Why has Safety Improved at Rail-Highway Grade Crossings?

by

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(includes addition of the effect of "ditch lights")

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Abstract

The number of collisions and fatalities at rail-highway intersections has declined significantly over the past thirty years, despite considerable increases in the volume of both rail and highway traffic. This paper disaggregates the improvement into its constituent causes. Negative binomial regressions are conducted on a pooled data set for 49 states from 1975 to 2001. The analysis concludes that about two-fifths of the decrease is due to factors such as reduced drunk driving and improved emergency medical response that have improved safety on all parts of the highway network. The installation of gates and/or flashing lights accounts for about a fifth of the reduction. The development of the "Operation Lifesaver" campaign, that seeks to inform the public on appropriate conduct at crossings, in the 1970s and early 1980s; and the installation of "ditch lights" on locomotives in the mid 1990s, each led to about a seventh of the reduction. Finally, about a tenth is due to closure of crossings resulting from line abandonments or consolidation of little-used crossings.

INTRODUCTION

By the mid 1960s, the problem of safety at rail-highway grade crossings had reached crisis proportions. While the absolute number of fatalities at crossings had peaked in the 1930s, the rate of fatalities relative to the amount of rail traffic continued to rise. In 1966 the rate of highway-user fatalities was 1.95 per million train miles compared with 1.13 in 1950. The underlying cause was the increase in road traffic coupled with the worsening financial condition of the railroads that limited the funds available to install flashing lights, gates and warning signs. Historically, the railroads had a common law duty to determine the type of warning device to install at a particular crossing and had to bear the costs of installation and maintenance.

As early as 1962 the Interstate Commerce Commission (ICC) argued that the solution was to transfer the financial burden and planning of crossing improvements to the highway authority. They argued that this change would be equitable because "[h]ighway users are the principal recipients of the benefits" (ICC, 1962). A decade later, the newly-formed federal Department of Transportation (DOT) concluded that it was anomalous that railroad grade crossings were "the only place along the highway where the state authorities do not have total control over the installation . . . of traffic control devices" (DOT, 1972).

The subsequent political debate led to the "Federal-Aid Rail-Highway Crossing Program" as part of the *Federal Highway Act* of 1973. This is commonly referred to as the "Section 130 Program." Over the following thirty years, the federal government has spent approximately $8 billion, at current prices, to improve grade crossings. The federal money is channeled through state agencies (often the highway authority) that play a key role in deciding which crossings should be improved. Federal funds typically cover 90% of the cost. The remaining 10% comes from the railroads, the state highway authority, the municipality or a combination of the three. In fiscal year 2001, the federal government allocated $155 million to the states, a level of funding that has remained nearly constant in nominal terms over the past 15 years.

A cost-benefit manual and software (DOT, 1986), an associated handbook (Federal Highway Administration, FHWA,1986), and a chapter in the *Manual on Uniform Traffic Control Devices* (FHWA, 1986), give professional guidance on how to set priorities for which crossings to improve. The improvements can take many forms. The most prevalent has been the upgrading of warning devices. Crossings that previously only had signs, known as "passive warning devices," were fitted with flashing lights that indicate the approach of a train. Crossings that previously had flashing lights were upgraded by the installation of gates that provide a barrier across the roadway. The proportion of public crossings with gates and/or lights, known as "active warning devices," increased from 26% in 1975 to 43% in 2001. Other types of improvements have included providing warning signs at crossings that previously were unmarked, renewing existing warning devices, installing better lighting, increasing sight-distances, improving the angle at which the highway and railroad intersect, and separating trains from road traffic by building bridges for one to cross the other.

The federal government has also encouraged the closing of little-used crossings and consolidating traffic onto a smaller number of crossings, which were provided with upgraded warning devices. The railroads have a legacy, dating back to the days of horse and buggy, of providing a crossing at every intersecting street. Between 1975 and 2001, almost 30% of crossings were closed due to the crossing consolidation program or because the railroads abandoned lines following liberalization of economic regulations by the *Staggers Act* of 1980.

Another manifestation of the safety efforts was increased emphasis on data collection. Using this data, it would appear that the programs put in place in the early 1970s have been very successful. The annual number of collisions between motor vehicles and trains at public crossings declined by 75% between 1975 and 2001. The number of annual deaths in these collisions, which amounted to nearly 1,000 in 1976, declined by 68% to 315 in 2001. (In addition, in 2001 there were 71 deaths involving collisions with pedestrians and other non-motorized users at public crossings, and 35 deaths at "private" crossings where adjacent landowners typically are the sole users.) The rate of highway-user fatalities declined from its peak of 1.95 per million train miles in 1966 to only 0.59 in 2001. The decline has been so dramatic that by 1997 grade crossings ceased to be the leading cause of death on the railroads. The number of annual trespassing victims surpassed the number of grade-crossing fatalities for the first time in more than half a century.

It would be incorrect to attribute all of the apparent improvement to the Section 130 program. Over the same time period, safety has also improved on the highways in general. Laws raising the minimum drinking age and increasing the penalties for drunk-driving have been enacted. Societal attitudes on impaired driving have changed. Improvements in automobile technology and emergency medical response have allowed more people to survive crashes. The rate of fatal highway crashes at locations other than highway-rail crossings per mile of travel declined by 52% between 1975 and 2001. Safety at rail-highway intersections has to be viewed in relation to the experience at highway-highway intersections and elsewhere on the highway network.

