

A USDOT NATIONAL UNIVERSITY TRANSPORTATION CENTER

Carnegie Mellon University



Do Vehicle Safety Inspection Programs Lead to Lower Fatality Rates?

Prithvi Acharya, Department of Engineering and Public Policy

ORCID: 0000-0002-5557-7523

H. Scott Matthews, Department of Civil and Environmental Engineering

ORCID: 0000-0002-4958-5981

Carnegie Mellon University

FINAL RESEARCH REPORT

Contract No. 69A3551747111

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

A DATA-DRIVEN ASSESSMENT OF SAFETY INSPECTION PROGRAMS' EFFICACY

Prithvi S. Acharya^a, H. Scott Matthews^b,

^a Department of Engineering & Public Policy, Carnegie Mellon University, USA ^b Department of Civil and Environmental Engineering, Carnegie Mellon University, USA Email: <u>acharyap@cmu.edu</u> Email: hsm@cmu.edu

ABSTRACT

Fifteen U.S. states currently require vehicles to undergo periodic safety inspections, to ensure safe tire tread-depth, functioning lights, mirrors and wipers, etc. The effectiveness of these programs has been called into question by several legislatures; since 2000, four of these states have repealed their inspection programs, finding them not to be cost-effective. Applying statistical models to data from the publicly available Fatality Analysis Reporting System (FARS), we analyze the impact of the abolition of safety inspections in these states, on the occurrence of fatal road accidents. We find that on average, the mean number of road fatalities per unit population was higher, five years following the repeal than two years prior. We also propose a generic model to estimate the potential impact of instating or repealing a safety inspection program for a given vehicle population.

Keywords: Vehicle safety, I/M Programs, FARS, statistical analysis

1. INTRODUCTION

Technological advances, and safety regulations continue to improve the safety of new light-duty motor vehicles (LDV's). However, routine maintenance—to ensure proper tire tread-depth, effective brakes, functioning lights, etc.,—is critical to the continued safe operation of LDV's. To ensure adherence to these safety requirements, many jurisdictions (including all E.U. member nations) administer vehicle inspection and maintenance (I/M) programs. Typically, these programs require vehicles to be inspected periodically, and only certified as road-legal after the completion of requisite maintenance to ensure they are safe to operate. In the United States, safety inspection programs (which are managed at the state-level) have received significant political opposition over the last half-century, leading to the abolition of I/M programs in several states. Figure 1 shows that while there were 32 states with I/M programs in the mid-1970's, more than half of these states have since repealed the programs. Much of this opposition posits that inspection programs are not an effective means of preventing road fatalities and are therefore a waste of time and money for vehicle-owners and administrative authorities.

As jurisdictions continue to debate the need for I/M programs, it is imperative that statistical analyses be conducted to assess the effectiveness of safety inspection programs, in achieving their stated aim of preventing road fatalities. Merrell et al. (1999) have applied econometric tools to assess the effectiveness of safety inspection programs, and while they concluded that I/M programs may not have any effect on fatality rates, their analyses are based on data from the 1970's and 80's, and do not benefit from more recent data. As a counterpoint, a time-series analysis conducted by Loeb and Gilad (1984), found the benefits of vehicle inspection programs to outweigh the costs. Other literature published around this time have all used limited datasets and had a high degree of variability in their conclusions on the effectiveness of safety inspection programs (Garbacz, 1990; Loeb, 1990). Sutter and Merrell (2002), go so far as to argue that safety inspections have absolutely no impact on highway safety, and that the states which continue to administer these programs do so purely due to the high "political transaction cost" of repealing them.

A more recent assessment of the abolition of New Jersey's I/M program asserted that there was no link between program repeal and fatal accident rates (Hoagland and Woolley, 2018). However, as discussed further in Section 2, our analyses differ from past literature in scope and methods. Unlike early studies, our research uses up-to-date, publicly available raw data on fatal motor vehicle accidents, from the

U.S. Department of Transportation. Second, rather than focusing on accidents in any one specific state, we intend to apply a pooled regression (and other panel data approaches) to data from every state in the country, allowing us to develop a more robust estimate of the population-adjusted rate of road-accident related fatalities, as a function of the presence or absence of an I/M program in that state. Third, and most importantly, our study considers the long-term effects of establishing or repealing an I/M program, rather than only the immediate effects, as is typical in the literature.



