FMCSA Safety Program Effectiveness Measurement: Carrier Intervention Effectiveness Model (CIEM), Version 1.1 Report for Fiscal Year 2012 Interventions

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

November 2016

FOREWORD

The Federal Motor Carrier Safety Administration (FMCSA), in cooperation with the John A. Volpe National Transportation Systems Center (Volpe), has developed a quantitative model to measure the effectiveness of motor carrier interventions in terms of estimated crashes prevented, injuries prevented, and lives saved. The model, documented in this report, is known as the Carrier Intervention Effectiveness Model (CIEM). 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. It also provides FMCSA and State safety program managers with a quantitative basis for improving enforcement processes and optimizing the allocation of safety resources in the field.

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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), has developed a quantitative model to measure the effectiveness of motor carrier interventions in terms of estimated crashes prevented, injuries prevented, and lives saved. The model, documented in this report, is known as the Carrier Intervention Effectiveness Model (CIEM). 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. It also provides FMCSA and State safety program managers with a quantitative basis for improving enforcement processes and optimizing the allocation of safety resources in the field. This report presents CIEM results for fiscal year (FY) 2012.

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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	poundforce	4.45	newtons	N
lbf/in^2	poundforce 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	poundforce	lbf
kPa	kilopascals	0.145	poundforce 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.)

TABLE OF CONTENTS

LIST OF FIGURES (AND FORMULAS)

LIST OF TABLES

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
USDOT	U.S. Department of Transportation
Volpe	John A. Volpe National Transportation Systems Center

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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, a redesign of the current enforcement model. The CSA enforcement model includes an array of carrier intervention types that replace the one-size-fits-all compliance review (CR) that was implemented as part of the old enforcement model. It is expected that a major benefit of the new enforcement model will be an improved level of safety in the operation of commercial motor vehicles (CMVs).

The introduction of CSA has necessitated a new approach for measuring the benefits and effectiveness of interventions at a national level and on an ongoing basis. The Carrier Intervention Effectiveness Model (CIEM) provides FMCSA with a tool for measuring the safety benefits of carrier interventions. During the phased implementation of CSA, the model incorporates both CRs (where safety impacts were previously measured by the Compliance Review Effectiveness Model, or CREM) and additional intervention types (i.e., warning letters, offsite investigations, onsite focused investigations and onsite comprehensive investigations) when assessing safety benefits.

This approach yields national-level measurements of the effectiveness of FMCSA's carrier interventions. The model is designed to be implemented on an annual basis, focusing on carriers receiving interventions in a given fiscal year (FY). Comparing results over a period of years will provide an indication of the effectiveness of FMCSA's compliance and enforcement program in terms of safety benefits.

MODEL APPROACH

The model computes carrier crash rates—defined as crashes per carrier power unit (PU)—for carriers receiving interventions, distinguishing between crash rates for defined periods prior to and following the interventions. The difference between these carriers' pre- and post-intervention crash rates represents the change in their safety performance during this timeframe. To control for systemic differences between small and large carrier operations, these comparisons are made for carriers distributed into size groups based on their PU count.

In addition, to remove the effect of confounding factors from the calculation of the change in safety performance, the difference between pre- and post-intervention crash rates is adjusted by the change in crash rates experienced by the general carrier population during a corresponding timeframe. A set of carefully designed filters is used to identify and remove missing and outlier carrier data.

The model incorporates statistical significance testing and, as a result, only considers size group changes in crash rates that are statistically significant. Statistically significant results, measured in terms of crashes prevented and lives saved, are then extrapolated to incorporate those carriers that received interventions but were not included in the initial model calculations because of missing or inaccurate data.

MODEL FINDINGS

All Carriers Receiving Interventions

The model was implemented for carriers receiving interventions in FY 2012. Total interventions decreased from 58,199 in FY 2011 to 43,275 in FY 2012. The decrease primarily reflects a decline in CSA warning letters from a peak in FY 2011. In contrast, onsite focused investigations exhibited an increase in FY 2012.

Statistically significant crash rate reductions occurred for carriers with up to 100 PUs. 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
2012	5,283	3,235	173

Additional Analysis

Additional insight can be gained by examining the impact of excluding warning letters from the model, and by implementing the model only for carriers whose first intervention is a warning letter. These separate model results reveal to what extent the changes in safety benefits observed from year to year are associated with warning letters versus the other intervention types. This further analysis showed that warning letters led to statistically significant crash rate reductions across three of the four carrier size groups in FY 2012. The same three size groups exhibited statistically significant crash rate reductions in FY 2011, but of lesser magnitude.

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, the safety fitness determination process, and a commercial motor carrier 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 to 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 current enforcement model. The CSA enforcement model includes an array of carrier intervention types replacing the one-size-fits-all CR intervention type implemented as part of the old enforcement model. It is expected that a major benefit of the new enforcement model will be an improved level of safety in the operation of CMVs. The introduction of the new enforcement model in 2010 has necessitated a new approach for measuring the benefits and effectiveness of interventions at a national level and on an ongoing basis.

1.2 PROJECT SCOPE

The Carrier Intervention Effectiveness Model (CIEM) provides FMCSA with a tool for measuring the safety benefits of carrier interventions. During the phased implementation of CSA, the model incorporates both CRs, previously measured by the CREM, and additional interventions, including warning letters, offsite investigations, onsite focused investigations and onsite comprehensive investigations. This approach yields national-level measurements of the effectiveness of FMCSA's carrier interventions.

While the new model succeeds the CREM, results from the two models are not directly comparable because the models require different methodologies to assess the different safety programs. However, both models measure the benefits of the programs in terms of crashes prevented, lives saved, and injuries prevented.

