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Does public education improve rail–highway crossing safety?

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Abstract

Improvements in rail–highway grade crossing safety have resulted from engineering, law enforcement, and educating the public about the risks and the actions they should take. The primary form of the latter is a campaign called Operation Lifesaver which started in the 1970s. This paper uses a negative binomial regression to estimate whether variations in Operation Lifesaver activity across states and from year-to-year in individual states are related to the number of collisions and fatalities at crossings. Annual data on the experience in 46 states from 1996 to 2002 are used. The analysis finds that increasing the amount of educational activity will reduce the number of collisions with a point elasticity of −0.11, but the effect on the number of deaths cannot be concluded with statistical certainty.

Keywords: Rail–highway crossings; Accident analysis; United States; Public education; Operation Lifesaver

1. Introduction

The number of collisions and fatalities at rail–highway intersections in the United States has declined significantly over the past 30 years, despite considerable increases in the volume of rail and highway traffic. An earlier paper (Mok and Savage, 2005) used a negative binomial regression on a pooled data set for 49 states from 1975 to 2001 to disaggregate the improvement into its constituent causes. One of the variables in the analysis dealt with a public education program called Operation Lifesaver (OL). Between 1972 and 1986, programs were established in each state to promote education and awareness of railroad-related hazards, especially the need to appreciate the risks when traversing grade crossings. In the earlier analysis, OL was represented by a 0–1 dummy variable indicating whether or not the program had been established in that particular state in a given year. The analysis found that establishment of OL led to a 15% decrease in the number of collisions between motor vehicles and trains, and a 19% reduction in the number of deaths that result from these collisions.

OL is a state-based organization, and the levels of activity vary greatly across the country. In addition, the level of activity in a state varies over time. Data were not available for the earlier analysis to permit use of a continuous variable to indicate the level of activity in a state. A national office for OL was only established in the late 1980s, and uniform reporting of activity to the national office was only instigated in 1996. The current paper uses information from these state-level reports from 1996 to 2002 to relate differences in activity levels between states and across time to the accident experience at crossings.

2. Operation Lifesaver

By the mid 1960s, rail–highway grade crossing safety had become an issue of great public concern. Highway traffic was increasing, and the railroads did not have the financial resources to increase the proportion of crossings that are equipped with gates and/or flashing lights (known as active warning devices) that indicate whether or not a train is approaching.

The public concern led to a flurry of activity in the early 1970s. The *Federal Highway Act* of 1973 contained provisions, known as the Section 130 program, that provided federal money to states to cover most of the cost of crossing upgrades. In effect, the planning and financial burdens of deciding on appropriate warning devices were transferred from the railroads to the highway authority. Benefit-cost manuals and software were prepared to assist highway engineers decide on the priorities for spending the money, and from 1977 a new chapter in the Federal Highway Administration's (FHWA) *Manual on Uniform Traffic Control Devices* provided standards for the type and design of signs and devices that should be installed.

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However, engineering improvements are only part of the solution to the problem. A perpetual issue has been highway users' poor perception of the dangers of grade crossings. Drivers sometimes misjudge the speed of approaching trains, and because they are in a hurry, they are tempted to drive around lowered gates and/or ignore the flashing lights. In excess of 80% of the fatalities at crossings with active warning devices occur when the highway user has ignored the warning device. At crossings with just signs identifying the location of the crossing (known as passive warning devices), the conduct expected of drivers in observing for an approaching train is both ill-defined and misunderstood (Lerner et al., 2002).

A public information campaign to educate drivers was established in Idaho in 1972 using the OL brand name. Its introduction was claimed to have produced a 40% decline in crossing fatalities. The program then spread state by state across the nation (excepting Hawaii and the District of Columbia) by 1986. The flagship activity is making presentations to school children, drivers' education classes, and community groups. A pool of 3000 people, mainly volunteers, gives a total of about 30,000 presentations a year to a combined audience of about 1.5 million. The volunteers include railroad employees, police officers and other concerned citizens. More specialized training classes are provided to certain types of commercial drivers such as school bus drivers, truck drivers, and the emergency services. Informational booths are placed at public events and in public places. Print and other media public service announcements are made.