Figure 1: Since 1976, 17 U.S. states have repealed I/M programs

Table I: Nationwide annua	l road-fatalities have	decreased steadily	over time.
---------------------------	------------------------	--------------------	------------

Year	Fatal Accidents	Vehicles Recorded	Persons Recorded	Total Fatalities	- -	Year	Fatal Accidents	Vehicles Recorded	Persons Recorded	Total Fatalities
1988	42,130	62,703	112,958	47,087	-	2003	38,477	58,877	101,862	42,884
1989	40,741	60,870	109,866	45,582		2004	38,444	58,729	100,760	42,836
1990	39,836	59,292	107,777	44,599		2005	39,252	59,495	101,262	43,510
1991	36,937	54,795	99,369	41,508		2006	38,648	58,094	98,356	42,708
1992	34,942	52,227	95,691	39,250		2007	37,435	56,253	94,338	41,259
1993	35,780	53,777	97,589	40,150		2008	34,172	50,660	84,510	37,423
1994	36,254	54,911	98,945	40,716		2009	30,862	45,540	76,510	33,883
1995	37,241	56,524	102,102	41,817		2010	30,296	44,862	74,863	32,999
1996	37,494	57,347	103,347	42,065		2011	29,867	44,119	73,364	32,479
1997	37,324	57,060	102,197	42,013		2012	31,006	45,960	76,436	33,782
1998	37,107	56,922	101,100	41,501		2013	30,202	45,101	74,331	32,893
1999	37,140	56,820	100,666	41,717		2014	30,056	44,950	73,711	32,744
2000	37,526	57,594	100,716	41,945		2015	32,538	49,478	81,620	35,484
2001	37,862	57,918	101,175	42,196		2016	34,748	52,714	86,474	37,806
2002	38,491	58,426	101,784	43,005	-	2017	34,247	52,645	84,921	37,133

2. DATA

The United States National Highway Traffic Safety Administration (NHTSA) administers a database

through the Fatality Analysis Reporting System (FARS), which has, since 1976, collected data on motor-vehicle accidents anywhere in the United States, which resulted in at least one fatality. FARS contains information on each accident (location, weather and road conditions, number of vehicles involved, etc.,), in addition to information on individual vehicles involved in these accidents (make and age, vehicle-related contributing factors to the accident, speed, etc.,), as well as demographic information of drivers, passengers and pedestrians. More details, including a full list of fields in the FARS data is available in NHTSA's *Analytical User Manual* (NHTSA, 2016). The models presented below were developed from thirty years' FARS, from 1988 to 2017 (the most recent year for which FARS data are available). During this time, five U.S. states and the District of Columbia repealed their I/M programs. Table I lists some descriptive statistics from these data and shows that the total number of road fatalities have been rather consistently, if slowly, reducing over time. In 2017, 37,133 fatalities were reported nationwide, resulting from 34,247 accidents. These involve all crashes including, for example, those between passenger vehicles and larger highway trucks.

In parallel, we also studied the existence of vehicle component failure-related fatal crashes in FARS. The FARS database has fields that represent "vehicle contributing factors" for issues like tires or brakes that were suspected to have had a contributing role in a crash. Such data should be valuable for a study premised on whether safety inspection program activities can reduce fatalities. However, the degree to which different states and accident investigators enter data into these fields varies widely. A summary of our data analysis on these parts of the FARS data is presented in Appendix A.

3. METHODS

The stated aim of most I/M programs is to reduce fatalities from road accidents by ensuring that vehicles are safe to operate. Therefore, we develop models which aim to assess whether there is any correlation between the presence of an I/M program in a state, and the number of fatalities involving vehicles registered in that state, each year. Specifically, we develop regression models against the population adjusted number of annual statewide fatalities, represented in *fatalities per 100,000 population* (Equation 1).