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

An objective of this project is to develop and continue to improve the new model, and to update the results on an annual basis. This report presents the results of the CIEM's implementation for carriers receiving interventions in fiscal year (FY) 2012, and describes the functionality of the model and how it is applied. Technical details of the model will be presented in "Carrier Intervention Effectiveness Model Technical Report" (forthcoming).

2. FMCSA CARRIER INTERVENTION EFFECTIVENESS MODEL

FMCSA employs a data-driven approach to oversee and enforce commercial motor carrier safety. This approach utilizes 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 model introduced a new and broader set of carrier interventions, giving FMCSA the flexibility to address safety problems more efficiently. The new set of interventions includes less labor-intensive alternatives to a CR that 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 of both CSA carrier interventions and pre-CSA interventions (i.e., interventions developed prior to CSA 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 improvement of carriers receiving FMCSA interventions to their past safety performance, prior to receiving interventions.[2] 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 carrier crash rates—defined as crashes per carrier power unit (PU)—for carriers receiving interventions, distinguishing between crash rates for defined periods prior to and following the interventions.[3] The difference between these carriers' pre- and post-intervention crash rates, once adjusted for exogenous factors based on the comparison group, represents the change in their safety performance during this timeframe. To control for systemic differences in how small versus large carriers improve their safety performance when faced with interventions, these calculations are first performed for various carrier size groupings (based on their PU count) and then aggregated.[4]

To remove the effect of confounding factors impacting the change in safety performance, the difference between pre- and post-intervention crash rates is adjusted by the change in crash rates experienced by a comparison group (representing those that did not receive interventions) during a similar timeframe. This adjustment removes the effect of historical trends and events (e.g., a national recession).

The CIEM replaces the CREM and shares some of its methodology. However, it employs new approaches to address FMCSA's overall enforcement program interventions, including both CSA and non-CSA interventions completed before, during, and after the transition from the CR program.

[2] The comparison group referenced throughout this report is only used to adjust final results.

[3] PU values are used as a proxy for carrier exposure to crashes. While vehicle miles travelled (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.

[4] While additional factors may be used to classify carriers into different comparison groups (e.g. short- versus long-haul operations; for hire versus private fleets), stratification by size was found to be the most effective classification method given data availability.

The new model also introduces a component estimating the impact of interventions applied to carriers with missing or suspect census data; such carriers would otherwise be left out of the computation of safety benefits attributable to FMCSA interventions. Finally, the model introduces a component determining the statistical significance of its own results. Non-statistically significant findings are excluded from the total estimation of safety benefits calculated in the model.

2.2 CARRIERS WITH INTERVENTIONS: CARRIER TREATMENT GROUP

The model's treatment group consists of carriers that received at least one FMCSA carrier intervention during the fiscal year and passed a set of missing and outlier data filters. The treatment group filters ensure that crash rates are comparable and reliable across carriers and carrier size groups.

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

- CSA interventions.[5]
  - Warning letter.
  - Offsite investigation.
  - Onsite focused investigation.
  - Onsite comprehensive investigation.
- CRs, including:
  - CR.
  - CR with cargo tank facility review.
  - CR with security contact review.
- Non-ratable CRs on interstate carriers, including focused CRs (which do not receive a rating) and hazardous materials (HM) reviews.
- Performance and Registration Information Systems Management (PRISM) warning letters.[6]

The treatment group filters require that a carrier:

- Is active and reports positive PU counts.
- Is not a new entrant throughout its pre- and post-intervention periods.
- Meets outlier tests to identify suspect crash and PU data.[7]

[5] This version of the model does not include follow-up verifications, direct notices of violation (DNOVs), direct notices of claims (DNOCs), or Cooperative Safety Plans (CSPs) because the data currently in MCMIS were shown to be inconsistent in terms of completeness and accuracy. Safety audits are not considered a CSA intervention type. Nor are they assessed separately by this model, because 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. .

[6] Further information on PRISM is provided by FMCSA at http://www.fmcsa.dot.gov/safety-security/prism/prism.aspx.

These filters were initially based on those used in the CREM, but were strengthened and refined to better identify suspicious data.

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 for changes in the general carrier population through the use of a comparison group. The comparison group consists of carriers that did not receive an intervention during the comparison period and passed a set of filters for missing and outlier data similar to those applied to treatment group carriers.[8] Similar to the treatment group filters, comparison group filters ensure that crash rates are comparable and reliable across carriers and carrier size groups.

Carriers are assigned to comparison groups based on carrier size groups identical to those in the treatment group. The resulting separate comparison groups allow for eliminating differences associated with carrier size from the model's calculation of adjusted crash rates.

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. Consequently, statistics for previous time periods may change, depending on the timeliness and completeness of the original reporting. For this study, MCMIS snapshots – which include the most current updates for prior months – are used to provide the most complete and accurate crash data available.[9]

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

[7] 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, and a factor of 1.75 for size groups 3 and 4, with the following 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 Table 4 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.

[8] The comparison group filters are identical to the treatment group filters. However, since the comparison group carriers do not have intervention dates, their power unit data for these calculations are always based on the modeled year's MCMIS April data snapshot for the pre-intervention period and on the subsequent year's September snapshot for the post-intervention period.

[9] Crash data for this report were taken from the December 2014 MCMIS data snapshot.

the pre- and post-intervention periods during the fiscal year.[10] Because some carriers receive multiple interventions within the modeled year, the model does not report the precise impacts of each individual intervention type; rather, it estimates the combined impact of all interventions performed during the modeled year.

