the change in crash rate experienced by a comparison group (representing carriers that did not receive interventions) during a similar timeframe. This adjustment helps to remove the effect of historical trends and events (such as a national recession or extreme weather).

The CIEM uses a set of carefully designed filters to identify and remove carriers with missing or outlier crash or power unit data from the calculations. The model later extrapolates its initial estimates of safety benefits to the entire population of carriers receiving interventions, including those that were screened out of the model. The CIEM also determines the statistical significance

[2] PU values are used as a proxy for carrier exposure to crashes. While vehicle miles traveled (VMT) have the potential to serve as a useful proxy for exposure in the model at a future point in time, FMCSA believes that PU information in MCMIS is currently more reliable.

[3] While additional factors may be used to classify carriers into different groups (e.g., short- versus long-haul operations; for-hire versus private fleets), the Agency believes stratification by size is the best approach for assessing the effectiveness of its interventions.

of the model output, and non-statistically significant changes in safety performance improvement are excluded from the total estimate of safety benefits calculated by the model.

2.2 CARRIERS WITH INTERVENTIONS: CARRIER TREATMENT GROUP

The model's treatment group consists of carriers that both received at least one FMCSA carrier intervention during the fiscal year and passed a set of data filters that check for missing and outlier data.

The following set of interventions, recorded in FMCSA's Motor Carrier Management Information System (MCMIS), are used to identify treatment group carriers:[4]

- Warning letters.
- Offsite Focused State/Federal investigations (non-ratable).
- Onsite Focused State/Federal investigations.
- Onsite Comprehensive State/Federal investigations.
- State/Federal Security Contact reviews.
- State/Federal Hazardous Materials (HM) reviews.
- Other State/Federal non-ratable reviews on interstate carriers.[5]

Carriers receiving one of these intervention types were then screened prior to placing them in the treatment group, to ensure they met the following requirements:

- Carrier was engaged in active operations and reported current nonzero PU counts to FMCSA for both the pre- and post-intervention time periods considered by the model.
- Carrier was not a new entrant at any point in its pre- and post-intervention periods.
- Carrier's reported crash and PU information met outlier tests to identify suspicious data.[6]

[4] The model currently does not include follow-up verifications, direct notices of violation, direct notices of claims, or Cooperative Safety Plans because the data currently in MCMIS for these actions are inconsistent in terms of completeness and accuracy. Safety audits are also not considered by this model, as safety audits are performed only on new entrant carriers, which have often not been in full operation during the entire 1-year pre-intervention period.

[5] This category includes non-ratable investigations that focus on specific aspects of a carrier's operations and are generally not triggered by one or more of the carrier's Behavioral Analysis and Safety Improvement Category (BASIC) scores, unlike the other intervention types listed, above.

[6] Outlier tests are: (a) driver-to-PU and PU-to-driver ratios cannot exceed 7.5, with the exception of exclusively driveaway/towaway carriers; (b) pre- to post-intervention and post- to pre-intervention change in PU count cannot exceed a factor of 3 for carrier size groups 1 and 2 or a factor of 1.75 for size groups 3 and 4. The following are exceptions: size group 1 and 2 carriers can exhibit a factor up to 5 if there is a corresponding change in the pre- to post-intervention or post- to pre-intervention driver count (between a factor of 1.5 and 10), and size group 3 carriers can exhibit a factor up to 2.5 if the corresponding change in driver count is by a factor between 1 and 5 (see Section 3.1, Table 5 for size group definitions). This filter allows more variability for smaller carriers because smaller PU changes result in larger proportional changes for these carriers compared to larger carriers; (c) to filter for suspiciously low and suspiciously high crash rates, pre- and post-intervention crash rates must be within five standard deviations of the carrier size group's mean crash rate, once all other filters have been implemented. Based on analysis of carrier crash incidence, this condition is overridden by any of the following conditions: if (i) the carrier is in size group 1 and has 5 or fewer crashes, or (ii) the carrier is in size groups 2, 3, or 4 and has 6 or fewer crashes; alternatively, carriers with 500 or more PUs must exhibit non-zero crashes regardless of how many standard deviations their crash rate is from the size group mean.

These requirements were initially based on those used in the CREM, but were strengthened and refined to better identify suspect data for the CIEM.

2.3 CARRIERS WITHOUT INTERVENTIONS: COMPARISON GROUP

To isolate the effects of interventions from other factors that may have influenced carriers' crash rates more broadly, the treatment group's change in crash rate is adjusted to account for changes in the general motor carrier population's crash rates through the use of a comparison group. The comparison group consists of carriers that did not receive an intervention during the assessment period and also passed a set of data filters identical to those applied to the treatment group carriers.

Beginning with Version 1.3 of the model, safety benefits adjustments based on the comparison group are performed separately for treatment group carriers receiving interventions in a particular month. That is, pre- and post-intervention crash data from treatment group carriers with interventions occurring during a given month of the fiscal year are compared against historical data from the comparison group, using pre- and post-intervention time intervals based on that same month. For example, for treatment group carriers receiving interventions during the month of October, the comparison group's data for the pre-intervention time period comes from the 12-month interval immediately prior to the midpoint of this month (October 15th), and the comparison group's data for the "post-intervention" time period comes from the 12-month interval immediately following this date. Thus, although there is only one comparison group, the model uses 12 different sets of pre- and post-intervention crash rate calculations, based on this group.(7) This process provides consistency to the data being compared between the two groups, in terms of the time periods being assessed, and helps to eliminate any influence from seasonality on this adjustment process.

Comparison group carriers are assigned to size groups, based on definitions identical to those used for the treatment group, and using similar data filters to control for incomplete or suspicious power unit data. This helps to control for differences associated with carrier size when the model calculates the adjusted crash rate changes for the treatment group.

2.4 MODEL DATA AND TIMEFRAMES

The model uses crash data reported by the States and carrier PU data obtained during interventions or from information submitted by carriers on the Motor Carrier Identification Report (Form MCS-150). These data, stored in MCMIS, are used to calculate pre- and post-intervention crash rates for treatment group carriers and corresponding crash rates for comparison group carriers. Crash data originating from State reporting systems are continuously fed into MCMIS via an automated interface, and a carrier's historical data in MCMIS may change over time, based on updated information submitted to the Agency, due to incompleteness in the original reporting. For this study, the most current MCMIS snapshots available—which

[7] Although there is only one comparison group, a few carriers may get excluded from some monthly calculations due to failing to meet particular monthly data filtering criteria.

include the most current updates for prior months—are used to capture the most complete and accurate crash data available.[8]

For the treatment group, a carrier's pre-intervention PU value is based on the MCMIS monthly data snapshot from the time period immediately following the first intervention it receives during the fiscal year. This particular snapshot contains the most recent PU information for the carrier at the time of its intervention. The date of the carrier's first intervention is used in order to delineate the pre- and post-intervention periods during the fiscal year.[9] Some carriers receive multiple interventions within the modeled year. In these cases, the model does not determine the precise impact of each individual intervention type when calculating overall safety benefits derived from the CSA program. Rather, it estimates the combined effect of all interventions performed during the modeled year.