The organization is funded by agencies of the federal Department of Transportation, the railroads, and from various state and local sources. As a volunteer-based organization, the budget is quite modest. The total funding of the national office and all of the state organizations, including gifts in kind, is less than $5 million a year. Each state organization is an independent entity, and the level and type of activity varies.

3. Analytical technique

There is a huge literature on modeling the risk at individual crossings. Models have existed for more than 60 years. Austin and Carson (2002) provide a historical review and a state-of-the-art model, using the negative binomial regression technique. The model in this paper also uses the negative binomial, but is at a much more macro level. Rather than looking at individual crossings, this analysis models the incident experience in a state in a given year. Therefore, the appropriate primary measure of exposure to incidents is the number of crossings, rather than the levels of highway and rail traffic that are used in models of risk at individual crossings (these latter two variables do appear in this regression, but as additional explanatory variables).

There are two main reasons for conducting the analysis at the state/year level rather than at the level of individual crossings. The first is that the data on OL activity is at the state level and not disaggregated to the individual municipalities in which a crossing may be located. The second is that while a federal data base contains estimates of the rail and highway traffic at individual crossings, these data are not updated on a regular basis, so that one cannot use this data source alone to construct a panel data set on individual crossings over time. As we will see, time-series variation in OL activity is as important as cross-sectional variation.

The estimated equation can be usefully visualized as having the form:

$$\text{count of incidents} = e^{(\beta\ \ln(\text{number of crossings}) + \gamma\ \text{other variables})} + \in$$

In the classic version of this model, the value of the coefficient β is constrained to equal unity. A state with twice as many crossings, holding everything else constant, should produce twice as many incidents. Test regressions were conducted without this constraint, and the estimated values of β were, indeed, found to be statistically indistinguishable from unity. Therefore, the regressions were estimated with this constraint.

The negative binomial regression is a more generalized version of the Poisson regression. It assumes that the mean, $E(y)$, and variance, $\text{Var}(y)$, of the count of incidents for a group of states/years with identical values of the explanatory variables have the following relationship:

$$\text{Var}(y) = E(y) + \alpha E(y)^2$$

The statistical output reports the estimated value and standard error of α. If α is found to be insignificantly different from zero, the model simplifies to the Poisson assumption. The regressions estimated in this paper reject the null hypothesis that $\alpha = 0$. Moreover, because the estimated values of α are positive, the data are referred to as overdispersed.

4. Variables and data

4.1. Number of observations

The data set consists of a panel of 46 states for the years 1996–2002. Hawaii is not included because it has negligible railroad mileage and crossings, and neither is the District of Columbia which has a negligible number of grade crossings, many of which are little used and do not even have any warning signs. Other observations had to be dropped either because the state OL organization did not submit a report to the national office for a given year, or because, after consultation with the national office of OL, it was felt that the reported data were incomplete or considered unreliable. Generally, volunteer coordinators are reporting on the activities of volunteer presenters, and in some cases the reporting is not very good. Consequently, three states were excluded in their entirety (Arizona, Maryland and Virginia), data on 14 annual observations involving 11 states were missing, and 16 years involving nine different states were dropped because the data were questionable or was incomplete. The total usable sample size was therefore 292 out of a possible 343 observations. Table 1 shows the annual averages for each state for most of the variables so as to give the reader some idea of the cross-section variation.