The 12-month period preceding a carrier's first intervention is defined as its pre-intervention period, while the 12-month period following this intervention is defined as its post-intervention period. The final monthly snapshot for a carrier's post-intervention period is used to define its post-intervention PU value. Pre- and post-intervention crash rates are calculated for all carriers in each size class grouping as the number of crashes occurring during these two periods, divided by each period's PU value. Figure 1 illustrates the timeframes delineated by these data points for the treatment group, using an intervention in FY 2012 as an example.[11]

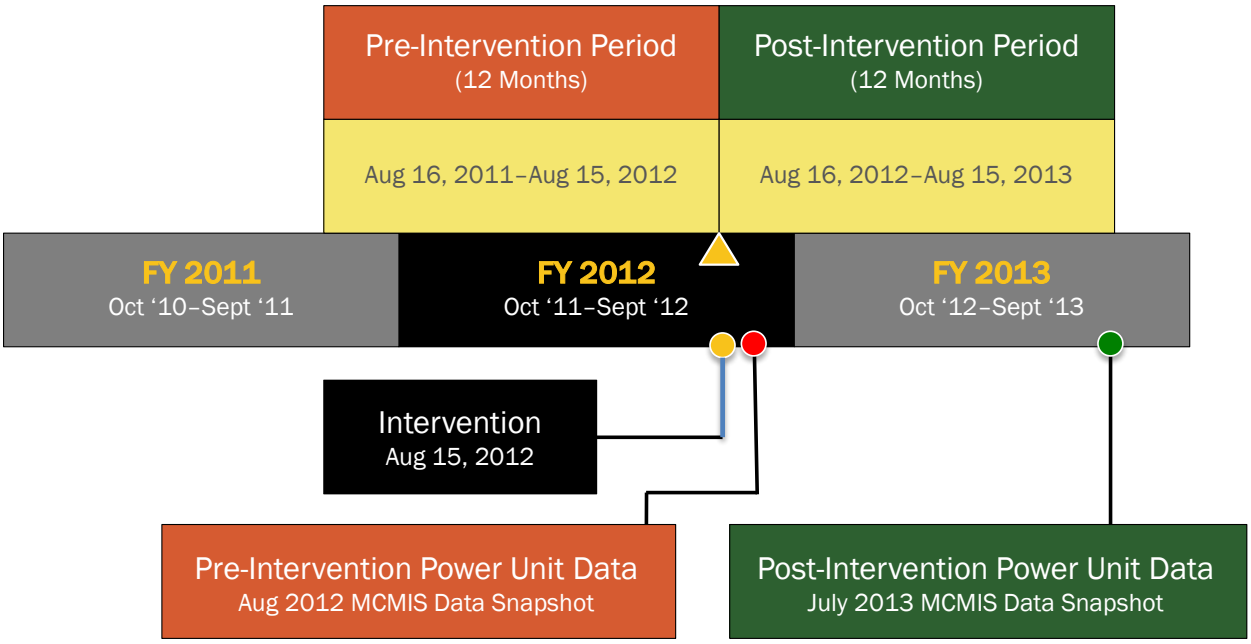

Figure 1. Diagram. Timeline for a carrier with a first intervention on August 15, 2012.

For comparison group carriers, which do not have an intervention during the comparison period, periods corresponding to the treatment group's pre- and post-intervention periods are defined as the 18 months preceding and following the midpoint of the fiscal year (March 31st). Therefore, by definition, the comparison group pre-intervention period covers the entire fiscal year prior to the modeled year, while the post-intervention period covers the entire fiscal year following the modeled year. These longer pre- and post-intervention periods for the comparison group, compared to the treatment group's 12-month periods, ensure that the comparison group pre- and

[10] Despite the use of the first intervention as a demarcation point, the impacts of subsequent interventions in the same year are implicitly included in the model. That is, 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. Conversely, the impacts of subsequent interventions that take place after the post-intervention period are not accounted for in the current model, but rather in the next annual implementation of the model, where the follow-up interventions would serve to delineate new before and after periods.

[11] In this study, crash rates are attributed to size groups, which are aggregations of carriers within the respective ranges of number of PUs operated by each carrier. Thus, crash rate statistics for pre-intervention and post-intervention periods for each 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.

post-intervention evaluation periods cover the entire range of potential pre- and post-intervention time periods for all treatment carriers for each model year.

The MCMIS data snapshot following March 31 is used to obtain the pre-intervention period PU values for each carrier in the comparison group, and the final snapshot of the post-intervention period is used for post-intervention period PU values. As with the treatment group, comparison group carriers' crash rates for each size group are calculated as the number of crashes occurring during each period divided by the corresponding PU values.[12] Figure 2 illustrates the timeframes delineated by these data points for the comparison group, using the FY 2012 model as an example.