Each treatment carrier's pre-intervention period is defined as the 12-month period preceding its first intervention, while its post-intervention period is defined as 12-month period following this intervention. The last monthly MCMIS snapshot occurring during the carrier's post-intervention period is used to obtain its post-intervention PU value. Pre- and post-intervention period crash rates are calculated for each size group by summing, across all treatment group carriers, the number of carrier crashes occurring during these assessment periods, and then dividing by the sum of the carrier PU values associated with these periods. Figure 1 illustrates the timeframes delineated by these data points for a hypothetical treatment group carrier with a first intervention in August 2019.[10]

[8] Crash data for this report were taken from the December 2021 MCMIS data snapshot.

[9] Despite the use of the first intervention as a demarcation point, the safety impact of subsequent interventions in the same year is implicitly included in the model. Those subsequent interventions that occur before the end of the carrier's post-intervention period may have sizable impacts during this same period, which will be reflected in the post-intervention crash rates calculated by the model. However, the impacts of subsequent interventions occurring after the post-intervention period are not taken into account by the model, but rather are captured in the following annual run of the model, where the first follow-up intervention during that particular fiscal year would serve to delineate new "before" and "after" periods for the carrier.

[10] Crash rate statistics for pre-intervention and post-intervention periods for each carrier size group are based on summations of crash and PU data for all carriers (measured in accordance with the individual carrier's date of intervention) in the size group.

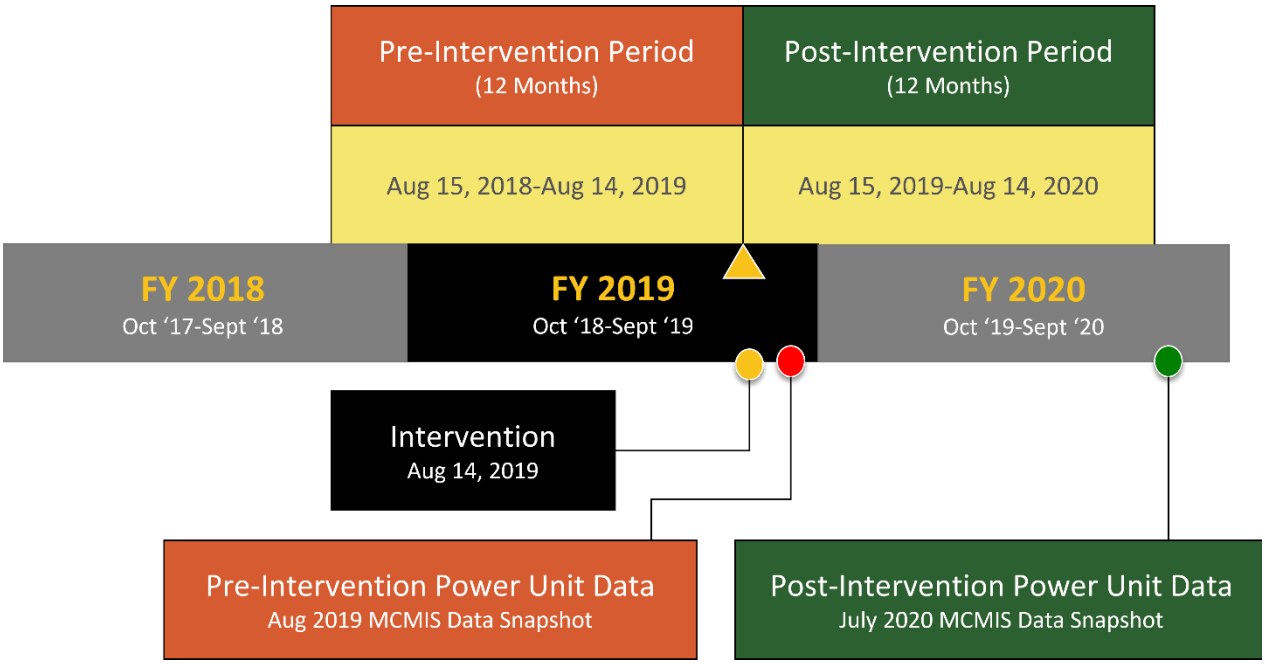

Figure 1. Diagram. Timeline for a carrier with a first intervention on August 14, 2019.

Beginning with Version 1.3 of the model, there are 12 sets of comparison group calculations for each carrier size group, providing 12 sets of pre- and post-intervention crash rates for carriers not receiving interventions, each based on using a different month to define the beginning and end of the 1-year pre- and post-intervention periods for these carriers. Treatment group carriers receiving interventions in a given month are paired with one of the 12 comparison group calculations, according to the month in which their first intervention occurred during the fiscal year.

MCMIS monthly data snapshots provide the pre-intervention period PU values for each carrier in each monthly comparison group, as in the case of the treatment group. As with the treatment group, the comparison group crash rate for each size group is calculated by summing the number of crashes occurring during each period, and then dividing by the corresponding PU value.

2.5 CALCULATION OF CRASHES PREVENTED

For each month in the fiscal year, the model uses pre- and post-intervention crash rates to determine the change in crash rates for both the carriers whose interventions occurred in that month and for the comparison group carriers, broken out by carrier size group. This change is converted to a percent measure by dividing the change by the original (pre-intervention) crash rate. The difference between the treatment and comparison groups' percent change in crash rate, known as the average treatment effect on the treated (ATET), becomes the estimated treatment carrier crash rate reduction attributable to interventions.[11] Figure 2 illustrates the steps used to determine this reduction in each size group.

[11] See Abadie, Alberto (2005). *Semiparametric Difference-in-Differences Estimators*, Review of Economic Studies (72, 1-19) for further information on Average Treatment Effect on the Treated.