At the same time there were trends that would be expected to increase the number of collisions and fatalities. More cars were being driven more miles, increasing highway traffic density and increasing the chance that a highway vehicle is present when a train approaches a grade crossing. Average annual daily traffic on non-grade-separated highways increased by 80% between 1975 and 2001. The amount of rail traffic on those parts of the network that were not abandoned has also increased. The average number of trains relative to the size of the rail network has increased by 30%. Taken together, the number of potential highway vehicle-train interactions has increased.

A perpetual problem has been highway users' poor perception of the dangers of grade crossings. Drivers misjudge the speed of approach of trains, and because they are in a hurry are tempted to drive around lowered gates and/or ignore the flashing lights. In some cases, where devices have been known to malfunction and no danger is visible, drivers may inappropriately suspect a false activation of the signals. 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 passive warning devices, the conduct expected of drivers in observing for an approaching train is ill-defined. Consequently, in each state nonprofit organizations called "Operation Lifesaver" were established to promote education and awareness of railroad-related hazards, especially the need to follow safety warnings at grade crossings. The first program was established in Idaho in 1972, and its introduction was claimed to have produced a 40% decline in crossing fatalities. The program then spread state by state across the nation by 1986.

Another perpetual problem is that users of crossings with passive warning devices either could not see an approaching train or misjudged how far it was away and how fast it was approaching. The government initiated a research project to determine ways to improve train visibility in 1991. The final rule, effective from 1998, required that the traditional single locomotive headlight should be augmented by two additional lights known as ditch or crossing lights. These lights illuminate parts of the right of way that are not illuminated by the traditional headlight, and the triangular pattern provides highway users with a greater perception of the train's speed and distance from the crossing.

The current research investigates the relative contribution of these various factors to the improvement in crossing safety. The difficulty that has faced past researchers is that at a national level all of these factors are highly collinear. The correlations are at least 0.6 and in many cases in excess of 0.9. This paper overcomes the problem by developing a panel data set for 49 states (excluding Hawaii) for the years between 1975 (when comprehensive data were first collected) and 2001. This introduces much more variability into the data and generally reduces correlations below 0.5, and in some cases considerably below 0.3.

Determination of the relative contributions of the various factors has political importance. The size of the Section 130 program has been held constant in monetary terms since the mid 1980s, and consequently its resources have been eroded by inflation. In the 2003 reauthorization of the federal surface transportation funding, it was proposed that states would be free to use the money previously earmarked for crossing improvements on any safety initiative, regardless of mode. Both the railroads and state highway authorities have argued that this proposal risks diverting funds from a worthwhile program.

ANALYTICAL TECHNIQUE

There is a huge literature on modeling the risk at individual crossings. Models have existed for more than sixty years. Austin and Carson (2002) provide a historical review and a state-of-the-art model. Explanatory variables typically include the annual average daily highway traffic (AADT), the daily number of trains, maximum allowable rail speed, the number of railroad tracks, the number of highway lanes, the angle at which the highway crosses the railroad, and the types of warning devices present. These models are widely used by state highway authorities to prioritize crossings for upgrading of warning devices.

Unlike most previous analyses of individual crossing risk, Austin and Carson (2002) use the negative binomial regression technique (Cameron and Trivedi, 1986; Hausman et al, 1984). This technique has now become almost standard in the analysis of accident frequency and is used in the current paper. The negative binomial regression uses a count of the number of highway-rail "incidents" and the number of fatalities in a given state in a given year as its dependent variable, rather than an incident rate. It is commonly recognized that the number of crashes in a given state in a given year will vary around some underlying mean, and the distribution is characterized by the Poisson process. Moreover, the dependent variable can only take non-negative integer values. The estimated equation can be usefully visualized as having the form:

$$\text{count of incidents} = e^{(\beta\ \text{exposure} + \gamma\ \text{other variables})} + \varepsilon$$

As already mentioned, the incident rate is not used directly. The count of incidents is the dependent variable while exposure to incidents is an explanatory variable. In a model of risk at individual crossings, the exposure to incidents is the expected number of times in a day that a train and a highway user will arrive simultaneously at the crossing (i.e., the expected number of potential conflicts). This will be a scalar transformation of the product of the highway AADT and the frequency of trains at the individual crossing. The model in this paper is at a much more macro level, and represents the incident experience in a state in a given year. Therefore, one should think that the appropriate measure of exposure to incidents is the number of crossings. A state with twice as many crossings, holding everything else constant, should produce twice as many potential conflicts and twice as many incidents and fatalities.

The Poisson distribution of incidents in state i for year t is characterized by a parameter λ_{it} which represents both the mean number of incidents and its variance. The statistical technique estimates λ_{it} based on the explanatory variables in the regression. Problems can emerge with the error structure when the regression does not contain every variable that explains the differences in λ_{it} across states and years. Given the low likelihood that one is ever able to fully account for all of the idiosyncratic differences, both we and other researchers have used a modified regression technique called the negative binomial. This estimation technique assumes that the error term is distributed according to a gamma distribution. The regression model assumes that the mean, E(y), and variance, Var(y), of the count of incidents for a group of states/years with identical values of the explanatory variables have the following relationship:

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

Note that if $\alpha = 0$, the equation becomes the standard Poisson condition. The statistical package used (Stata) reports the estimated value and standard error of α. The regressions estimated as part of this paper have values of α for which one can reject the null hypothesis that $\alpha = 0$. Moreover because the estimated values of α are positive, the data are referred to as "overdispersed."