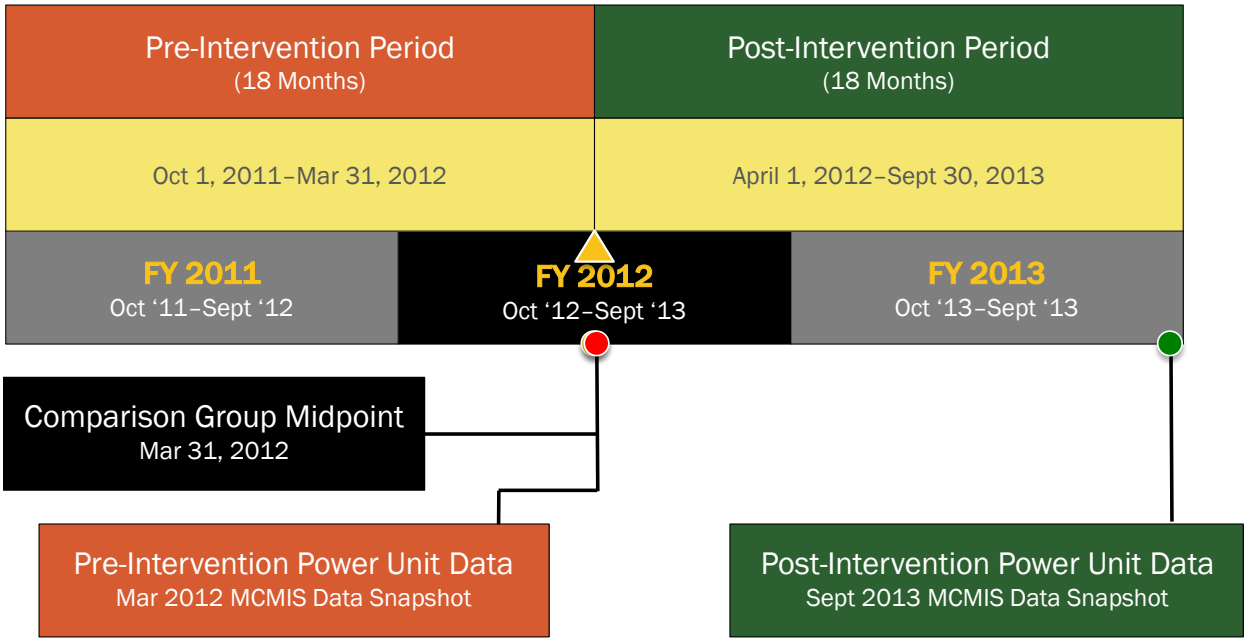

Figure 2. Diagram. Timeline for a FY 2012 comparison group carrier.

2.5 CALCULATION OF CRASHES PREVENTED

Pre- and post-intervention crash rates are used by the model to determine the change in crash rates, by carrier size group, for the treatment and comparison groups. Crash rate 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' crash rate changes, known as the average treatment effect on the treated (ATET), is the crash rate reduction attributed to interventions.[13] Figure 3 illustrates the steps used to determine this reduction in each size group.

[12] To account for the comparison group's pre- and post-intervention periods being longer than those for the treatment group (eighteen versus twelve months), comparison group crash rates are divided by 1.5 to yield equivalent annual crash rates.

[13] 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.

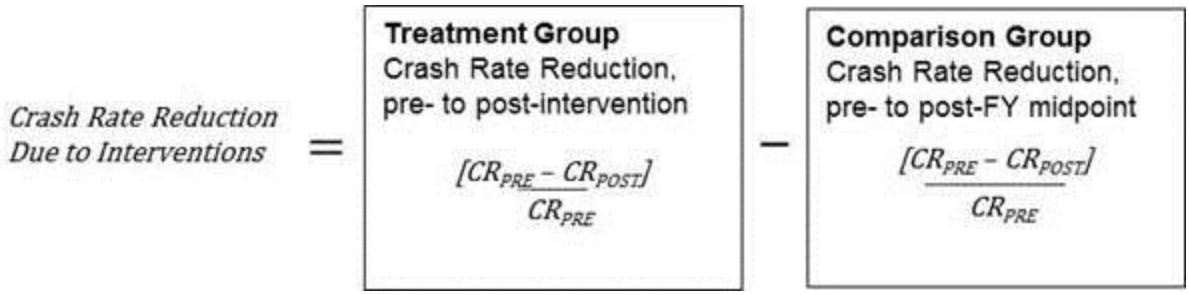

Figure 3. Formula. Crash rate reduction due to interventions.

Figure 4 shows how the crash rate reduction due to interventions is converted to a measure of crashes prevented, which also depends on the treatment group's pre-intervention crashes and pre- and post-intervention PU counts. This reduction is calculated separately for each carrier size group and added across the four size groups, yielding an initial estimate of total fiscal year crashes prevented for the modeled year among treatment group carriers.

$$\text{Crashes Prevented} = \left[\frac{\text{Crash Rate Treatment}_{PRE} - \text{Crash Rate Treatment}_{POST}}{\text{Crash Rate Treatment}_{PRE}} - \frac{\text{Crash Rate Comparison}_{PRE} - \text{Crash Rate Comparison}_{POST}}{\text{Crash Rate Comparison}_{PRE}} \right] \times \frac{\text{Crashes Treatment}_{PRE}}{\text{Treatment PU}_{PRE}} \times \text{Treatment PU}_{POST}$$

Figure 4. Formula. Initial estimate of crashes prevented as a result of interventions..

Two additional steps are required to estimate crashes prevented across the entire population of interstate and intrastate commercial motor carriers. The first step is a test to identify which of the initial estimates are statistically significant at a target level of significance (in this analysis, the 95 percent level). This test determines whether the estimated treatment group crash rate change, adjusted for the comparison group crash rate change by carrier size group, is different from zero at the 0.05 statistical significance level (i.e., the 95 percent confidence interval around the estimated effect on crash rates does not include zero).[14] Crash rate changes that do not pass this test are not attributed to the interventions and are not used to estimate crashes prevented.

The final step for determining crashes prevented across the motor carrier population is to account for the crashes prevented among carriers that received interventions but were excluded from the treatment group due to missing or outlier data. Such carriers, on average, can be assumed to exhibit a response to interventions similar to that of the observed treatment group. Therefore, the results from the observed treatment group crash rate reductions are extrapolated to account for potential crashes prevented among these additional carriers. The sum of crashes prevented among both the treatment group carriers included in the model and the treatment group carriers filtered out of the model represents total crashes prevented across the motor carrier population as a result of the interventions performed in a given fiscal year.

[14] For further information, see Cochran, William G. (1977). *Sampling Techniques* (third edition).

2.6 CALCULATION OF DIRECT SAFETY BENEFITS

Once the model estimates the total crashes prevented from interventions performed during the fiscal year, injuries prevented and lives saved as a result of the crashes prevented can be estimated using historical crash severity data. This model uses 2-year average probabilities of a crash involving an injury or fatality, along with 2-year average values of the number of injuries and fatalities in such crashes. Two-year averages are used, rather than just 1 year of crash statistics, to provide stability to the model's safety benefit calculations. For each model year, the 2-year averages are calculated using historical data on crashes that occurred during the modeled fiscal year and the prior fiscal year, and the frequency of fatalities and injuries occurring in such crashes.[15] Figure 5 presents the formulas for these calculations.