Equation 1

 $\begin{array}{l} \mbox{Adjusted Fatality Rate}_{state=A,year=B} \\ = \frac{Total \ Number \ of \ Fatalities \ in \ Accidents \ in \ Year \ B, \ where \ at \ least \ one \ vehicle \ was \ registered \ in \ State \ A}{Population \ of \ State \ A} \end{array}$

It must be noted that while the analyses we conduct are at the state-level, the "state" considered is not the state in which the fatal accident occurred, but in-fact the state to which each vehicle involved in the accident was registered. As discussed in more detail by Hoagland & Wooley (2018), this approach accounts for the fact that vehicles are regulated (and specifically, subject to inspections) based on the state in which they are registered, regardless of where the vehicle was when an accident occurred. Since FARS provides time-series for accidents in each of the fifty states, over a long duration, we developed regressors by-year and by-state, and applied panel data methods to these regressors. Both variations of the model presented in this paper are independently pooled data models. Pooled models were selected since regulations vary between states, and since we assume that the fatality rates in each state and year are independent of fatality rates in other states or years.

3.1 REGRESSORS

In order to develop a panel data type regression model, where the predicted variable is the adjusted fatality rate, as discussed above, we developed a number of regressors (by-year and by-state), which are listed in Table II. Using these regression features, we developed two variations on a pooled panel data model as discussed below.

3.2 FIRST REGRESSION MODEL

We develop a pooled panel data model, regressing every regressor discussed in Table II, against the adjusted fatality rate.

Feature	Data Source	Notes
Vehicle mean age		
Mean age of driver		
Mean number of vehicles in each accident		
Proportion of vehicles with listed "contributing vehicle		
failure".		
Proportion of vehicles involved in a DUI-related	FARS	From vehicles in the FARS database for a given year, which are registered in the
accident	TAKS	
Proportion of vehicles involved in speeding-related		
accident	_	given state.
Mean number of lanes at accident site	_	
Proportion of vehicles involved in accident during		
recorded inclement weather		
VMT per capita	- NHTSA (VM 202)	
Proportion of VMT on rural roads	$\operatorname{NIII} \operatorname{SA}(\operatorname{VIVI-202})$	
Active I/M program?	GAO 2015	Binary variable (1 = program exists, 0 = no program)

Table II: Panel re	gression features	were developed	from FARS data.
--------------------	-------------------	----------------	-----------------

3.3 FINAL MODEL

The final model was therefore a pooled panel data model, regressing six variables from FARS against the adjusted fatality rate (fatalities/100,000pop).

4. **RESULTS**

The results from the first model, presented in Table III, show that nine out of the eleven regressors considered appear to have a statistically significant relationship with our dependent variable. The most significant positive effect (increase in adjusted fatality rate with increase in regressors) appears to be from the proportion of miles driven on rural roads. The presence of an I/M program also showed a negative effect of -0.86. This can be interpreted as that the presence of a safety inspection program in that state reduces the number of fatalities in a given year by 0.86 fatalities/100,000 population. It is worth noting in this model that the coefficients for the proportion of accidents where inclement weather were recorded, are negative (indicating that, as per the model, when an increased proportion of vehicles registered in a state are involved in accidents due to inclement weather, the adjusted fatality rate reduces). This is a counter-intuitive finding and warrants further analysis. However, based on this first model, it appears that two variables – mean vehicle age, and mean number of vehicles involved in each accident, were found to not be significant (p < 0.05). Therefore, these two variables were excluded from analysis in the final model.

Predictors	Estimates	CI	p-value
(Intercept)	6.41	-2.28 - 15.10	0.149
Vehicle Mean Age	0.01	-0.35 - 0.37	0.967
Mean Number of Vehicles in Accident	-2.66	-5.83 - 0.51	0.101

Proportion w/ DUI	5.69	0.31 - 11.07	0.039
Proportion w/ Contributing Vehicle Failure	-23.21	-42.154.26	0.017
Mean Number of Lanes	3.36	1.62 - 5.10	< 0.001
Proportion w/ Speeding	-7.63	-12.263.01	0.001
Proportion w/ Inclement Weather	-10.98	-16.185.77	< 0.001
Mean Driver Age	-0.2	-0.280.12	< 0.001
Proportion of VMT on Rural Roads	13.84	11.04 - 16.65	< 0.001
VMT Per Capita	0.01	0.01 - 0.01	< 0.001
Active IM Program? (Binary Variable)	-0.86	-1.710.01	0.048
Dependent Variable:	Fatalities/10	0,000 Population	
Observations:	409		
R^2 / R^2 adjusted	0.689 / 0.68	0	