There are versions of the negative binomial regression that allow for the magnitude of the overdispersion to vary across different groups in the panel. This is to say that the data for, say, Texas may have a different level of overdispersion than, say, New York State. Note that this represents differences in the α values, and not possible differences in the values of the estimated coefficients between states. Regressions were conducted using a random effects model whereby the differences in α between states are not related to any of the explanatory variables. A likelihood-ratio test strongly rejected any improvement in fit in the regression with the number of fatalities as the dependent variable, and in the regression with the number of incidents as the dependent variable, the log likelihood actually got worse. Therefore, the regressions are estimated with the data treated as a pool of time-series and cross-sectional elements.

VARIABLES AND DATA

The data set consists of panel data for 49 states from 1975 to 2001. Hawaii is excluded because it has negligible railroad mileage and crossings. The District of Columbia is also excluded because it has a negligible number of grade crossings, many of which are little used and do not even have any warning signs. There were no fatal incidents in the District over the period. Inclusion of the District would have a misleading effect on the analysis because it has extraordinary high highway AADTs, yet most of the traffic will never encounter a grade crossing.

Two separate regressions are conducted. The first is on the number of incidents in a state in a given year at public crossings 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 is 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 in the printed Federal Railroad Administration (FRA) annual reports on grade crossing safety (FRA, annual). In addition, the FRA's web site has an excellent searchable database on all grade crossing incidents since 1975. The data from the printed volumes was double checked against the on-line data base, and a number of minor discrepancies corrected for some states, primarily for the period before the mid 1980s.

The variable representing the amount of exposure to incidents and deaths 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. In the regression, the variable is expressed in logarithms. The effect is to imply that:

$$\text{Count of Incidents} = \text{Crossings}^{\beta} \text{ x other variables}$$

In the classic Poisson formulation, β is restricted to equal unity. Twice as many crossings should imply that there will, on average, be twice as many incidents. In this analysis β will not be constrained in this way. The reason is that the crossings that have been closed will probably not be "typical" crossings. Lines that have been abandoned will typically be those with a lower-than-average number of trains, and crossings that are closed as part of the consolidation program generally have lower-than-average highway traffic. Because the number of expected conflicts at these crossings will be lower than average, crossing closure should have a less-than-proportional effect on incidents and deaths. This can be verified by conducting standard statistical tests on the estimated coefficient based on a null hypothesis that $\beta = 1$. Moreover, the form of the regression means that β can be interpreted as an elasticity. This useful feature has been carried over to the other continuous independent variables, which are also expressed in logarithms.

Explanatory variables include the amount of rail and highway traffic. Highway AADT and the frequency of trains will affect the number of potential conflicts at crossings. These variables vary markedly both between states and over time. The inventory of individual crossings contains information on both of these variables obtained by surveys undertaken at the crossings. Unfortunately, the data are not updated on a regular basis. Therefore, one cannot use this data source alone to construct a historical database of changes in AADT and rail traffic.

State average AADT is readily available from the FHWA's *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:

$$\text{AADT}_{it} = \frac{\text{Non-Interstate Annual Vehicle Miles Traveled}_{it}}{\text{Miles of Non-Interstate Highways}_{it} \ * \ \text{Days}_t}$$

where annual vehicle miles traveled in the state are in Table VM-2 (the data is reported in millions of miles, and is multiplied by a million), and miles of highway are in Table HM-20 (prior to 1980, Table M-12). (Note that urban expressways and freeways are not shown as an explicit category prior to 1980. For these years the miles of freeway are taken to the same as in 1980, and the amount of travel is assumed to vary from its 1980 level proportionate to total urban travel.) Days is the number of days in the year. AADT varies widely by state, ranging from an average of 4,500 in New Jersey down to 180 a day in North Dakota. The national average non-Interstate AADT has increased markedly over time from 750 in 1975 to 1,350 in 2001.

Disaggregated data on train miles is not available by state. National annual data is 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 (AAR) annual *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 website, and the average number of daily trains was calculated for each state. A "state correction factor" was derived by comparing the state average to the national average. This factor varied from 1.72 in Nebraska (72% above the national average) to 0.21 in South Dakota (79% below the national average). Data were then calculated on the average number of daily trains for state i in time period t by the formula:

$$\text{Trains per Day}_{it} = \frac{\text{National Train Miles}_t}{\text{National Railroad Route Miles}_t \ * \ \text{Days}_t} \ * \ \text{State Correction Factor}_i$$

The average number of trains per day varies from 18 a day in Illinois and Nebraska down to less than four a day in Rhode Island, Maine, New Hampshire and South Dakota. Over time the number of trains varies with the state of the economy. Comparing 2001 with 1975 the number of national train miles has declined by 6%, but the size of the network has declined by 28%, leading to a 31% increase in average number of trains per day from 10.4 to 13.6.

The next variable is the proportion of crossings with active warning devices. These data are reported in the FRA's annual reports on crossing safety. The original intention was to differentiate between those crossings fitted with gates, and those fitted with lights and not gates (these include the standard flashing lights, highway signals, wig-wags, bells or flag persons). However, the proportion of crossings with only flashing lights has remained constant over time, at about 20% of crossings, as some crossings with passive warning devices were upgraded to lights, and some of those fitted with lights had gates added. The proportion with gates increased markedly from 5.5% of crossings in 1975 to 23% in 2001.