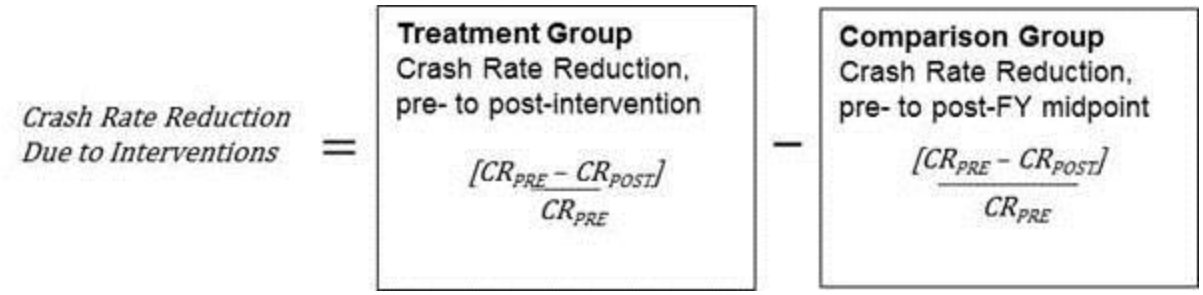

Figure 2. Formula. Estimated size group percent crash rate reduction due to interventions for a given month.

Figure 3 shows how the ATET is converted to a measure of crashes prevented, taking into account the treatment group's pre- and post-intervention PU counts. This statistic is calculated separately for each carrier size group and then summed across the size groups, yielding an initial estimate of total crashes prevented during the modeled fiscal year among treatment group carriers.

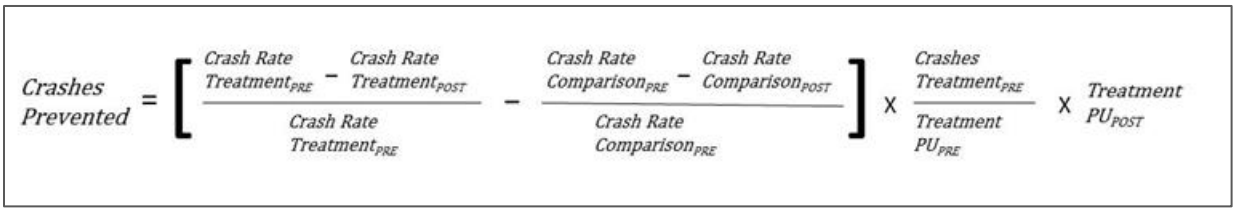

Figure 3. Formula. Initial estimate of crashes prevented as a result of interventions.

Three additional steps are required to estimate crashes prevented across the entire population of interstate and intrastate carriers receiving interventions. The first step identifies those "month by size group" crash rate reduction estimates that are statistically significant (using an alpha=0.95 level of statistical significance). This test determines whether the actual ATET values differ from zero at the 0.05 statistical significance level (i.e., the 95 percent confidence interval around the estimated ATET does not include zero).(12) Crash rate changes that do not pass this test are not attributed to the interventions and are not used to estimate crashes prevented.

The next step for calculating crashes prevented across the motor carrier population is to account for the crashes prevented among those carriers receiving interventions but excluded from the treatment group due to missing or outlier data required as model inputs. Such carriers, on average, can be assumed to exhibit a response to interventions similar to that of the observed treatment group. Therefore, the calculated crashes prevented for the treatment group are extrapolated to account for potential crashes prevented among these additional carriers. The sum of estimated crashes prevented among the treatment group carriers included in the model, as well as those filtered out of the model, represents the total estimated crashes prevented from the interventions performed in the given fiscal year, for each "month by size group" grouping considered by the model. In the final step of the model, all of the estimates of crashes prevented in each of the "month by size group" groupings are then summed together.

[12] Crash rates calculated by the model fall into the category of ratio estimates. For further information on measuring the precision of ratio estimates, see Cochran, William G. (1977). *Sampling Techniques* (third edition).

The extrapolated benefits are calculated by multiplying the initial non-extrapolated benefits by an expansion factor, equal to the total number of carriers receiving interventions during the fiscal year divided by the total number of carriers in the treatment group. Carrier counts used in the numerator of this expansion factor are prorated by the number of months they are in operation during the post-intervention period. For example, a carrier that was in business for only 6 months during the post-intervention period would only count as 6/12 (or 0.5) of a carrier. However, in those instances where the carrier is not in operation during all or part of the post-intervention period, due to having been placed out of service by an Agency enforcement action following an intervention, no proration occurs. In such instances, the model credits the Agency for the reduction in crashes associated with the carrier during the post-intervention period, conservatively assigning to the carrier a crash rate reduction equal to the average reduction associated with its "month by size" grouping.

2.6 CALCULATION OF OVERALL DIRECT SAFETY BENEFITS

Once the model estimates the total crashes prevented due to interventions performed during the fiscal year, it estimates the number of injuries prevented and lives saved as a result of the crashes prevented, using historical MCMIS data to measure the likelihood of any given crash resulting in a fatality or injury. In this step, the model estimates 2-year average probabilities of a crash resulting in an injury or fatality, based on crash data in MCMIS spanning the modeled fiscal year and the prior fiscal year. The parameters shown in Figure 4 are estimated based on these probabilities.(13)

$$\textit{Number of } \textbf{\textit{fatal crashes}} \textit{ prevented} =$$

$$\textit{probability of a fatal crash given a crash occurred } \boldsymbol{x} \textit{ number of crashes prevented}$$

$$\textit{Number of } \textbf{\textit{injury crashes}} \textit{ prevented} =$$

$$\textit{probability of an injury crash given a crash occurred } \boldsymbol{x} \textit{ number of crashes prevented}$$

$$\textbf{\textit{Lives saved}} =$$

$$\textit{number of fatal crashes prevented } \boldsymbol{x} \textit{ average number of fatalities per fatal crash}$$

$$\textbf{\textit{Injuries prevented}} =$$

$$(\textit{average number of injuries per fatal crash } \boldsymbol{x} \textit{ number of fatal crashes prevented}) + (\textit{average number of injuries per injury crash } \boldsymbol{x} \textit{ number of injury crashes prevented})$$

Note: All probabilities and averages are for the 2-year period encompassing the modeled fiscal year and the prior year.

Figure 4. Multiple formulas. Formulas for calculating numbers of fatal crashes prevented, injury crashes prevented, lives saved, and injuries prevented.

[13] The distribution of crashes by severity is determined at the national level and is assumed to be constant across the carrier size groups.

2.7 SAFETY BENEFITS ASSOCIATED WITH INDIVIDUAL INTERVENTION TYPES

To determine safety benefits associated with individual intervention types, each carrier receiving an intervention during the fiscal year is linked to a particular intervention type based on the nature of the first intervention it received during that year.

Because one carrier can receive more than one type of intervention during a given fiscal year, some degree of confounding occurs among the intervention types with this procedure. However, the number of carriers that receive more than one type of intervention during a given fiscal year is small (less than 5 percent) and, consequently, the impact of this confounding is considered minimal. Carriers with more than one intervention are kept in the treatment group because removing them from the estimation process could introduce an upward bias in the estimated safety benefits for any given intervention type, given that a carrier generally receives a second intervention only when the carrier continues to underperform.