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

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

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

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

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

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

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

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

Figure 5. Multiple formulas. Calculating numbers of crashes prevented, lives saved, and injuries prevented.

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

[15] The distribution of crashes by severity is determined at the national level, assuming the same distribution holds across the carrier size groups.

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3. RESULTS OF IMPLEMENTING THE MODEL

3.1 RESULTS INCLUDING ALL INTERVENTION TYPES

The model was implemented for carriers receiving the specified intervention types in FY 2012. Table 2 presents two sets of data for FY 2012 and for the two preceding fiscal years.[16] The first three columns show the number of interventions conducted by FMCSA and its State partners and are considered as input into the model, by type, for each of the three fiscal years. The next three columns report the number of carriers receiving these intervention types as their first intervention in each fiscal year. As explained in the previous section, the model uses the number of carriers that had one or more interventions in a given year, based on the date of the first intervention, regardless of subsequent interventions. Since the model uses the date of the first intervention to determine which carriers had interventions during the modeled year, the totals in the last three columns represent the total number of carriers considered by the model for each modeled year.

[16] Some of the intervention counts for FY 2010 and FY 2011 differ from those reported in the previously published CIEM Summary Report for FY 2009–11 (January, 2015). Subsequent to the release of that report, FMCSA made minor modifications to the way the CIEM identifies particular intervention types in instances where such information was not recorded or ambiguous in MCMIS. The intervention counts in Table 2 reflect these changes.

Table 2. Carrier interventions by type and number of carriers by first intervention.

Intervention Type	Number of Interventions FY 2010	Number of Interventions FY 2011	Number of Interventions FY 2012	Number of Carriers Receiving Interventions (by first intervention) FY 2010	Number of Carriers Receiving Interventions (by first intervention) FY 2011	Number of Carriers Receiving Interventions (by first intervention) FY 2012
CSA Warning Letter	5,790	39,004	23,835	5,765	38,918	23,806
Offsite Investigation	687	639	618	620	623	608
Onsite Focused Investigation	1,199	6,246	10,470	1,090	5,427	9,809
Onsite Comprehensive Investigation*	829	1,400	7,039	775	1,357	6,665
PRISM Warning Letter	7,415	1,764	-	7,390	1,754	-
Compliance Review	14,564	8,263	-	13,177	7,638	-
Non-ratable Review	881	883	1,313	774	754	1,180
Total	**31,365**	**58,199**	**43,275**	**29,591**	**56,471**	**42,068**

*In FY 2012, all reviews that were previously considered motor carrier safety compliance reviews are now included in the CSA onsite comprehensive investigations total.

Total interventions declined by approximately 25 percent in FY 2012, primarily reflecting a decline in warning letters issued that year. Note that starting with FY 2012, CRs are no longer reported as a separate intervention type, as CRs were replaced by onsite comprehensive investigations. As a result, the number of onsite comprehensive investigations performed in FY 2012 exhibits a substantial increase over the previous year.

Given the set of carriers receiving interventions, the treatment group for each year was determined by applying the data quality filters discussed in Section 2.2. Table 3 displays the number of carriers failing each data quality filter, and the resulting number of treatment group carriers for the three model years.

Table 3. Carriers excluded from treatment group by data quality filters and resulting treatment group totals.

Filter Criteria	FY 2010	FY 2011	FY 2012
Inactive during the pre or post periods	3,351	3,482	2,839
Zero power units during the pre or post periods	3,172	3,079	2,491
New entrant during the pre or post periods	6,012	9,043	9,590
Fails driver-to-PU ratios	140	198	190
Fails change in pre-PU to post-PU or pre-driver to post-driver ratios	532	822	709
Carriers with 500+ PUs and zero crashes	6	14	6
Fails crash rate thresholds	16	12	16
Having an out-of-service order during the pre or post period	35	45	80
Total excluded carriers*	**8,513**	**12,161**	**11,868**
Total carriers receiving interventions	**29,591**	**56,471**	**42,068**
Percent excluded	**28.8%**	**21.5%**	**28.2%**
Total carriers in treatment group	**21,078**	**44,310**	**30,200**

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

The first three filters in Table 3 account for the majority of the fluctuation in the percentage of total carriers excluded across the three years (from 28.8 percent down to 21.5 percent, and rising again to 28.2 percent). The remaining filters impact a much smaller number of carriers, and the proportion of total carriers screened out by them during each fiscal year is relatively constant.

Table 4 presents the number of treatment and comparison group carriers for FY 2012 and the two preceding fiscal years by size group. The number of treatment group carriers in all four size groups decreased in FY 2012, consistent with the decline in total treatment group carriers.

Table 4. Number of treatment and comparison group carriers for FY 2010–12, by size group.[17]

Carrier Size Group	FY 2010 Treatment Group	FY 2011 Treatment Group	FY 2012 Treatment Group	FY 2010 Comparison Group	FY 2011 Comparison Group	FY 2012 Comparison Group
1 (1–5 PUs)	10,706	25,179	16,650	704,115	756,996	809,135
2 (6–20 PUs)	6,897	12,485	8,897	65,287	66,247	67,975
3 (21–100 PUs)	2,912	5,291	3,769	12,503	12,169	12,299
4 (100+ PUs)	563	1,355	884	1,685	1,489	1,446
Total	**21,078**	**44,310**	**30,200**	**783,590**	**836,901**	**890,855**

3.1.1 Crash Rate Reduction

Table 5 presents the initial treatment and comparison group crash rate reductions by year and carrier size group.

Table 5. Initial treatment and comparison group crash rate reductions for FY 2010–12, by size group.