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. While active warning devices should reduce risk, the regression might misstate the magnitude of the effect because only higher risk crossings are provided with active warning devices. This is less of a problem in the current model. Our data represent the situation in a state in a given year. 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, of -0.08, 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 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 the highway safety performance at parts of the roadway other than grade crossings. Slightly different versions of this variable are used in the two equations. In the equation explaining fatalities at grade crossings the variable is the number of fatalities in motor vehicle crashes (obtained from the FHWA's *Highway Statistics*, Table FI-20), less the number of fatalities at grade crossings involving motor vehicles, divided by annual vehicle miles traveled. For this variable, the number of annual vehicle miles traveled is for all classes of road. In the equation explaining incidents at grade crossings, the variable is the number of fatal motor vehicle crashes (obtained from the National Highway Traffic Safety Administration's annual *Traffic Safety Facts*) less the number of fatal incidents at grade crossings involving a motor vehicle (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 is poor and somewhat unreliable. There is considerable variation both over time and across states. Both variables are expressed as rates per 100 million vehicle miles traveled. Between 1975 and 2001 the highway death rate has fallen by more than 50%. The most dangerous states (New Mexico, Montana, and Mississippi) have more than twice the death rate of the safest (Massachusetts and Rhode Island).

Ideally one would wish to represent the effect of Operation Lifesaver with a continuous variable indicating the extent of activities in a given state in a given year. Examples are the number of person-hours of effort, or the size of the annual budget. Unfortunately information of this type is not readily available by state over the history of Operation Lifesaver. The organization is inherently local in nature. A national headquarters was only established in 1989. Data was not collected centrally prior to 1989. Consequently, the existence of Operation Lifesaver is represented by a dummy variable equal to one for years in which the program was operational in a state, and zero otherwise. This information was obtained from Operation Lifesaver.

The rule that required fitting of ditch lights to trains was issued at the end of August 1995, and took effect from December 31, 1997. Assuming that locomotives were fitted with these additional lights at a constant rate from September 1995 to December 1997, the average proportion of locomotives so fitted would be zero in 1994 and prior years, 0.05 in 1995, 0.33 in 1996, 0.78 in

1997 and 1 from 1998 onwards. It was not possible to determine whether the rate of installation varied by state.

A series of dummy variables was also included for each state. There are many factors that affect the occurrence of grade crossing incidents that vary across the country in ways that are not captured by the other explanatory variables. These include (but are not limited to) geographic and socioeconomic factors such as topography (which will affect sight lines at crossings), the degree of settlement at the time that the railroads were first built, and the degree of urbanization. Because a constant term is included in the regressions, it is always necessary to exclude one dummy variable. That state then acts as the base against which others are compared. Georgia was selected to be the base state because it has a large number of crossings and is ranked in the middle with regard to incidents and deaths per crossing. Some might argue that state dummy variables should not be included in the regressions, as they might subtract from the power of the other variables in explaining the differences between states. While this may be true, inclusion of the variables is consistent with the purposes of this paper, which is more concerned with analyzing change over time than trying to explain the differences between different parts of the country.

REGRESSION RESULTS

The regression results are shown in Tables 1 and 2. Table 1 contains information on goodness of fit and the estimated coefficients for main variables for both the incidents and fatalities regressions. Table 2 contains the estimated coefficients for the state dummy variables for both regressions. 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 0.30 for the incidents equation and 0.28 for the fatalities equation.

In both equations the coefficient on the exposure variable, the number of crossings, is significantly less than unity. This implies that the number of incidents and fatalities falls at a lower rate than the number of crossings. Closing 10% of crossings is estimated to reduce the number of incidents by 5.1% and the number of fatalities by 2.7%. The explanation is that the crossings that have been closed probably had lower than average risk either because the number of trains was few (in the case of crossings closed due to line abandonment) or because the amount of highway traffic was limited (in the case of crossing consolidation). Moreover, in the case of crossing consolidation, the risk does not totally disappear because the displaced highway traffic is still traversing the railroad at a neighboring crossing.

The effects of the variables that indicate the expected number of conflicts between trains and highway users, for the most part, are consistent with prior expectations. A 10% increase in the average number of trains per day leads to almost proportional increase in the number of fatalities, and a 6.6% increase in the number of incidents. The effect of increases in highway traffic are somewhat smaller. An increase in highway AADT of 10% leads to a 4.4% increase in fatalities, but a very small increase of only 0.2% in the number of incidents. The latter effect is statistically indistinguishable from zero.

The results of this analysis are not necessarily inconsistent with the large body of existing literature which have found that highway traffic volume is a very strong predictor of the risk of incidents at individual crossings. All of that literature is at a very *micro* level and focused on differences in risk between individual crossings. It makes sense that heavily-used crossings will generate more incidents than lightly-used crossings. The current analysis is at a much more *macro* level and asks what is the effect on changes in highway traffic density on crossing safety in general, and should not be taken to imply that highway traffic volumes are not good predictors when making *micro* level comparisons of individual crossings.

The installation of active warning devices has a considerable effect on risk. Increasing the proportion of crossings with active warning devices by 10% leads to a 4.8% decrease in incidents and a 3.1% decline in fatalities. Both effects are highly statistically significant, particularly in the incidents regression.

Even stronger effects are found with regard to safety elsewhere on the highways. A 10% decrease in the rate of fatal crashes elsewhere on the highway is associated with an 8.5% decrease in the incidents at grade crossings. A 10% decrease in the fatality rate elsewhere on the highway is associated with a 5.8% decrease in fatalities at grade crossings. This means that the improvement in safety at grade crossings cannot be considered in isolation to public policy initiatives and changes in driver behavior on the roads in general. The fact that the coefficients of these variables are less than unity should not be taken as an indication that safety has not improved as fast at grade crossings than it has at other locations. In fact the reverse is true. While highway safety away from grade crossings has improved by about 55% between 1975 and 2001, the rate of incidents and fatalities at grade crossings per vehicle mile traveled has declined by more than 80%.