3. RESULTS OF IMPLEMENTING THE MODEL

3.1 RESULTS INCLUDING ALL INTERVENTION TYPES

The CIEM was implemented for carriers receiving interventions during FY 2021 (based on Version 1.3 of model). Table 3 presents counts of the various intervention types both considered by the model and conducted during FY 2021, as well as the 2 prior fiscal years. The first three columns give the number of interventions conducted by FMCSA and its State partners. The next three columns give the number of carriers receiving these intervention types as their first intervention in each fiscal year.[14]

Table 3. Total interventions by type, and number of carriers receiving interventions, by first intervention, for FYs 2019–2021.

Intervention Type	Number of Interventions FY 2019	Number of Interventions FY 2020	Number of Interventions FY 2021	Number of Carriers Receiving Interventions (by first intervention) FY 2019	Number of Carriers Receiving Interventions (by first intervention) FY 2020	Number of Carriers Receiving Interventions (by first intervention) FY 2021
Warning Letter	25,652	22,250	25,919	25,574	22,204	25,876
Offsite Investigation	1,013	5,058	4,821	891	4,640	4,423
Onsite Focused Investigation	6,177	3,938	4,905	5,668	3,591	4,360
Onsite Comprehensive Investigation*	5,494	2,908	2,064	5,130	2,793	1,899
Other Non-ratable Review	342	127	77	313	116	61
Total	**38,678**	**34,281**	**37,786**	**37,576**	**33,344**	**36,619**

*Investigations previously labeled as CRs are now included in the "onsite comprehensive investigations" category.
Note: Investigation counts include both State and Federal investigations.

Total interventions increased by about 10 percent in FY 2021. There was a roughly 5 percent decrease in offsite investigations from FY 2020 and roughly 25 percent increase in onsite focused investigations. This shift in intervention types was most likely driven by adjustments made to in-person working policies implemented at the end of the COVID pandemic. During the pandemic period, offsite investigations were increased to minimize person-to-person contact between safety investigators and carrier employees.

Table 4 displays the number of carriers receiving interventions that failed the various data quality filtering criteria used by the model (see Section 2.2), and the resulting number of treatment group carriers available to the model, for the last 3 years modeled.

[14] As explained in the previous section, model estimates are based on changes in carrier safety performance for those receiving interventions during a given fiscal year.

Table 4. Carriers excluded from treatment group by filter criteria, for FYs 2019–2021.

Filter Criteria	FY 2019	FY 2020	FY 2021
Inactive during the pre or post periods	4,422	3,208	4,259
Zero power units during the pre or post periods	4,534	3,298	4,360
New entrant during the pre or post periods	11,350	9,370	12,075
Fails driver-to-PU ratios	155	129	152
Fails change in pre-PU to post-PU or pre-driver to post-driver ratios	869	821	1,005
Carriers with 500+ PUs and zero crashes	7	5	9
Fails crash rate thresholds	29	33	39
Having an out-of-service order during the pre or post period	2,246	1,523	2,077
Total excluded carriers*	**13,847**	**11,260**	**13,954**
Total carriers receiving interventions	**37,576**	**33,344**	**36,619**
Percent excluded	**37%**	**34%**	**38%**
Total carriers in treatment group	**23,729**	**22,084**	**22,655**

*A carrier may be excluded by multiple criteria; therefore, the total excluded carriers does not equal the sum of the carriers meeting each filter criteria.

The first three filters in Table 4 account for the majority of the carriers excluded from the treatment group across the 3 years. The remaining filters impact a smaller number of carriers. Table 5 presents the number of treatment and comparison group carriers for fiscal years 2019–2021, by size group.

Table 5. Number of treatment and comparison group carriers for FYs 2019–2021, by size group.

Carrier Size Group	FY 2019 Treatment Group	FY 2020 Treatment Group	FY 2021 Treatment Group	FY 2019 Comparison Group	FY 2020 Comparison Group	FY 2021 Comparison Group
1 (1–5 PUs)	12,653	11,064	11,370	985,854	1,084,084	1,052,954
2 (6–20 PUs)	7,521	7,286	7,577	80,993	93,444	87,634
3 (21–100 PUs)	2,969	3,082	3,080	16,576	20,043	17,761
4 (101+ PUs)	586	652	638	2,395	3,009	2,491
Total	**23,729**	**22,084**	**22,665**	**1,085,818**	**1,200,580**	**1,160,840**

3.1.1 Crash Rate Reduction

Table 6 presents the initial treatment and comparison group crash rate reductions experienced by both groups during the post-intervention period, by year and carrier size group.

Table 6. Initial treatment and comparison group crash rate reductions for FYs 2019–2021, by size group.

Carrier Size Group	FY 2019 Treatment Group	FY 2020 Treatment Group	FY 2021 Treatment Group	FY 2019 Comparison Group	FY 2020 Comparison Group	FY 2021 Comparison Group
1 (1–5 PUs)	56.7%	58.1%	54.6%	6.2%	6.5%	-9.2%
2 (6–20 PUs)	39.7%	37.7%	31.2%	5.5%	6.2%	-12.2%
3 (21–100 PUs)	27.2%	22.6%	17.1%	7.7%	9.4%	-8.6%
4 (101+ PUs)	12.3%	8.9%	-1.5%	7.6%	8.9%	-5.0%

Note: Negative crash rate reductions indicate increases in crash rates.

The table shows that during FY 2021 crash rate reductions are positive for the first three size groups within the treatment group. The largest carriers within the treatment group, as well as all three comparison groups, show an increase in crash rates. Compared to the previous year, crash rates reductions for both the treatment and control group worsened. This trend among large trucks and busses appears to follow a post-COVID rise in crashes for all vehicle types.[15] Despite the national trend of increasing crashes post-COVID, the positive crash rate reductions in the treatment group suggest that the interventions assessed by the CIEM are reducing large truck and bus crashes.

Table 7 presents the net percent reductions in crash rates, from the pre- to the post-intervention periods, for the treatment group, by fiscal year and carrier size group, after accounting for changes in the comparison group.

Table 7. Net percent reductions in crash rates for treatment group carriers, FYs 2019–2021.

Carrier Size Group	FY 2019	FY 2020	FY 2021
1 (1–5 PUs)	50.3%	50.6%	63.9%
2 (6–20 PUs)	34.1%	31.4%	43.2%
3 (21–100 PUs)	18.7%	10.7%	25.4%
4 (101+ PUs)	1.6%	1.1%	3.9%

Note: Values in this table may not equal the treatment group crash rate reduction minus comparison group crash reduction from Table 6. This is because net percent reductions for carriers receiving interventions in a particular month that are not statistically significant are not included in the final assessment of crash rate reductions.