4.2. Dependent variables

Two separate regressions are conducted. The first is on the number of incidents in a state in a given year at public crossings

Table 1
Descriptive statistics—annual averages by state

State	Years included (1996–2002 except where indicated)	Total public crossings	Incidents per 1000 crossings	Deaths per 1000 crossings	OL presentations and special training per 1000 crossings	Non-interstate highway average annual daily traffic	Average trains per day	Proportion of crossings with active warning devices	Highway fatal crash rate per 100 million vehicle miles traveled	Highway fatality rate per 100 million vehicle miles traveled
Alabama	All	3488	32	3.4	211	1275	12.5	0.32	1.73	1.93
Alaska	1996, 1998–2002	225	17	0.0	182	719	9.5	0.39	1.63	1.84
Arizona	1997–1902	3164	29	4.5	169	611	14.1	0.28	1.87	2.13
California	All	7862	17	1.9	315	2917	15.5	0.57	1.13	1.26
Colorado	All	1943	14	1.3	376	888	9.6	0.37	1.46	1.64
Connecticut	All	368	12	0.8	564	2320	8.9	0.74	1.00	1.08
Delaware	1996–1997, 1999, 2001–2002	300	19	3.3	134	3277	5.3	0.78	1.30	1.47
Florida	1997–2002	3953	19	2.3	150	2691	14.1	0.73	1.77	1.96
Georgia	All	5946	20	1.6	150	1723	13.7	0.36	1.38	1.55
Idaho	1999–2002	1356	14	1.8	400	644	11.0	0.24	1.67	1.91
Illinois	All	9329	18	2.5	426	1449	21.6	0.54	1.24	1.38
Indiana	1996, 1998–2002	6449	27	3.2	141	1578	17.4	0.49	1.15	1.29
Iowa	All	5157	17	1.3	97	551	11.1	0.34	1.35	1.54
Kansas	All	6887	10	1.3	88	410	11.6	0.25	1.56	1.78
Kentucky	1997–2002	2507	22	1.6	253	1214	15.9	0.50	1.63	1.82
Louisiana	All	3527	47	5.4	136	1348	11.3	0.36	1.94	2.18
Maine	All	844	8	0.0	113	1348	4.6	0.65	1.22	1.35
Massachusetts	1997, 1999–2002	1157	10	0.9	655	2637	8.5	0.76	0.80	0.85
Michigan	1996–1997, 1999–2002	5560	20	1.9	69	1617	9.7	0.44	1.29	1.44
Minnesota	All	5108	18	1.5	125	763	8.5	0.25	1.07	1.20
Mississippi	1996–2000	2834	42	5.6	111	1026	9.4	0.28	2.34	2.65
Missouri	All	4763	16	2.1	260	1002	15.1	0.36	1.53	1.75
Montana	All	1474	11	1.1	603	294	11.7	0.25	2.09	2.40
Nebraska	All	3876	12	1.8	144	413	22.3	0.23	1.38	1.60
Nevada	1998–2002	301	5	0.7	419	935	11.5	0.52	1.69	1.95
New Hampshire	1997–2002	403	6	0.0	126	1575	4.6	0.62	1.01	1.10
New Jersey	2001–2002	1858	15	1.1	218	3578	9.1	0.71	1.00	1.09
New Mexico	All	783	19	4.0	291	750	18.4	0.41	1.76	2.02
New York	1997–2002	3120	7	0.5	1011	2175	15.8	0.73	1.11	1.21
North Carolina	All	4597	18	1.0	107	1859	9.7	0.49	1.56	1.75
North Dakota	All	4477	4	0.5	116	181	5.7	0.11	1.17	1.34
Ohio	All	6404	21	2.6	256	1693	20.3	0.53	1.19	1.32
Oklahoma	1997, 1999–2002	4320	18	3.2	89	792	11.5	0.30	1.42	1.65
Oregon	All	2309	10	0.7	156	837	9.6	0.36	1.27	1.43
Pennsylvania	1997–2002	5503	10	0.8	108	1711	9.3	0.51	1.37	1.51
Rhode Island	1996–1999, 2001–2002	125	3	0.0	1561	2237	4.7	0.71	0.96	1.01