Operation Lifesaver is also found to have a very significant effect on safety. Implementation of this public relations campaign is found to result in a 15% decrease in the number of incidents and a 19% decrease in the number of fatalities. (One takes the exponential of an estimated dummy variable coefficient to find its effect in this type of regression.) While this is much smaller than the greater than 40% decrease claimed from its initial implementation in Idaho, this still represents a substantial safety benefit from a program that has a very modest budget and primarily relies on volunteer labor. The magnitude of the result attests to considerable public misperception of the risks posed by grade crossings, the meaning of various warning signs, and the type of conduct required at crossings with passive warning devices (Lerner et al., 2002).

The installation of ditch lights is found to have a particularly large effect. The equipping of the entire fleet is estimated to have reduced the number of incidents by 29% and the number of fatalities by an amazing 44%.

The state dummy variables are shown in Table 2, organized in descending order of the effect on the number of incidents. The format of the negative binomial regression has an underlying multiplicative relationship between the variables. The magnitude of a dummy variable can be found by taking the exponential of the estimated coefficient. For example, Texas has an estimated coefficient in the incidents equation of 0.8794. Taking the exponential gives 2.41, which means that the number of incidents is 2.41 times that in Georgia (the base state), or 141% higher, for identical values of the other variables. At the other end of the spectrum, Wyoming has a coefficient of negative 2.0838. Taking the exponential is 0.124, or 88% below Georgia, all else being equal. In general, the states with the highest relative risk tend to be those in a broad band down the center of the country which combine a flat landscape, extensive rail operations and small towns. In contrast the north-central and mountain west states have the lowest relative risk.

GOODNESS OF FIT

One way to look at the goodness of fit of the regressions is to compare the actual versus predicted national annual totals. These are shown in Figures 1 and 2 for incidents and fatalities, respectively. The actual totals are shown as the dots, and the sum of the predicted values for the 49 states are represented by the points along the fitted line.

Figure 1 indicates that, in general, the regression appears to predict the actual number of incidents with remarkable accuracy. The major discrepancy is the increase in incidents from 1975 to 1979, which contrasts with a predicted downward trend. There are a couple of possible explanations. The first was suggested by staff at the FRA who suspect that there may have been under-reporting by some states in the early years of the program. As the program became more established, the quality of reporting improved and this led to an increase in the recorded number of incidents. The second is related to some unusual trends in general highway safety in the mid 1970s. The 1973 energy crisis led to increases in the price of gasoline and the imposition of a national 55mph speed limit in 1974. Both the number and rate of highway crashes and fatalities dropped significantly, and to a much greater extent then would be expected, from 1973 to 1974 and 1975. Not surprisingly, this unusual improvement was eroded over the latter part of the 1970s. It is likely that the experience at grade crossings mirrored the extraordinary dip in overall highway crashes around 1975,

At least from 1979, there has been a continuous decline in the number of incidents, with a couple of periods of very swift decline. The first of these is an almost 40% drop in the number of predicted incidents between 1979 and 1983. This was a period when Operation Lifesaver was spreading across the country. It was also a time that exposure to risk declined because the number of trains dropped considerably due to the combined effect of the economic downturn, and the initial adjustments to deregulation of the railroads and the trucking industry in 1980. There is another notable decline by about 30% between 1994 and 1998, which coincided with the installation of ditch lights.

Figure 2 shows the equivalent graph for the number of fatalities. Compared with Figure 1, there is much more year-to-year variability in the underlying data, and the regression appears to be less successful in accurately predicted the annual totals. The greater variability is to be expected. Annual fatalities are only about a tenth as numerous as the number of incidents and are vulnerable to fluctuations due to multiple-fatality incidents. That said, the fluctuations between 1975 and 1979 are really extreme, and defy explanation.

As with the incidents graph, there are two periods of rapid decline in the annual totals. The first is a predicted 33% decline between 1979 and 1983 coinciding with the reduction of train traffic and the introduction of Operation Lifesaver. Then there is a decline of about 40% between 1995 and 1998 when ditch lights were fitted. An interesting feature is the apparent increases in fatalities in the late 1980s and again after 1992. The explanation appears to be the increased exposure to risk as the amount of train traffic increased with upswings in the economy. It is interesting to note that the turn around in the increase in fatalities in the late 1980s coincided with the start of the recession in 1990. Similarly, the effect of the introduction of ditch lights might be even greater than the graph would suggest, because it came at a time when the boom in the economy led to additional train traffic that would be expected to increase the numbers of fatalities.

DECOMPOSITION OF CHANGES IN INCIDENTS AND FATALITIES

From 1975 to 2001 the number of annual crossing incidents involving motor vehicles fell by 8,276 from 10,971 to 2,695. The number of annual fatalities in these incidents fell by 471 from 786 to 315. What can the regressions tell us about the contribution of the various causes to this decline?

The format of the estimated incidents equation for state i in year t is:

$$\text{Incidents}_{it} = e^{\alpha} e^{\beta \ln(\text{crossings}_{it})} e^{\gamma_1 \ln(\text{AADT}_{it})} e^{\gamma_2 \ln(\text{Trains}_{it})} e^{\gamma_3 \ln(\text{Active Devices}_{it})} e^{\gamma_4 \ln(\text{Highway Safety}_{it})} e^{\gamma_5 \text{Operation Lifesaver}_{it}} e^{\gamma_6 \text{Ditch Lights}_{t}} e^{\gamma_7 \text{State}_{i}} + \varepsilon_{it}$$

the change from year to year for this state can be decomposed to the following:

$$\begin{aligned}
\text{Incidents}_{it+1} - \text{Incidents}_{it} = {} & e^{\alpha}\left[e^{\beta \ln(\text{crossings}_{it+1})} - e^{\beta \ln(\text{crossings}_{it})}\right] e^{\gamma_1 \ln(\text{AADT}_{it})} e^{\gamma_2 \ln(\text{Trains}_{it})} \\
& e^{\gamma_3 \ln(\text{Active Devices}_{it})} e^{\gamma_4 \ln(\text{Highway Safety}_{it})} e^{\gamma_5 \text{Operation Lifesaver}_{it}} e^{\gamma_6 \text{Ditch Lights}_{t}} e^{\gamma_7 \text{State}_{i}} \\
& + e^{\alpha} e^{\beta \ln(\text{Crossings}_{it})} \left[e^{\gamma_1 \ln(\text{AADT}_{it+1})} - e^{\gamma_1 \ln(\text{AADT}_{it})}\right] e^{\gamma_2 \ln(\text{Trains}_{it})} e^{\gamma_3 \ln(\text{Active Devices}_{it})} \\
& e^{\gamma_4 \ln(\text{Highway Safety}_{it})} e^{\gamma_5 \text{Operation Lifesaver}_{it}} e^{\gamma_6 \text{Ditch Lights}_{t}} e^{\gamma_7 \text{State}_{i}} \\
& + \ldots\ldots + \varepsilon_{it+1} - \varepsilon_{it}
\end{aligned}$$

The equation will also include (in place of the ellipses) similar terms to the first two that involving changes from period t to t+1 for the variables Trains, Active Devices, Highway Safety, Operation Lifesaver, and Ditch Lights. In addition there will be crossproduct terms involving every possible combination of the value of variables in period t and changes in variables. There will be 127 terms in total. Of course, most of the cross-product terms will be quite small as they involve the product of two (or more) relatively small changes in the constituent variables. In addition some of the crossproduct terms will be positive and some negative, and will tend to cancel each other out.

This decomposition was carried out for each of the annual changes from 1975 to 1976 through 2000 to 2001 for each of the states. This is a total of 1,274 cases for both equations. The cases were then summed together to produce a composite for the nation over the 27-year period. The resulting decomposition is shown in Table 3.

The estimation suggests that the reduction of 8,276 incidents per year can be decomposed into a reduction of 1,040 due to crossing closures, a reduction of 1,786 due to installation of active warning devices, a reduction of 3,913 due to generally improved highway safety, a reduction of 1,455 due to the implementation of Operation Lifesaver, and a reduction of 1,279 due to the introduction of ditch lights. These reductions more than counteract increases of 89 and 556 due to the increased amounts of highway and train traffic, respectively. In addition there is a net increase of 259 incidents due to the cross product terms, and a net increase of 294 incidents due to the error term. This latter effect mainly represents the fact that the actual number of incidents in 1975 was remarkably low, whereas in 2001 the actual and predicted numbers are much closer.

Turning to the fatalities equation, the estimation suggests that the reduction of 471 fatalities per year can be decomposed into a reduction of 60 due to crossing closures, a reduction of 115 due to the installation of active warning devices, a reduction of 305 due to generally improved highway safety, a reduction of 164 due to the implementation of Operation Lifesaver, and a reduction of 268 due to the introduction of ditch lights. These increases counteracted increase of 201 and 157 due to increased traffic on the roads and the railroad, respectively. In addition there is a minuscule decrease due to the cross product terms, and a net increase of 95 fatalities due to unexplained changes in the error term. Again, this is associated with the unusually low number of fatalities in 1975, the first year of the analysis.

CONCLUSIONS

A number of conclusions can be drawn from the decomposition. The first is that general improvements in highway safety dominate. The magnitude of the effect is about twice the size of that due of the installation of active warning devices. Improvements in crossing safety cannot be viewed in isolation to general changes in highway safety. Reductions in drunk-driving, advances in automotive technology such as braking, and improvements in the effectiveness of emergency medical response have as much effect at highway-rail intersections as they do at highway-highway intersections. That said, some of the improved safety elsewhere on the highway is a result of actions similar to those in the Section 130 program such as signalization of intersections and improved geometry and signage. To some extent it is possible that some of the benefits of the Section 130 Program may be included in the estimated magnitude of this variable. Though the correlation between Section 130 expenditures (measured by the installation of active warning devices) and the death and fatal crash rates elsewhere on the highway is less than -0.5.

The second is that the effect of the installation of ditch lights would appear to be huge. Even though they were introduced at a time when the risks at crossings were already much reduced from the 1970s, their introduction is estimated to have reduced annual collisions by 1,279 and fatalities by 268. The magnitude of the effect on incidents is similar in size to that of Operation Lifesaver and the installation of active warning devices. In terms of fatalities, the magnitude is the same as the *combined* effect of Operation Lifesaver and the installation of active warning devices. It would seem that the triangle of locomotive lights has been really effective in allowing motorists to judge how far a train is from a crossing and the speed at which it is moving. The magnitude effect probably exceeds all expectations by the proponents of increased locomotive conspicuity.

Third, the implementation of Operation Lifesaver also has a remarkably large effect. In terms of the number of incidents averted, the effect is four-fifths of the size of that due to installation of active warning devices. In terms of fatalities, the effect is larger than that due to installation of active warning devices. This result is not too surprising. More than half of all fatalities occur at crossings with passive warning devices and, because the traffic volumes are much lower, the risks to the highway user are at least four times as great as at a crossing with active warning devices (Savage, 1998). The behavior expected of highway users at these crossings is ill defined, and consequently there are great potential benefits from educating users on proper conduct.