The net crash rate reductions, after adjusting for crash rate changes in the comparison group, are positive and statistically significant[16] in each size group, for all 3 fiscal years, indicating a net decrease in crash rates for carriers who received an intervention. Note that the crash rate reduction was observed despite the post-pandemic increase in crash rates observed across all carriers. The table also suggests that smaller carriers tend to experience greater net crash rate reductions following interventions than their larger counterparts.

3.1.2 Safety Benefits

Crash severity statistics for fiscal years 2019–2021, calculated using a 2-year average, are shown in Table 8. These statistics are used by the model to convert model estimates of crashes

[15] See NHTSA Traffic Safety Facts 2021 for an overview of crashes for all vehicle types.

[16] Note that statistical significance indicates that the change appears to be real, rather than a random effect, and does not reflect on the magnitude of the reduction.

prevented, as a result of the interventions, to additional estimates for injuries prevented and lives saved.

Table 8. 2-year average crash severity statistics for FYs 2019–2021.

Fiscal Year	Fatal Crashes (% of Total)	Injury Crashes (% of total)	Fatalities per Fatal Crash	Injuries per Fatal Crash	Injuries per Injury Crash
2019	2.61	35.8	1.12	0.92	1.44
2020	2.87	35.0	1.11	0.79	1.39
2021	2.88	34.2	1.13	0.83	1.38

Table 9 presents estimated safety benefits associated with FMCSA carrier interventions for FYs 2019–2021, in terms of crashes prevented, injuries prevented, and lives saved within the treatment group (i.e., carriers receiving interventions that passed the model's data filters).

Table 9. Estimated crashes prevented, injuries prevented, and lives saved in the treatment group, for FYs 2019–2021.

Fiscal Year	Number of Carriers	Crashes Prevented	Injuries Prevented	Lives Saved
2019	23,729	5,656	3,051	166
2020	22,084	4,677	2,374	149
2021	22,655	7,443	3,685	243

Table 10 extrapolates these benefits to all carriers receiving interventions, including those screened out of the initial model calculations by the data filters. Based on this extrapolation, it is estimated that interventions conducted during FY 2021 prevented 11,305 crashes, resulting in 5,599 injuries prevented, and 370 lives saved.

Table 10. Estimated crashes prevented, injuries prevented, and lives saved for all carriers receiving interventions for FYs 2019–2021.

Fiscal Year	Number of Carriers	Crashes Prevented	Injuries Prevented	Lives Saved
2019	37,367	8,379	4,519	246
2020	32,707	6,819	3,461	217
2021	36,035	11,305	5,599	370

3.2 RESULTS EXCLUDING WARNING LETTER AS A FIRST INTERVENTION

Because the issuance of such a letter does not involve any investigative work on the part of the Agency, removing these carriers from the model helps to identify safety benefits specifically associated with safety investigator and program analyst personnel-hours dedicated to Agency investigations. This section presents the results of implementing the model for carriers who received intervention types other than warning letters as their first intervention.

Table 11 presents the number of treatment group carriers, by size group, excluding carriers that received a warning letter as a first intervention for fiscal years 2019–2021.

Table 11. Number of treatment group carriers, excluding carriers that received a warning letter as their first intervention, by size group, for FYs 2019–2021.

Carrier Size Group	FY 2019	FY 2020	FY 2021
1 (1–5 PUs)	4,205	3,828	3,588
2 (6–20 PUs)	2,969	3,147	3,123
3 (21–100 PUs)	1,284	1,443	1,415
4 (101+ PUs)	280	303	301
Total	**8,738**	**8,721**	**8,427**

3.2.1 Crash Rate Reduction

Table 12 presents the percent reductions in crash rate, by carrier size group, by fiscal year, for treatment group carriers whose first intervention was not a warning letter, and for comparison group carriers. The comparison group comprises the same carriers used for the comparison group in the overall model, as shown in Table 5.

Table 12. Treatment and comparison group percent reductions in crash rate, excluding carriers that received a warning letter as their first intervention, by size group, for FYs 2019–2021.

Carrier Size Group	FY 2019 Treatment Group	FY 2020 Treatment Group	FY 2021 Treatment Group	FY 2019 Comparison Group	FY 2020 Comparison Group	FY 2021 Comparison Group
1 (1–5 PUs)	50.1%	49.6%	42.6%	6.2%	6.5%	-9.2%
2 (6–20 PUs)	30.9%	29.1%	24.9%	5.5%	6.2%	-12.2%
3 (21–100 PUs)	21.8%	16.5%	14.0%	7.7%	9.4%	-8.6%
4 (101+ PUs)	11.1%	7.0%	-2.8%	7.6%	8.9%	-5.0%

Note: A negative crash rate reduction indicates an increase in crash rate.

Table 13 presents the net percent reductions in crash rate, by carrier size group, by fiscal year, for these same treatment group carriers, adjusted for the crash rate reductions in the comparison group.

Table 13. Net percent reductions in crash rate, excluding carriers that received a warning letter as their first intervention, by size group, for FYs 2019–2021.

Carrier Size Group	FY 2019	FY 2020	FY 2021
1 (1–5 PUs)	43.5%	42.67%	51.6%
2 (6–20 PUs)	22.5%	20.7%	36.7%
3 (21–100 PUs)	7.7%	5.9%	16.5%
4 (101+ PUs)	1.6%	-	4.3%

Notes: Due to rounding, values in this table may not equal the treatment group crash rates minus the comparison group crash rates from Table 12.
The net percentage reductions in crash rate was not significant for carrier size group four, during FY 2020.

Carriers receiving a first intervention other than a warning letter in fiscal years 2021 exhibited statistically significant crash rate reductions in all size groups, However, compared to the results for all intervention types, including warning letters (see Table 7), the net crash rate reductions for the first three size groups are lower, with the difference for size group 1 being about 12.3 percentage points lower, size group 2 about 6.5 percentage points lower, and size group 3 about 8.9 percentage points lower. For size group 4, the two analyses only differed by about 0.4 percentage points. Hence, for most groups, the impact of the warning letters upon carrier crash reduction, at least for those carriers targeted to receive them, appears greater than what was achieved with the other intervention types. However, one should note that carriers slated for non-warning letter interventions as a first intervention type (i.e., investigations) tend to have poorer safety profiles than those receiving warning letters, and may present more of a challenge in terms of changing their behavior. Potential differences in the safety profiles of carriers receiving different types of interventions make direct comparisons concerning the relative effectiveness of the various intervention types problematic (see Section 3.3.2).