Table 1 (*Continued*)

State	Years included (1996–2002 except where indicated)	Total public crossings	Incidents per 1000 crossings	Deaths per 1000 crossings	OL presentations and special training per 1000 crossings	Non-interstate highway average annual daily traffic	Average trains per day	Proportion of crossings with active warning devices	Highway fatal crash rate per 100 million vehicle miles traveled	Highway fatality rate per 100 million vehicle miles traveled
South Carolina	All	3004	22	2.2	126	1358	12.0	0.47	2.05	2.29
South Dakota	1997–2002	2139	7	0.1	85	199	2.8	0.10	1.76	1.98
Tennessee	All	3234	26	2.3	144	1432	16.9	0.39	1.74	1.93
Texas	All	12128	26	3.2	134	1300	12.5	0.41	1.52	1.74
Utah	All	977	21	3.7	280	950	10.3	0.44	1.33	1.54
Vermont	1996–1997, 1999–2002	496	5	0.3	127	1185	5.4	0.54	1.03	1.14
Washington	All	2795	13	0.8	405	1151	8.9	0.35	1.12	1.26
West Virginia	All	1640	11	0.5	159	1056	11.1	0.43	1.84	2.03
Wisconsin	All	4383	23	1.5	143	1079	10.5	0.44	1.19	1.34
Wyoming	All	446	6	0.0	498	487	18.6	0.54	1.71	2.01

involving a motor vehicle. Railroads are required to file a report (Form FRA F 6180-57) on all collisions between trains and highway users regardless of severity. The analysis is restricted to public crossings as these are the crossings for which the most data are available. The analysis is also restricted to incidents involving motor vehicles because data are not available on the amount of pedestrian, equestrian and bicycle traffic. The second regression concerns the number of deaths that occur in these incidents. The persons killed are mainly highway users, but there are fatal injuries sustained by train crew and passengers. Data for both of these items are available from the printed Federal Railroad Administration (FRA) annual reports on grade crossing safety (FRA, 2005a,b), and in an excellent searchable data base on their web site. While the negative binomial regression uses the count of incidents and fatalities as the dependent variable, the average annual rate per thousand crossings in each state is shown in Table 1 for ease of cross-sectional comparison.

4.3. *Exposure*

The exposure variable is the number of public crossings in a state. Information on the “inventory” of crossings is given in the printed FRA annual grade crossing safety report.

4.4. *Operation Lifesaver*

The measure of activity by OL is the number of presentations and special training events. It is expressed as a rate per thousand crossings to avoid problems of collinearity with the exposure variable. This was felt to be the most reliable and consistently reported measure of activity. Presentations make up 95% of the total. Special training events are also included because it is not clear whether certain activities, such as talks to truck drivers, school bus drivers and emergency responders are consistently classified in one category or the other. State coordinators are also required to report the number of people in attendance at these events. Theoretically, this would be a preferable measure. However, in practice there are some anomalies which make use of this measure questionable.

About a third of the presentations are made to school children who are too young to drive. For some, but not all, states it is possible to identify those presentations made at kindergartens or to grade 1–8 students. Ultimately it was decided to include these presentations as OL feels that educating young children affects the behavior of their parents, and over time these youngsters will become drivers. A complication is that OL not only provides education on grade crossing risks, but also highlights the risks of trespassing at locations away from grade crossings. One might imagine that presentations to younger children would focus on this aspect of railroad risk, albeit that most presentations probably touch on both types of risk. Unfortunately, OL reports do not record whether a presentation is primarily focused on grade crossings or primarily focused on trespassing.

OL has other activities beside presentations, such as placing public service announcements. Casual reading of the state reports suggests that states that are very active in making presentations are also very active in other activities. So the variable used should be seen as a proxy for the total level of activity. One might argue that one should model the education effects with a lag so that educational activities this year affect incident experience next year. Even if one had the luxury of a long time series of data, and could afford to lose observations, it is debatable whether a lag should be used. Presentations should affect behavior immediately.