One qualification needs to be made with respect to the Operation Lifesaver. The estimated equation is multiplicative in nature. Consequently, implementation produces a proportional reduction in risk. The number of incidents is estimated to fall by 15% and the number of fatalities by 19%. Operation Lifesaver spread across the country during the late 1970s and early 1980s when the level of risk was much higher than it is today. Therefore, while we are estimating that the initial implementation of Operation Lifesaver prevented 1,455 annual incidents and 164 annual fatalities, the effect of ceasing these activities today would be much smaller. The effect of ceasing Operation Lifesaver today would be approximately 500 additional annual incidents and 75 additional annual deaths.

Finally, the installation of active warning devices from 1975 to the present is estimated to have reduced the number of incidents by 1,786 a year and the number of fatalities by 115. Of course, installing active warning devices is a capital cost, with the safety benefits continuing over the life of the equipment. The calculations in this paper can be used as the basis of a full-life benefit-cost analysis. This analysis is shown in Table 4. Footnotes to the table contain information on the sources of data used.

On the cost side, extending the calculations in Savage (1998), it is estimated that Section 130 expenditures from 1975 to 2001 have amounted to about $8.5 billion in current prices, when one includes the match funds from state and local authorities and the railroads. The benefits are assumed to continue over the 30-year life of the equipment. Of course, safety benefits in future years do have to be discounted to estimate a present value of the benefits. Currently the Office of Management and Budgets (1992) recommends a discount rate of 7%.

The current paper produces estimates of the number of annual deaths and incidents averted. When combined with FRA recommendations on the value of a statistical life saved, and information on typical property damages in collisions, monetary values of the benefits can be calculated. In addition, data on injuries was collected as part of this paper, and over the 1975 to 2001 period, injuries were 4.3 times as numerous as fatalities. FRA reports allow us to segment these injuries by severity, using the Abbreviated Injury Scale, and to assign a monetary value to these injuries averted.

The calculation in Table 4 indicates that nearly all the benefits come from the averted deaths and critical injuries sustained in collision with trains that are moving at greater than 30 mph. The present value of the benefits is $12.5 billion compared with the $8.5 billion invested. The benefit-cost ratio of the Section 130 program is approximately 1.5, or 50¢ of net benefits for every $1 expended. Not included in these figures are annual maintenance expenses, or the benefits from the fewer delays to rail and highway traffic due to the reduced number of incidents.

Of course, Section 130 money has not been used exclusively on installation of active warning devices. It has been partly used to renovate existing crossings that already had active warning devices, consolidate crossings, close some crossings by providing bridges, renew passive warning devices and many other types of crossing improvements. However, if some of these other improvements have been collinear with the increased installation of active devices, then the estimated number of incidents and fatalities averted will include these other improvements as well. Assuming that the expenditures in the Section 130 program have not all been devoted to installation of active warning devices, and the possibility that some of benefits have been captured by the variable representing safety improvements elsewhere on the highway, the estimated benefit-cost ratio should be regarded as the lower bound for the actual effectiveness of this program. In retrospect, the Section 130 program can be regarded as remarkably successful, and has led to real saving of life and serious injury at a relatively modest cost.

REFERENCES

American Association of Railroads (annual). *Railroad Facts*. Washington, D.C.: Association of American Railroads, Washington, D.C. (Formerly known as *Yearbook of Railroad Facts*.)

Austin, R. D., and J.L. Carson (2002). An Alternative Accident Prediction Model for Highway-Rail Interfaces. *Accident Analysis and Prevention,* Vol 34, No. 1, pp. 31-42.

Cameron, A.C, and P. Trivedi (1986). Econometric Models of Count Data: Comparisons and Applications of Some Estimators and Tests. *Journal of Applied Econometrics,* Vol 1, No. 1, pp. 29-54.

Department of Transportation (1972). *Rail-Highway Safety Part II: Recommendations for Resolving the Problem*. Report to Congress from Secretary of Transportation. Washington, D.C.: U.S. Department of Transportation.

Department of Transportation (1986). *Rail-Highway Crossing Resource Allocation Procedure: User's Guide*. (Second Edition.) Report FHWA-IP-86-11. Washington, D.C.: U.S. Department of Transportation.

Federal Highway Administration (1986). *Rail-Highway Grade Crossing Handbook.* (Second Edition.) Report FHWA-TS-86-215. Washington, D.C.: FHWA, U.S. Department of Transportation.

Federal Highway Administration (1988 and later editions). *Manual on Uniform Traffic Control Devices for Streets and Highways*. FHWA, U.S. Department of Transportation.

Federal Highway Administration (annual). *Highway Statistics*. Washington, D.C.: FHWA, U.S. Department of Transportation.

Federal Railroad Administration (annual). *Accident/Incident Bulletin*. Washington, D.C.: FRA, U.S. Department of Transportation. (Since 1997 this has been incorporated in a combined publication called *Railroad Safety Statistics*)

Federal Railroad Administration (annual). *Rail-Highway Crossing Accident/Incident and Inventory Bulletin*. Washington, D.C.: FRA, U.S. Department of Transportation. (Since 1997 this has been incorporated in a combined publication called *Railroad Safety Statistics*)

Federal Railroad Administration (2003). *Regulatory Evaluation and Regulatory Flexibility Assessment for Use of Locomotive Horns at Highway-Rail Grade Crossings Final Rule.* Washington, D.C.: FRA, Office of Safety Analysis, U.S. Department of Transportation.

Hausman, J., B. Hall, B. and Z. Griliches (1984). Econometric Models for Count Data with an Application to the Patents-R&D Relationship. *Econometrica*, Vol. 52 No. 4, pp. 909-938.

Interstate Commerce Commission (1962). *Prevention of Rail-Highway Grade Crossing Accidents Involving Railway Trains and Motor Vehicles.* Washington, D.C.: Interstate Commerce Commission.