3.2.2 Safety Benefits

Table 14 and Table 15 present estimated safety benefits, by fiscal year, from FMCSA interventions, excluding carriers whose first intervention in the fiscal year was a warning letter. Table 14 presents the estimated crashes prevented, injuries prevented, and lives saved for this subset of treatment group carriers.

Table 14. Estimated crashes prevented, injuries prevented, and lives saved for treatment group carriers, excluding carriers that received a warning letter as their first intervention, FYs 2019–2021.

Fiscal Year	Number of Carriers	Crashes Prevented	Injuries Prevented	Lives Saved
2019	8,738	1,490	804	44
2020	8,721	1,285	652	41
2021	8,427	2,405	1,191	79

Table 15 extrapolates these benefits to all carriers receiving these interventions, including those screened out of the initial model calculations by the data filters. The safety benefits presented in Table 14 and Table 15 are based on statistically significant net crash rate reductions, as reported in Table 13. Safety benefits extrapolated to all carriers whose first intervention was not a warning letter in FY 2021 are estimated to be 2,953 crashes prevented, 1,462 injuries prevented, and 97 lives saved.

Table 15. Estimated crashes prevented, injuries prevented, and lives saved for all carriers receiving an intervention, excluding carriers that received a warning letter as their first intervention, FYs 2019–2021.

Fiscal Year	Number of Carriers	Crashes Prevented	Injuries Prevented	Lives Saved
2019	11,853	1,998	1,078	59
2020	10,930	1,617	821	52
2021	10,588	2,953	1,462	97

3.3 RESULTS FOR INDIVIDUAL INTERVENTION TYPES

This section presents results of implementing the model for carriers receiving specific types of interventions, by size group and type of first intervention, for fiscal years 2019–2021. Table 16 presents the number of treatment group carriers for fiscal years 2019–2021, by first intervention type and size group. The table indicates that treatment group carriers assigned Onsite Focused, Onsite Comprehensive, Offsite Focused interventions, or Warning Letters as a first intervention had higher crash rates during the 12 months prior to their interventions than their counterparts not receiving interventions (i.e., the comparison group). This trend holds for all size groups but is most noticeable in the smallest group (1–5 power units), where the combined pre-intervention crash rates associated with each of these four interventions are typically one order of magnitude higher than the comparison group crash rate for this size group. Among these intervention types, carriers receiving either a Warning Letter or Onsite Comprehensive Review had the highest combined pre-intervention crash rate in this small size group (about 15 crashes per 100 power units per year vs. 1 crash per 100 power units per year for the comparison group).

In the largest size group (101+ power units), carriers assigned Onsite Comprehensive and Offsite Focused had pre-intervention period crash rates that were moderately higher than the crash rate associated with the comparison group. Pre-intervention crash rates of carriers assigned Warning Letters or Offsite Focused interventions were lower, although still higher than the comparison group.

Table 16. Number of treatment group carriers and pre-intervention crash rates for both treatment group and comparison group (crashes per power unit per year), by first intervention type and size group, for FY 2021.*

Carrier Size (PUs)	Cmpr. Grp. Crash Rate	Onsite Focused		Onsite Comprehensive		Offsite Focused		Other Non-Ratable Reviews		Warning Letter	
		Carrier Count	Pre-Interv. Crsh. Rate	Carrier Count	Pre-Interv. Crsh. Rate	Carrier Count	Pre-Interv. Crsh. Rate	Carrier Count	Pre-Interv. Crsh. Rate	Carrier Count	Pre-Interv. Crsh. Rate
1–5	0.010	1,289	0.159	647	0.080	1,624	0.086	28	0.145	7,782	0.145
6–20	0.013	1,361	0.093	411	0.050	1,337	0.063	14	0.061	4,454	0.065
21–100	0.017	604	0.072	151	0.037	657	0.047	3	0.102	1,665	0.038
101+	0.019	104	0.040	37	0.030	157	0.023	3	0.004	337	0.021
Total	**NA**	**3,358**	**NA**	**1,246**	**NA**	**3,775**	**NA**	**48**	**NA**	**14,238**	**NA**

*Treatment carriers' pre-intervention crash rates are based on each carrier's 12-month crash history prior to its intervention. For each size group, this crash rate is equal to the total treatment group crashes, summed across each carrier's 12-month pre-intervention period, divided by the total number of power units associated with these carriers during these time periods. Comparison group pre-intervention crash rates are based on a weighted average of the various 12-month pre-intervention crash rates associated with each month where an intervention was performed, as discussed in Section 2.3.

3.3.1 Crash Rate Reduction

Table 17 presents the treatment group initial percent reductions in crash rate from the pre- to the post-intervention period, by intervention type and carrier size group, adjusted for the crash rate reductions in the comparison group. Again, the comparison group comprises the same comparison group carriers used for the overall model, as reported in Table 5.

For Onsite Focused and Comprehensive investigations, net crash rate reductions were statistically significant for all size groups except size group 4 (101+ Power Units) in FY2021. As in previous fiscal years, net crash reductions associated with Warning Letters were statistically significant in all four size groups. For these three intervention types (Onsite Focused investigations, Onsite Comprehensive investigations, and Warning Letters) the largest reductions occurred in the two smallest size groups, as in the case of results based on the overall model (see Table 7).

For Offsite Focused reviews, net crash rate reductions values were statistically significant for the first three size groups during FY 2021. Non-ratable reviews could not be shown to have a statistically significant impact on crash rates in any size group, possibly due, in part, to the small number of carriers receiving such interventions.

Table 17. Percent net crash rate reductions (treatment minus comparison group) for individual intervention, FY 2021.

Carrier Size Group	Onsite Focused	Onsite Comprehensive	Offsite Focused	Non-Ratable Reviews	Warning Letter
1 (1–5 PUs)	60.5%	34.4%	18.4%	-	68.2%
2 (6–20 PUs)	41.3%	14.4%	18.5%	-	47.8%
3 (21–100 PUs)	23.4%	4.7%	8.9%	-	25.1%
4 (≥100 PUs)	4.3%	-	-	-	3.9%

Note: dash indicates non-statistically significant net reduction.

3.3.2 Safety Benefits

Table 18 presents the estimated safety benefits experienced by carriers receiving various types of interventions as a first intervention, for fiscal years 2019–2021.