Analytically the biggest concern is endogeneity, caused when the level of OL activity in a state is dependent on the inherent grade crossing risk in that state. Locations with a high inherent risk may engender much OL activity, and in low-risk areas there may not been much pressure to mount extensive programing. Endogenous feedback will affect the magnitude of the estimated relationship between OL activity and crossing collisions.

From a social viewpoint, rather than from an analytical viewpoint, one would hope that OL activity is endogenously determined. However, in reality it is not. As can be seen in Table 1, there is considerable variation around the nationwide average of 215 presentations and training events per thousand public crossings each year. Among the states with extensive OL programs are Illinois which is a high-risk state, and a number of states in the Northeast which traditionally have had a low risk of collisions. At the other end of the spectrum are 10 states with less than 120 annual presentations and special events per thousand crossings. Some of these states, such as North and South Dakota, have historically low collision risk, primarily because both highway and rail traffic is light. However others, such as Mississippi, Michigan and North Carolina, are among those with the highest rate of grade crossing collisions in the country. There are often random historical reasons explaining the level of activity in each state. These include emergence of dominant personalities that have championed the cause, differences in formal structure (charitable organization versus part of state government), and different levels of commitment from school districts.

In addition to the cross-sectional variation, there is also considerable variation across years for individual states due to a diverse set of exogenous reasons. As way of illustration, Table 2 shows the distribution of the coefficient of variation (standard deviation divided by the mean) for the total number of presentations and special training for the 46 states that are included in the regression analysis. There are some states (such as Georgia, California, Utah, Washington State and Missouri) that have a reasonably consistent level of activity, but for many others (such as Pennsylvania, Illinois, Maine, Montana and New Hampshire) there are wild fluctuations. In three-fifths of the states, the standard deviation is at least a quarter of the size of the mean.

Table 2
Year-to-year variability in OL activity by state

Coefficient of variation for annual number of presentations and special training events	Number of states
0.0–0.2	10
0.2–0.4	19
0.4–0.6	7
0.6–0.8	8
0.8–1.0	0
1.0–1.2	2

There are myriad reasons for these year-to-year variations: the volunteer coordinators change and are replaced by either energetic new people or less-organized people, prolific presenters retire, school districts change their policies regarding presentations in schools, and railroads change their policies regarding allowing employees to make presentations during working hours. There can be as much time-series variability in activity as there is cross-sectional variation.

Overall, there would seem to be numerous exogenous influences that determine the level of activity both across states and across time, and not much suggestion of a strong endogenous relationship.

4.5. Other explanatory variables

Other explanatory variables include the levels of rail and highway traffic. Highway average annual daily traffic (AADT) and the frequency of trains will affect the number of potential conflicts at crossings. These variables vary markedly both between states, as can be seen in Table 1, and over time. State average AADT is readily available from the FHWA's 2005 *Highway Statistics*. The variable excludes travel on urban and rural interstate highways and urban expressways and freeways. These roads are grade-separated, and travelers do not encounter grade crossings. The state average non-interstate AADT for state i in year t is given by:

$$\mathrm{AADT}_{it} = \frac{\text{non-interstate annual vehicle miles traveled}_{it}}{\text{miles of non-interstate highways}_{it} \times \text{days}_t}$$

where annual vehicle miles traveled in the state are in Table VM-2 (the data are reported in millions of miles, and is multiplied by a million), and miles of highway are in Table HM-20. Days is the number of days in the year.