Carrier Size Group	FY 2010 Treatment Group	FY 2011 Treatment Group	FY 2012 Treatment Group	FY 2010 Comparison Group	FY 2011 Comparison Group	FY 2012 Comparison Group
1 (1–5 PUs)	34.6%	38.1%	35.6%	2.0%	3.8%	-1.9%
2 (6–20 PUs)	19.3%	28.3%	24.9%	3.2%	-2.9%	-8.5%
3 (21–100 PUs)	3.7%	17.1%	14.7%	4.8%	0.4%	-2.3%
4 (100+ PUs)	-2.8%	10.9%	2.6%	2.4%	6.9%	-2.9%

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

Note that the crash rate reductions for the comparison group in Table 5 are negative for all size groups in FY 2012, and consequently they will amplify the crash rate reductions of the treatment group in the subsequent step of the model, when net crash rate reductions due to interventions are calculated for each size group. The negative comparison group crash rate reductions are consistent with observed crash rate increases nationally in FY 2013, which represents the bulk of the comparison group post-intervention period; that year, total CMV crashes rose about 6.7 percent when compared with FY 2012.[18]

Table 6 presents the percent reductions in crash rates for the treatment group, once adjusted for the crash rate reductions in the comparison group, by year and carrier size group. Similar to the previous year, carrier size groups 1, 2, and 3 exhibit statistically significant adjusted crash rate reductions in FY 2012, while size group 4 exhibits a non-statistically significant reduction.

[17] The number of carriers reported here is larger than in the previously published CIEM Summary Report for FY 2009–11 (January 2015) as a result of including intrastate non-HM and foreign domiciled carriers in the treatment group, and correspondingly in the comparison group; previously, these carriers were included in the extrapolated total carrier count only.

[18] MCMIS, as reported on FMCSA's Analysis & Information (A&I) Web site as of July 14, 2016: 138,099 crashes in FY 2013, and 129,427 in FY 2012 <http://ai.fmcsa.dot.gov/CrashStatistics/rptSummary.aspx>.

Table 6. Adjusted percent reductions in crash rates.

By Carrier Size Group	FY 2010	FY 2011	FY 2012
1 (1–5 PUs)	32.7%	34.3%	37.5%
2 (6–20 PUs)	16.0%	31.2%	33.4%
3 (21–100 PUs)	-1.2%*	16.7%	17.0%
4 (100+ PUs)	-5.2%*	4.0%*	5.5%*

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

*Non-statistically significant adjusted reduction.

As noted in Section 2.5, the adjusted crash rates represent the pre- to post-intervention change in treatment group crash rates adjusted for the corresponding comparison group crash rates. This means that, for example, size group 1 carriers with interventions in FY 2012 experienced a 37.5 percent crash rate reduction as a group, after subtracting out the crash rate change for comparison group carriers in the same size group in the same modeled year. The table suggests that smaller carriers generally exhibit greater net crash rate reductions from interventions than their larger counterparts. This is consistent with results obtained from the previous enforcement model, CREM, used to calculate safety benefits for years 2002–09, and from the FY 2009 implementation of the CIEM.

3.1.2 Safety Benefits

Table 7 presents safety benefits associated with FMCSA carrier interventions for FY 2012 and the preceding two fiscal years. The left side of the table presents estimated crashes prevented, injuries prevented, and lives saved among treatment group carriers, for carriers that passed the model's data filters. The right side of the table extrapolates these benefits to all carriers receiving interventions, including those that were screened out of the initial model calculations by the data filters. These benefits declined slightly in FY 2012 compared to FY 2011, reflecting the decline in total interventions, although this decline was offset somewhat by larger adjusted crash rate reductions experienced in FY 2012 by carrier size groups 1, 2, and 3.

Table 7. Estimated crashes prevented, injuries prevented, and lives saved.

Fiscal Year	Treatment Group Carriers Number of Carriers	Treatment Group Carriers Crashes Prevented	Treatment Group Carriers Injuries Prevented	Treatment Group Carriers Lives Saved	Extrapolated to all Carriers Receiving Interventions Number of Carriers	Extrapolated to all Carriers Receiving Interventions Crashes Prevented	Extrapolated to all Carriers Receiving Interventions Injuries Prevented	Extrapolated to all Carriers Receiving Interventions Lives Saved
2010	21,078	1,281	800	42	29,591	1,830	1,142	59
2011	44,310	5,394	3,313	176	56,471	6,567	4,033	215
2012	30,200	4,021	2,462	132	42,068	5,283	3,235	173

The safety benefits reported in Table 7 reflect only those associated with statistically significant adjusted crash rates, as reported in Table 6. Carrier size groups not yielding statistically significant crash rate improvements during the post-intervention period, after adjusting for crash rate changes in the comparison group, are assumed to experience no safety benefits.

3.2 RESULTS EXCLUDING WARNING LETTER AS A FIRST INTERVENTION

Additional insight can be gained by examining the impact of excluding warning letters from the analysis and by implementing the model only for carriers whose first intervention is a warning letter. Specifically, these separate model results can reveal to what extent the changes in safety benefits observed from year to year are associated with the large observed changes in numbers of warning letters issued versus the other intervention types in the corresponding years.[19] This section reports the results of implementing the model for carriers receiving intervention types other than warning letters as their first intervention. Section 3.3 reports the results of implementing the model only for carriers whose first intervention is a warning letter.

Table 8 presents the number of treatment group carriers, by size group, excluding carriers that received a warning letter as a first intervention. Unlike the trends exhibited in Table 4, the number of treatment group carriers in all four size groups remains relatively stable, exhibiting modest changes (10–20 percent) from FY 2011 to FY 2012; these increases are largely driven by the increase in onsite focused investigations, as noted above.

Table 8. Number of treatment group carriers, by size group, excluding carriers that received a warning letter as their first intervention.