Our final model shows (Table IV) that several of our regression variables may be statistically significant. Here too, there is a counter-intuitive, negative effect of recorded instances of speeding and inclement weather, which warrant further analysis. The highest positive effects (i.e., regressors correlated to an increase in adjusted fatality rate) were attributable to the proportion of miles typical drivers in each state drive on rural roads (vs. urban roads and highways), followed by the proportion of fatal accidents involving drivers under the influence of alcohol or drugs (DUI). Regarding the presence of I/M programs, the lagged term (i.e., was there an active I/M program in this state five years ago) was found with a high confidence (p < 0.01) to have a negative impact on adjusted fatality rates, with a coefficient estimate between -0.42 and -1.97. This may be interpreted to mean that in states which had an inspection program five years before any year being analyzed, the number of road fatalities may be expected to be between 0.42 and 1.97 fewer per 100,000 citizens, than if the state did not have an inspection program. In real terms, for a state such as New Jersey (2017 population, 9.01 million), repealing an existing program could lead to 38-178 additional deaths in the fifth year after the program has been repealed.

Predictors	Estimates	CI	p-value
(Intercept)	-0.27	-6.92 - 6.38	0.937
Proportion w/ DUI	3.93	-1.61 - 9.48	0.166
Proportion w/ Contributing Vehicle Failure	-21.45	-40.792.10	0.03
Mean Number of Lanes	3.07	1.38 - 4.75	< 0.001
Proportion w/ Speeding	-5.45	-9.591.32	0.01
Proportion w/ Inclement Weather	-10.15	-14.665.64	< 0.001
Mean Driver Age	-0.16	-0.240.09	< 0.001
Proportion of VMT on Rural Roads	11.17	8.35 - 13.98	< 0.001
VMT Per Capita	0.01	0.01 - 0.01	< 0.001
Active IM Program? (lagged 5 years)	-1.2	-1.970.42	0.003
Dependent Variable:	Fatalities/10	00,000 Population	
Observations:	361		
R^2 / R^2 adjusted	0.716/0.70)9	

5. DISCUSSION

Our preliminary results show that the presence (or absence) of a vehicle safety inspection program in a U.S. state has a negative correlation to the population adjusted number of fatalities caused by motor accidents involving vehicles registered in that state. Moreover, they show that the ability of vehicle inspections to reduce road fatalities can potentially last for up to seven years. Conversely, our results point to that the negative effects of repealing an I/M program may also last for several years, and that

as such, analyses of the relationship between road fatality rates and I/M programs should consider these long-term effects in order to fully capture the correlation.

These results also show that further analyses are required to explain findings surrounding some other regressor variables. For example, both models we constructed appear to show that in states and years where inclement weather was recorded more often, or where vehicle speeding was recorded more often, the adjusted fatality rate was lower. One possible reason for this may be that the resolution of these data in the FARS dataset are very low, and these fields are populated more accurately by first responders in some states than others. Alternatively, it could be that some part of the effects of these variables are already being captured by another variable or an externality. In the future, we intend to add more regressors to our model, to potentially better explain these trends, and to improve models' fit overall (i.e., to improve the R² value, a measure of the proportion of data which are correctly explained by our model).

Through the development of these models, we wish to quantify the impact of establishing or repealing vehicle safety inspection programs, allowing legislators to quantitatively estimate the impact of policy-changes on road fatalities in their specific jurisdiction or state, and thus better gauge the cost-effectiveness of I/M programs as a means of preventing road fatalities, in comparison to other possible policy interventions with the same aim.

6. FUTURE WORK

Going forward, we seek to improve on the model above in various ways. First, we believe that a fixed effects models would be more appropriate to use than a pooled model, specifically that we should consider multiple effects for the presence of state inspection programs over time. There could be one variable to note states that never had a program over the time period of the FARS data, and another to capture states who gained or lost a program. Such a model should more accurately capture the expected fatality rate changes associated with programs. Second, we would also like to use a longer time series of the FARS data, and explore the use of different metrics for the fatality rate beyond population, such as registered vehicles. Third, we will explore the use of a log-log based model to help better represent and communicate the percentage change results of fatality rates associated with changes in inspection programs. Finally, the FARS data used above was for all vehicle types, including passenger vehicles crashing into large commercial haul trucks. We also intend to explore the focused subset of crashes involving only passenger vehicles. We will try to collaborate with colleagues with more experience in statistical modeling using causal methods.