Disaggregate data on train miles are not available by state. National annual data are available on the number of train miles from the FRA's annual *Accident/Incident Bulletin*. This is for railroads of all sizes. The number of railroad road miles, which is a measure of the route length, is reported by the Association of American Railroads (2005) *Railroad Facts*. This publication includes definitive measures of route length of the large "Class I" railroads, and an estimate of the route length of the smaller railroads. Of course, not all states have the same frequency of trains. A point estimate of the state-by-state distribution of train frequency can be obtained from the FRA's crossing inventory data. The most current inventory file for public at-grade crossings was downloaded from the FRA's web site, and the average number of daily trains were calculated for each state. A "state correction factor" was derived by comparing the state average to the national average. Data were then calculated on the average number of daily trains for state i in time period t by the formula:

$$\text{trains per day}_{it} = \frac{\text{national train miles}_t}{\text{national railroad route miles}_t} \times \text{days}_t \times \text{state correction factor}_i$$

As shown in Table 1, there is considerable variation from state to state. In addition, the number of trains varies over time, primarily due to the state of the economy.

The next variable represents the proportion of crossings fitted with active warning devices (gates and/or flashing lights, highway signals, wig-wags, bells or flag persons). These data are reported in the FRA's annual reports on crossing safety. In regression models of risk at individual crossings, there is a problem that the installation of active warning devices is endogenous. The inherent risk at the crossing (due to the amount of road traffic, crossing alignment, etc.) determines the priority given to the crossing when budget decisions are made for installation of devices. This is less of a problem in the current model. In an ideal world, Section 130 monies would be distributed to states in relation to the relative risks. In this case, there would be problems of endogeneity. Of course, political realities mean that funds have to be distributed with regard to "equity" and perhaps other considerations. Overall there is a low correlation across states between the number of incidents per crossing and the proportion of crossings with active warning devices, suggesting that other factors may be at work. For example, among the states with high numbers of incidents per crossing, some (Florida, Indiana and Ohio) have a high proportion of crossings with active warning devices, while some southern states (Louisiana, Mississippi, Alabama and Arkansas) have a very low proportion. Therefore endogeneity is much less of an issue in this analysis than it is in Austin and Carson's (2002) study of individual crossings.

The next variables represent highway safety performance on parts of the roadway away from grade crossings. Improvements in vehicle engineering, emergency medical response, and reduced impaired driving affect the risk of driving both at rail–highway intersections and at other places on the highway system. Slightly different versions of this variable are used in the two equations. In the fatalities equation, the variable is the number of fatalities in all motor vehicle crashes (obtained from the FHWA's *Highway Statistics*, Table FI-20) less those occurring at grade crossings, divided by annual vehicle miles traveled on all classes of road. The variable is expressed as a rate per hundred million vehicle miles traveled. In the incidents equation, the variable is the total number of fatal motor vehicle crashes (obtained from the National Highway Traffic Safety Administration's, 2005 *Traffic Safety Facts*) less those occurring at grade crossings (obtained from the FRA searchable online data base), divided by annual vehicle miles traveled. Ideally, one would want to use a measure reflecting crashes of all severities elsewhere on the highway. However, unlike the reporting requirements at grade crossings, data on non-fatal crashes, and especially property-damage-only crashes, elsewhere on the highway are poor and somewhat unreliable. There is considerable variation both over time and across states.

In Mok and Savage (2005), a 1995 federal rule requiring increased lighting of trains was found to be particularly effective in improving safety. The traditional single headlight was required to be augmented by two additional lights lower down on the front of the locomotive. These are known as ditch or crossing lights, and provide added illumination of the sides of the track and, what is more important, the triangular pattern provides highway users with a greater perception of an approaching train's speed and distance from the crossing. Assuming that locomotives were fitted with these additional lights at a constant rate from the announcement of the rule in September 1995 to the deadline for fitting them in December 1997, the average proportion of locomotives so fitted would be 0.33 in 1996, 0.78 in 1997 and unity from 1998 onwards. It was not possible to determine whether the rate of installation varied by state.

All of the explanatory variables are expressed as logarithms, which means that the estimated coefficients can be interpreted as elasticities.