Carrier Size Group	FY 2010	FY 2011	FY 2012
1 (1–5 PUs)	5,820	5,978	7,194
2 (6–20 PUs)	3,950	3,589	3,899
3 (21–100 PUs)	1,744	1,589	1,802
4 (100+ PUs)	369	416	470
Total	**11,883**	**11,572**	**13,365**

3.2.1 Crash Rate Reduction

Table 9 presents the percent reductions in crash rate, by carrier size group, for both treatment group carriers whose first intervention was not a warning letter and for comparison group carriers. The comparison group utilized here comprises the same comparison group carriers used for the overall model, as shown in Table 2.

[19] Because some carriers receive a warning letter followed by a subsequent intervention, this analysis does not identify the safety benefits associated exclusively with warning letters; rather, it identifies the safety benefits associated with warning letters as a first intervention in the fiscal year. However, since the vast majority of warning letters are not followed by an intervention in the same fiscal year, the results of implementing the model for carriers with warning letters as the first intervention may be similar to what would be obtained by only considering carriers that received warning letters only during the fiscal year.

Table 9. Treatment and comparison group percent reductions in crash rate, excluding carriers that received a warning letter as their first intervention.

Carrier Size Group	FY 2010 Treatment Group	FY 2011 Treatment Group	FY 2012 Treatment Group	FY 2010 Comparison Group	FY 2011 Comparison Group	FY 2012 Comparison Group
1 (1–5 PUs)	47.8%	39.4%	31.6%	2.0%	3.8%	-1.9%
2 (6–20 PUs)	30.5%	28.4%	18.7%	3.2%	-2.9%	-8.5%
3 (21–100 PUs)	9.3%	19.6%	9.6%	4.8%	0.4%	-2.3%
4 (100+ PUs)	-3.1%	10.4%	1.7%	2.4%	6.9%	-2.9%

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

Table 10 presents the crash rate percent reductions, by carrier size group, for these same carriers, once adjusted for the crash rate reductions in the comparison group. Carrier size groups 1, 2, and 3 exhibit statistically significant adjusted crash rate reductions in FY 2012, while size group 4 does not exhibit a statistically significant reduction, consistent with the previous year.

Table 10. Adjusted percent reductions in crash rates, excluding carriers that received a warning letter as their first intervention.

Carrier Size Group	FY 2010	FY 2011	FY 2012
1 (1–5 PUs)	45.9%	35.5%	33.5%
2 (6–20 PUs)	27.2%	31.3%	27.2%
3 (21–100 PUs)	4.5%*	19.2%	11.9%
4 (≥100 PUs)	-5.4%*	3.5%*	4.7%*

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

* Non-statistically significant adjusted reductions.

For the size groups with both positive and statistically significant adjusted crash rate reductions in FY 2012, the table shows results somewhat lower (by about 10–30 percent), than those calculated for the entire population of carriers receiving all intervention types (see Table 6).

3.2.2 Safety Benefits

Table 11 presents safety benefits, by year, as a result of FMCSA interventions, excluding carriers whose first intervention in the fiscal year was a warning letter. The left side of the table presents the estimated crashes prevented, injuries prevented, and lives saved among treatment group carriers. The right side of the table reports these benefits for all carriers receiving these interventions, including those that were screened out of the initial model calculations by the data filters.

Table 11. Estimated crashes prevented, injuries prevented, and lives saved, excluding carriers that received a warning letter as their first intervention.

Fiscal Year	Treatment Group: Number of Carriers	Treatment Group: Crashes Prevented	Treatment Group: Injuries Prevented	Treatment Group: Lives Saved	Extrapolated to All Carriers Receiving Interventions: Number of Carriers	Extrapolated to All Carriers Receiving Interventions: Crashes Prevented	Extrapolated to All Carriers Receiving Interventions: Injuries Prevented	Extrapolated to All Carriers Receiving Interventions: Lives Saved
2010	11,883	1,318	823	43	16,436	1,839	1,148	60
2011	11,572	1,840	1,130	60	15,799	2,372	1,457	78
2012	13,365	1,473	902	48	18,262	1,939	1,187	63

The safety benefits reported in Table 11 reflect only those associated with statistically significant adjusted crash rate reductions, as reported in Table 10. Carrier size groups not yielding statistically significant crash rate improvements during the post-intervention period, after adjusting for crash rate changes in the comparison group, are assumed to have experienced no safety benefits.

Extrapolated safety benefits for carriers whose first intervention was something other than a warning letter in FY 2012 are estimated to be:

- 1,939 crashes prevented.
- 1,187 injuries prevented.
- 63 lives saved.

These findings represent about a 19 percent decline in the three benefit measures when compared to carriers receiving similar interventions in FY 2011, and a 3–5 percent increase when compared to carriers receiving such interventions in FY 2010.

3.3 RESULTS FOR WARNING LETTER AS A FIRST INTERVENTION

This section reports the results of implementing the model only for carriers whose first intervention was a warning letter. Following a large increase in warning letters in FY 2011 with the national rollout of CSA, the number of warning letters issued declined by more than 40 percent in FY 2012, from a total of 40,768 to 23,835. Table 12 presents the number of treatment group carriers, by year and size group, receiving a warning letter as a first intervention. The overall decline in warning letters from FY 2011 to FY 2012 occurs at each of the carrier size group levels.

Table 12. Number of treatment group carriers receiving a warning letter as their first intervention, by size group.

Carrier Size Group	FY 2010	FY 2011	FY 2012
1 (1–5 PUs)	4,886	19,201	9,456
2 (6–20 PUs)	2,947	8,896	4,998
3 (21–100 PUs)	1,168	3,702	1,967
4 (100+ PUs)	194	939	414
Total	**9,195**	**32,738**	**16,835**

3.3.1 Crash Rate Reduction

Table 13 presents the treatment group percent reductions in crash rate, by year and carrier size group, for carriers whose first intervention was a warning letter, and for the comparison group. The comparison group utilized here comprises the same comparison group carriers used for the overall model, as reported in Table 4.