ACKNOWLEDGEMENTS

We thank Prof. Mitchell Small for providing thoughtful feedback on the econometric tools and statistical methods used to develop our models. We also thank Dr. Dana E. Peck and Prof. Paul S. Fischbeck, for early work in framing the problem statement of this study. We also thank CITA for additional funding that allowed us to initiate this project.

REFERENCES

- 1. Garbacz, C. (1990) 'How effective is automobile safety regulation?', *Applied Economics*, 22(12), pp. 1705–1714. doi: 10.1080/00036849000000076.
- Hoagland, A. and Woolley, T. (2018) 'It'S No Accident: Evaluating the Effectiveness of Vehicle Safety Inspections', *Contemporary Economic Policy*, 36(4), pp. 607–628. doi: 10.1111/coep.12284.
- Loeb, P. D. (1990) 'Automobile safety inspection: further econometric evidence', Applied Economics. Chapman & Hall Ltd., 22(12), pp. 1697–1704. doi: 10.1080/00036849000000075.

- 4. Loeb, P. D. and Gilad, B. (1984) 'The efficacy and cost-effectiveness of motor vehicle inspection. A state specific analysis using time series data.', *Journal of Transport Economics & Policy*, 18(2), pp. 145–164.
- 5. Merrell, D., Poitras, M. and Sutter, D. (1999) 'The Effectiveness of Vehicle Safety Inspections: An Analysis Using Panel Data', *Southern Economic Journal*, 65(3), p. 571. doi: 10.2307/1060816.
- National Highway Traffic Safety Administration (2016) 'Fatality Analysis Reporting System (FARS) Analytical User 's Manual', (October), p. 590. Available at: https://crashstats.nhtsa.dot.gov/Api/Public/Publication/812315.
- Sutter, D. and Poitras, M. (2002) 'The Political Economy of Automobile Safety Inspections', *Public Choice*. Kluwer Academic Publishers, 113(3/4), pp. 367–387. doi: 10.1023/A:1020843328626.

Appendix A: FARS 'vehicle contributing factors'

The FARS database includes fields for 'vehicle contributing factors', which are intended to record any factors of vehicle maintenance or failure which may have contributed to the fatal accident. Table 1 lists the contributing factors which may be recorded in FARS. When examining individual factors, it is generally true that 'tires' are the most commonly recorded factor throughout the data-set. However, in any given year, there is a wide range across states in the percentage of vehicles recorded to have each type of contributing factor.

Contributing	FARS Code	FARS Code	FARS Code
Factor	1975-1981	1982-2009	2010-2017
Tires	1	1	1
Brake System	2	2	2
Steering System	3	3	3
Suspension	4	4	4
Powertrain	5	5	5
Exhaust	6	6	6
Headlights	7	7	7
Signal Lights	8	8	8
Other Lights	9	9	9
Mirrors	11	11	12
Wipers	12	12	10
Body	14	14	14
Trailer Hitch, Safety Chains	15	15	15
Wheels	1	16	11
Safety Systems	-	17, 19	16
Other Vehicle Defects	-	10, 13 ,18	17, 97

Table 1: Sixteen types of vehicle defects may be recorded in FARS

For example, nationwide, states recorded anywhere between zero and 3.5% of fatal accidents in their jurisdiction that year to include at least one vehicle with tires as a contributing factor, with a median value of just over 1% of fatal accidents (involving in-state passenger vehicles) in each state. Figure 1 shows this variation (in percentage of accidents with a recorded vehicle contributing factor) across the fifty states and D.C., for the year 2018. Not only is there a large variation across states, but also within states over time. This is illustrated in figure 2, which shows the temporal variation in the proportion of fatal passenger vehicle accidents, in which at least one contributing factor was recorded. These large variations may be due to several reasons, including changes to the FARS recording criteria, as well as inconsistencies in each states' accident data recording policies. There does not appear to be a distinction in these trends and fluctuations between states which have safety I/M programs, and those which never had them, or used to have them. Based on evidence in the literature, it is likely that these rates are under-reported.



Figure 1: In 2018, states recorded between 0% and 8.3% of fatal passenger vehicle accidents as having at least one 'vehicle contributing factor'.



Figure 2: The proportion of factors recorded varies with time and across states