Table 18. Estimated crashes and injuries prevented, and lives saved, by first intervention type, for FYs 2019–2021.*

Intervention Type	Number of Carriers			Crashes Prevented			Injuries Prevented			Lives Saved		
	FY19	FY20	FY21	FY19	FY20	FY21	FY19	FY20	FY21	FY19	FY20	FY21
Onsite Focused	5,668	3,591	4,360	955	666	1,922	515	338	952	28	21	63
Onsite Comprehensive	5,130	2,793	1,899	809	410	178	436	208	88	24	13	6
Offsite Focused	891	4,640	4,423	6	377	490	3	192	243	0	12	16
Other Non-ratable Review	313	116	61	0	0	0	0	0	0	0	0	0
Warning Letter	25,574	22,204	25,876	6,245	5,363	8,344	3,369	2,722	4,132	183	171	273

*Due to model calculations being performed at a finer level of granularity, estimated safety benefits associated with each intervention type may not add up to the totals shown in Table 1. Some of this disparity may be due to smaller sample sizes available when calculating safety benefits associated with specific intervention types conducted in a particular month, for the size group.

Carriers whose first intervention during FY 2021 was an onsite focused investigation constitute about 12 percent of all carriers represented in the table and account for about 18 percent of the estimated crashes and injuries prevented, and estimated lives saved. Carriers whose first intervention began as an onsite comprehensive investigation constitute approximately 5 percent of the carriers represented in the table and account for approximately 2 percent of the estimated crashes and injuries prevented, and estimated lives saved. Carriers whose first intervention began as a warning letter constitute 71 percent of the carriers represented in the table and account for approximately 76 percent of the estimated crashes and injuries prevented, and estimated lives saved. The disproportional amount of the safety benefits associated with Warning Letters may be attributable to the higher rate at which this intervention is associated with small carriers: 55 percent of the carriers receiving Warning Letters as a first intervention were in the smallest size group (1–5 PUs), compared to 42 percent for carriers receiving Onsite Focused interventions, and 52 percent of carriers receiving Onsite Comprehensive investigations as a first intervention (not shown in tables). Carriers in this size group experienced the largest crash rate reductions across almost all intervention types (see Table 17).

These findings do not necessarily speak to the relative effectiveness of the individual intervention types, because the safety profile of a carrier assigned one intervention type may drastically differ from the safety profile of a carrier assigned another. However, the data continue to suggest that the major intervention types considered by the model (Onsite Focused, Offsite Focused, Onsite Comprehensive investigations, as well as Warning Letters) result in positive benefits, based on 1-year pre- and post-intervention assessment periods. One should also note that the total effect of the intervention type (in terms of crashes and injuries prevented and lives saved) is not only a function of the percent reduction in carrier crash rates associated with the intervention type (as shown in Table 16), but also a function of the total number of carriers receiving that intervention type and the number of drivers associated with those carriers.

Lastly, one should bear in mind that the CIEM cannot measure the extent to which carriers may experience “regression to the mean” during the post-intervention period. This concept refers to the notion that crashes are rare events and many carriers, particularly small ones, may experience

a decrease in their post-intervention crash rates simply because their crash history during the pre-intervention period was an anomaly. In other words, during the post-intervention period carriers may simply revert to a pattern of behavior (in terms of crashes) that is historically more typical for them. In such situations, it is at least conceivable that this "regression to the mean" is a key contributor to crash reduction in the post-intervention period, rather than the intervention.

Whether it is due to regression to the mean or to the possibility that smaller carriers simply respond more positively to Agency interventions, the disparity in net crash rate reductions across carrier size groups should be considered when assessing individual intervention types, since the distribution of the intervention types differs across size groups, as discussed above.

3.4 CRASH RATE REDUCTION BY BASIC CRASH INDICATOR INTERVENTION THRESHOLD

Carriers may receive an intervention for reasons that are not directly related to the carrier's history of crashes. In fact, many carriers who receive an intervention have crash rates below FMCSA's BASIC Crash Indicator intervention threshold. Additionally, only a minority of carriers receive a comprehensive onsite review as an intervention (see Table 3). Excluding warning letters, the majority of interventions are focused reviews, which may only examine a small area of a carrier's operations.[17] By contrast, prioritized carriers whose BASIC Crash Indicator exceeds the intervention threshold are much more likely to have reviews that focus on aspects of their operation directly related to crash history. The effect of the intervention on a carrier's future crash rate may depend on both the reason for the review, as well as the nature of the review. Accordingly, this section breaks out the crash rate reduction by carriers scoring above and below the BASIC Crash Indicator intervention threshold at the time of the carrier's first intervention. Table 19 summarizes the crash rate reductions for all treatment group carriers, presented in Section 3.3, based on all intervention types.

Table 19. All treatment group carriers.

Carrier Size Group	Carriers in Treatment Group	Pre-intervention Crash Rate (Crashes per 100 PUs)	Crash Rate Reduction	Net Crash Rate Reduction
1 (1–5 PUs)	11,370	13.5	54.6%	63.9%
2 (6–20 PUs)	7,577	6.9	31.2%	43.2%
3 (21–100 PUs)	3,080	4.6	17.1%	25.4%
4 (≥100 PUs)	638	2.4	-1.5%	3.9%

The crash rate percent reduction column represents the percent change in crash rates during the post intervention period. The net crash rate percent reduction column represents the percent change in crash rates after accounting for the crash rate change in the control group. Table 20 presents similar information for the subset of carriers whose BASIC crash indicator was above

[17] Carriers may have been prioritized based on their history of driver or vehicle roadside violations, complaints, or other reasons not directly related to their crash history. While almost all intervention criteria used by the FMCSA are ultimately related to crash risk, the strength of the relationship between intervention reasons and crash risk varies by intervention category. A carrier's crash history is one of the strongest indicators of future crash risk. For a review of the relationship between CSA intervention categories and crash risk, see https://csa.fmcsa.dot.gov/Documents/CSMS_Effectiveness_Test_Final_Report.pdf.

the intervention threshold at the time the carrier received their first intervention. For this score, the intervention threshold depends on the operation type of the carrier. For passenger carriers, a crash BASIC indicator at or above the 50th percentile prioritizes the carrier for intervention; for hazmat carriers the threshold is the 60th percentile; and for general carriers, the threshold is 65.

Table 20. Crash rate percent reductions for treatment group carriers with crash indicator above intervention threshold.