Table 13. Treatment and comparison group crash rate reductions for carriers receiving a warning letter as their first intervention.

Carrier Size Group	FY 2010 Treatment Group	FY 2011 Treatment Group	FY 2012 Treatment Group	FY 2010 Comparison Group	FY 2011 Comparison Group	FY 2012 Comparison Group
1 (1–5 PUs)	9.0%	37.6%	38.5%	2.0%	3.8%	-1.9%
2 (6–20 PUs)	-5.2%	28.1%	30.0%	3.2%	-2.9%	-8.5%
3 (21–100 PUs)	-10.5%	15.7%	20.0%	4.8%	0.4%	-2.3%
4 (100+ PUs)	-3.0%	11.2%	3.9%	2.4%	6.9%	-2.9%

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

Table 14 presents the crash rate percent reductions, by carrier size group, for these same carriers, once adjusted for the crash rate reductions in the comparison group. With the exception of the largest size group, which was not statistically significant, the net crash rate reductions were considerably higher in FY 2012 compared to FY 2011: 20 percent higher for the smallest carriers (40.4 percent versus 33.8 percent); 24 percent higher for carriers with 6–20 PUs (38.5 percent versus 31 percent); and 45 percent higher for carriers with 21–100 PUs (22.3 percent versus 15.4 percent).

Table 14. Adjusted crash rate reductions (treatment minus comparison group) for carriers receiving warning letter as first intervention.

Carrier Size Group	FY 2010	FY 2011	FY 2012
1 (1–5 PUs)	7.0%*	33.8%	40.4%
2 (6–20 PUs)	-8.4%*	31.0%	38.5%
3 (21–100 PUs)	-15.3%	15.3%	22.3%
4 (≥100 PUs)	-5.4%*	4.3%*	6.9%*

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

*Non-statistically significant adjusted reduction.

3.3.2 Safety Benefits

Table 15 presents the estimated safety benefits, by year, experienced by carriers receiving a warning letter as their first intervention. The left side of the table presents crashes prevented, injuries prevented, and lives saved among treatment group carriers. The right side of the table extrapolates these benefits to all carriers receiving warning letters as a first intervention, including those that were screened out of the initial model calculations by the data filters.

Table 15. Estimated crashes avoided, injuries prevented, and lives saved: carriers receiving a warning letter as their first intervention.

Fiscal Year	Treatment Group: Number of Carriers	Treatment Group: Crashes Prevented	Treatment Group: Injuries Prevented	Treatment Group: Lives Saved	Extrapolated to All Carriers Receiving Interventions: Number of Carriers	Extrapolated to All Carriers Receiving Interventions: Crashes Prevented	Extrapolated to All Carriers Receiving Interventions: Injuries Prevented	Extrapolated to All Carriers Receiving Interventions: Lives Saved
2010	9,195	-	-	-	13,155	-	-	-
2011	32,738	3,542	2,175	116	40,672	4,219	2,591	138
2012	16,835	2,548	1,560	83	23,806	3,341	2,046	109

The safety benefits reported in Table 15 reflect only those associated with statistically significant adjusted crash rates and positive crash rate reductions, as reported in Table 14. Carrier size groups not yielding statistically significant or positive crash rate improvements during the post-intervention period, after adjusting for crash rate changes in the comparison group, are assumed to have experienced no safety benefits. As reported in Section 3.3.1, unlike previous years, all carrier size groups with a first intervention being a warning letter experienced statistically significant crash rate reductions in FY 2012. Despite the fact that in FY 2012 the comparison group showed an increase in crash rates in all size groups (increasing the likelihood that calculated net benefits from interventions will be higher), the estimated number of lives saved in FY 2012 is about 25 percent lower than in FY 2011 (110 in FY 2012 compared with 138 in FY 2011). This decrease in overall safety benefits is likely attributable to the substantially lower number of warning letters issued in FY 2012 compared with FY 2011.

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4. CONCLUSIONS

The CIEM provides FMCSA with a means for measuring the safety benefits of both CSA interventions and pre-CSA interventions still used by the Agency. As such, it can be used for annual measurement of safety benefits during the phased CSA implementation and beyond. The model builds on the approach of the CREM, used to measure the effectiveness of CRs until FY 2009. However, in contrast to the CREM, the CIEM now incorporates the various intervention types that comprise FMCSA's overall enforcement program, which has expanded with CSA. Four intervention types not recorded consistently at this time are not included explicitly in the CIEM, but could be incorporated into the model structure in the future. The model also introduces a component addressing statistical significance and an approach for extrapolating directly measured safety benefits to carriers with missing or outlier crash or PU data.

Overall, the set of FMCSA intervention types specified in the model are shown to have reduced motor carrier crash rates in FY 2012 (as in prior years). Consistent with CREM results in prior years, crash rate reductions are generally more pronounced for the smaller carrier size groups. Total carrier interventions experienced a substantial decline in FY 2012, driven by a reduction in the number of warning letters issued. In contrast, overall percent reductions in crash rates for carriers receiving interventions were higher in FY 2012 than in the previous year. The result of these two opposing trends is a moderate decline in total safety benefits estimated by the model for FY 2012.

Further analyses were performed by implementing the model for two subsets of the full treatment group: carriers whose first intervention each year was not a warning letter, and carriers whose first intervention was a warning letter. For both subsets, statistically significant crash rate reductions were observed for carrier size groups 1, 2, and 3. This further analysis provides a measure of the effectiveness of CSA warning letters. This finding demonstrates that warning letters, which are much less expensive than more labor-intensive interventions, can be an efficient tool in reducing crashes for many carriers.

In summary, FY 2012 provides strong evidence for the effectiveness of FMCSA's carrier interventions. Future implementation of the model will enable FMCSA to continue to measure the impacts of carrier interventions.