Table 3
Regression results

	Incidents involving motor vehicles at public crossings		Fatalities from incidents involving motor vehicles at public crossings	
	Coefficient	*t*	Coefficient	*t*
Constant	−11.2098	16.91	−16.1693	12.01
Number of public crossings	Exposure		Exposure	
Log of Operation Lifesaver presentations and special training per 1000 crossings	−0.1089	3.26	−0.0552	0.90
Log of average annual daily non-interstate highway traffic	0.7741	10.79	0.8372	5.99
Log of average daily number of trains	0.4803	7.43	1.0114	7.21
Log of proportion of public crossings with active warning devices	−0.8107	6.93	−1.1805	4.85
Log of highway fatal crashes per 100 million vehicle miles traveled (excluding grade crossing incidents)	0.9005	8.68		
Log of highway fatalities per 100 million vehicle miles traveled (excluding grade crossing incidents)			1.2829	6.91
Log of proportion of locomotives with ditch lights	−0.2029	3.17	−0.1988	1.73
α	0.1063	9.39	0.2239	5.98
Observations	292		292	
Constant-only log likelihood	−1284.24		−745.58	
Log likelihood	−1169.87		−681.41	
Pseudo R^2	0.0891		0.0861	

5. Regression results

The regression results are shown in Table 3. The data for both regressions are overdispersed, as indicated by the estimated values of α, which are positive and significantly different from zero. Therefore the Poisson model can be rejected, and the use of the negative binomial is supported. The pseudo R^2 is 0.089 for the incidents equation and 0.086 for the fatalities equation.

OL activity is found to have a significant effect on the number of incidents. The coefficient implies that increasing the amount of educational activity will reduce the number of collisions with a point elasticity of −0.11. A relationship between OL activity and the number of deaths cannot be established with statistical certainty. In some ways this is not surprising. Deaths are only a tenth as numerous as incidents and are heavily concentrated in a few states. Half of all the fatalities occur in just eight states, and in half the states the average number of fatalities per year is five or fewer. Consequently, there is considerable year-to-year random variability in the number of fatalities, and it is more difficult to find statistical robust relationships.

The coefficients on the other variables are generally statistically significant and accord with the findings in Mok and Savage (2005). The elasticity of incidents and fatalities to changes in highway traffic is found to be 0.77 and 0.84, respectively. The elasticities from a change in the number of trains are 0.48 for incidents and 1.01 for fatalities.

Increasing the proportion of crossings with active warning devices decreases the number of incidents with an elasticity of −0.81, and reduces fatalities with an elasticity of −1.18. Factors that lead to improved safety elsewhere on the highway are found to have a relatively similar effect at grade crossings. The elasticity of safety improvement elsewhere on the highway network is 0.9 with respect to the number of crossing incidents and 1.3 with respect to fatalities. Finally, the elasticity of the proportion of locomotives fitted with ditch lights with respect to both incidents and fatalities is −0.2 (albeit that we can only be 90% confident of the statistical significance of the latter effect).

6. Commentary and conclusions

Grade crossing safety professionals argue that safety is improved by actions characterized as the three E's: engineering, education and enforcement. The strong effects of engineering solutions such as installing active warning devices and improving the conspicuity of trains are evident from these regressions, and a substantial prior literature. Quantifying and evaluating enforcement activities, such as placing police offers at crossings to issue citations, or installing camera enforcement, is more difficult and has engendered a much smaller pool of literature. This paper suggests that educational activities also have a measurable effect on modifying driver behavior and improving safety.

In some ways, the result is not too surprising. A recent Transportation Research Board report (Lerner et al., 2002) found that there is considerable public misperception of grade crossing risks, confusion about the meaning of the various warning signs, and uncertainty about the type of conduct required in reconnoitering for a train at crossings with passive warning devices. Crossings with only passive warning devices form the majority of crossings in the United States. Despite the fact that traffic volume at these crossings tends to be much lower than average, more than half of all fatalities occur at these crossings. So, there would seem to be great potential benefits from making drivers better informed.

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