Carrier Size Group	Carriers in Treatment Group	Pre-intervention Crash Rate (Crashes per 100 PUs)	Crash Rate Percent Reduction	Net Crash Rate Percent Reduction
1 (1–5 PUs)	1,781	51.0	86.5%	91.7%
2 (6–20 PUs)	1,717	17.4	68.7%	76.4%
3 (21–100 PUs)	874	9.1	47.4%	51.4%
4 (≥100 PUs)	189	4.7	17.1%	16.3%

Table 20 shows that net crash rate reductions are much larger when the analysis is restricted to carriers whose BASIC crash indicator score was above the intervention threshold.[18] Most carriers who are prioritized for an intervention do not have scores above the intervention threshold. For the present analysis, about 16 percent of size group 1 carriers in the treatment group had a BASIC crash score above the intervention threshold. For size group 2, about 23 percent of the treatment group carriers exceeded the threshold, and for size groups 3 and 4, about 28 and 30 percent of treatment group carriers exceeded the threshold, respectively.

Table 21 shows the net crash reductions for treatment group carriers whose crash BASIC were below the intervention threshold at the time of the intervention. These carriers were selected for an intervention for reasons not directly related to their history of crashes. The crash rates for these carrier groups were lower than the overall treatment group crash rates, and, with the exception of size group 1, all the groups in this subset experienced negative net-crash rate reductions, indicating they performed worse in the post-intervention period after accounting for the effects of exogenous factors captured by the control group. However, it should be noted that carriers in this subset already had low crash rates to begin with and were more likely to receive interventions not directly related to crash history.

[18] See https://csa.fmcsa.dot.gov/Documents/SMSMethodology.pdf for a review of BASIC methodology.

Table 21. Crash rate percent reductions for treatment group carriers with crash indicator below-intervention.

Carrier Size Group	Carriers in Treatment Group	Pre-intervention Crash Rate (Crashes per 100 PUs)	Crash Rate Reduction	Net Crash Rate Reduction
1 (1–5 PUs)	9,589	5.8	-3.7%	1.5%
2 (6–20 PUs)	5,860	3.7	-21.3%	-13.6%
3 (21–100 PUs)	2,206	2.9	-20.7%	-16.7%
4 (≥100 PUs)	449	1.7	-16.1%	-16.9%

Taken together, Table 20 and Table 21 suggest that using the overall crash rate reduction for all carriers receiving interventions (as shown in Table 19) is a conservative measure of intervention effectiveness. The majority of carriers who receive an intervention do so for reasons other than their crash history. Focusing on carriers singled out for interventions due to their crash rates, as shown in Table 20, suggests that interventions may be more effective at reducing crashes for carriers whose crash histories are problematic.

However, an alternate explanation for the difference in intervention effectiveness reported in Table 20 and Table 21 is that the subset of carriers above the crash intervention threshold may include carriers with anomalously high crash rates, while the subset of carriers below the crash intervention threshold may include carriers with anomalously low crash rates. At the level of the carrier, crashes are rare events, so carriers with an unusually high crash rate in the pre-intervention period may be likely to experience a decrease in crashes during the post-intervention period regardless of intervention effectiveness. By splitting the treatment group between carriers with the worst crash rates and all other carriers, net crash reductions for the high crash subset may include carriers who's crash reduction was caused by a "regression to the mean" effect,[19] potentially overstating the effectiveness of interventions for this group. At the same time, for the low crash rate subset, this analysis could be underestimating the effect of interventions on carriers with low crash rates as measured during the pre-intervention period. Therefore, "regression to the mean" cannot be excluded as a potential explanation for the greater reduction in crash rates reported in Table 20.

[19] "Regression to the mean" occurs when repeated observations are initially high or low due to random noise and trend toward the distribution's mean over time. A second observation of a carrier's crash rate is more likely to be closer to the group mean compared to the first observation in cases where first observation was unusually high or low due to random factors.

4. CONCLUSIONS

CIEM provides FMCSA with a tool for measuring the safety benefits of carrier interventions. The model incorporates intervention types currently used by the Agency, including those measured by the previous model, CREM, and new intervention types (i.e., Warning Letters, Offsite investigations, Onsite Focused investigations, Onsite Comprehensive investigations and other non-ratable reviews) when assessing safety benefits.

Overall, the population of carriers targeted for interventions by FMCSA in FY 2021 experienced a reduction in crash rates during the 1-year periods subsequent to their interventions, as in prior years. Consistent with prior years' results, crash rate reductions were generally more pronounced for the smaller carrier size groups. For all size groups, interventions remained effective in reducing motor carrier crash rates despite the general increase in motor vehicle crash rates following the COVID-19 pandemic.

Further analysis evaluated the subset of treatment group carriers whose first intervention each year was not a warning letter. Excluding carriers whose first intervention was a warning letter helps to identify those safety benefits specifically associated with safety investigator and program analyst labor hours. Compared to the results for all intervention types, the net crash rate reductions for the first three size groups are lower when excluding this intervention type.

A separate analysis, focusing on carriers whose Basic Crash Indicator score was above the intervention threshold at the time of intervention, showed that this subset of carriers experienced larger net crash rate reductions in comparison to all carriers receiving interventions. Conversely, carriers receiving interventions for reasons other than their crash history, only showed a slight net crash rate reduction in the smallest size group, while showing a net increase in crash rates in the three remaining size groups. This analysis suggests that the CIEM is producing conservative estimates of overall intervention effectiveness, in terms of crash rate reduction. Focusing on carriers selected for interventions due to their crash rates may provide a better measure of the ability of interventions to reduce crash rates in those carriers whose crash rates are considered unacceptable. It should be noted, however, that this analysis could not rule out a regression to the mean process.

Model estimates for FY 2021 include benefits associated with individual intervention types. For this analysis, each carrier receiving an intervention during the fiscal year was linked to a particular intervention type according to the first intervention type assigned to it during that year. The model found positive safety benefits for the main intervention types used by the Agency, in terms of crashes prevented, injuries prevented, and lives saved. These findings, however, do not necessarily speak to the relative effectiveness of one individual type versus another, for two reasons. First, the safety profile of a typical carrier receiving one type of intervention may drastically differ from the safety profile of a carrier receiving another type. In addition, the impact of the intervention, in terms of total crashes and injuries prevented and lives saved, is not only a function of the achieved percent reduction in carrier crash rates associated with the intervention (as shown in Table 17), but also a function of the total number of carriers receiving that intervention type and the number of drivers associated with those carriers.

It is also important to note that the CIEM cannot measure the extent to which carriers may experience "regression to the mean" during the post-intervention period. This refers to the notion that crashes are rare events and, consequently, many carriers, particularly small ones, may experience a decrease in their crash rates in the post-intervention period, simply by virtue of the fact that their crash history in the pre-intervention period was an anomaly. Smaller carriers are more susceptible to "regression to the mean."

In summary, the FY 2021 data on pre- and post-intervention safety performance provide evidence for the effectiveness of FMCSA's carrier interventions, as in previous years. Future implementation of the model will enable FMCSA to continue to measure the impact of carrier interventions performed by the Agency.