Lerner, N.D., R.E. Llaneras, H.W. McGree, and D.E. Stephens (2002). *Traffic Control Devices for Passive Railroad-Highway Grade Crossings*. National Cooperative Highway Research Program, Report 470. Washington, D.C.: Transportation Research Board.

National Highway Traffic Safety Administration (annual) . *Traffic Safety Facts*. Washington, D.C.: NHTSA, U.S. Department of Transportation. (Formerly known as *Fatal Accident Reporting System*.)

Office of Management and Budgets (1992). *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. Circular A-94. Washington D.C.: Office of Management and Budgets.

Savage, I (1998). *The Economics of Railroad Safety*. Boston: Kluwer Academic Publishers.

TABLE 1: Regression Results (excluding State Dummy Variables)

	Incidents involving Motor Vehicles at Public Crossings		Fatalities from Incidents involving Motor Vehicles at Public Crossings	
	Coeff.	t	Coeff.	t
Constant	-1.9704	2.02	-5.7515	2.63
Log of Number of Public Crossings	0.5080	5.09*	0.2724	3.31*
Log of Average Annual Daily Non-Interstate Highway Traffic	0.0199	0.30	0.4390	2.86
Log of Average Daily Number of Trains	0.6646	7.02	0.9901	4.66
Log of Proportion of Public Crossings with Active Warning Devices	-0.4886	7.64	-0.3117	2.15
Log of Highway Fatal Crashes per 100 million Vehicle Miles Traveled (excluding grade crossing incidents)	0.8531	17.92		
Log of Highway Fatalities per 100 million Vehicle Miles Traveled (excluding grade crossing incidents)			0.5775	5.18
Operation Lifesaver Dummy Variable	-0.1586	7.68	-0.2130	4.54
Proportion of Locomotives with Ditch Lights	-0.3484	11.61	-0.5746	8.53
Also State Dummy Variables (Excluding Georgia) – see Table 2				
alpha	0.0258	15.98	0.0761	9.93
Observations	1323		1323	
Constant-only Log Likelihood	-7720.31		-4524.80	
Log Likelihood	-5387.62		-3259.51	
Pseudo R^2	0.3021		0.2796	

* = comparison with a null hypothesis that coefficient = 1.

TABLE 2: Regression State Dummy Variables (listed in descending order of risk)

State Dummy Variables compared with Georgia	Incidents involving Motor Vehicles at Public Crossings			Fatalities from Incidents involving Motor Vehicles at Public Crossings		
	Coeff.	Effect	t	Coeff.	Effect	t
Texas	0.8794	141%	6.46	1.3110	271%	6.46
Michigan	0.6066	83%	4.86	0.6786	97%	4.86
Indiana	0.6029	83%	4.62	0.7217	106%	4.62
Ohio	0.5126	67%	3.71	0.6078	84%	3.71
Wisconsin	0.4939	64%	1.52	0.2281	26%	1.52
California	0.4231	53%	1.35	0.2458	28%	1.35
Louisiana	0.3822	47%	2.41	0.3779	46%	2.41
Illinois	0.3557	43%	2.46	0.5900	80%	2.46
North Carolina	0.2243	25%	1.39	0.2028	22%	1.39
Florida	0.2042	23%	1.52	0.2314	26%	1.52
Minnesota	0.1704	19%	3.25	0.5937	81%	3.25
New Jersey	0.1226	13%	2.80	-0.8740	-58%	2.80
Pennsylvania	0.0365	4%	1.62	-0.2667	-23%	1.62
Alabama	0.0323	3%	0.98	0.1504	16%	0.98
Virginia	0.0199	2%	4.54	-0.9807	-62%	4.54
Mississippi	-0.0478	-5%	1.97	0.4757	61%	1.97
Iowa	-0.0800	-8%	0.92	0.1677	18%	0.92
Oklahoma	-0.0832	-8%	3.77	0.5861	80%	3.77
Washington	-0.0985	-9%	0.62	-0.1320	-12%	0.62
Massachusetts	-0.2118	-19%	4.17	-1.7272	-82%	4.17
Colorado	-0.2203	-20%	0.12	0.0340	3%	0.12
Delaware	-0.2598	-23%	1.40	-1.0536	-65%	1.40
Arkansas	-0.2635	-23%	2.30	0.4620	59%	2.30
Missouri	-0.2644	-23%	1.30	0.1766	19%	1.30
Kentucky	-0.2703	-24%	3.81	-0.7196	-51%	3.81
Maryland	-0.2852	-25%	2.71	-1.3225	-73%	2.71
South Carolina	-0.3099	-27%	1.53	-0.2616	-23%	1.53
Tennessee	-0.3202	-27%	2.88	-0.4618	-37%	2.88
Maine	-0.3704	-31%	1.79	-0.9189	-60%	1.79
Utah	-0.4293	-35%	0.01	0.0026	0%	0.01
Connecticut	-0.5148	-40%	2.43	-1.4045	-75%	2.43
Oregon	-0.5156	-40%	1.90	-0.5282	-41%	1.90
New York	-0.5312	-41%	4.38	-0.7484	-53%	4.38
Kansas	-0.5731	-44%	2.57	0.5387	71%	2.57
Arizona	-0.6729	-49%	2.32	-0.9848	-63%	2.32
West Virginia	-0.8581	-58%	4.42	-1.3206	-73%	4.42
Nebraska	-0.9485	-61%	0.23	-0.0601	-6%	0.23
Alaska	-0.9518	-61%	2.25	-1.7882	-83%	2.25

Idaho	-0.9785	-62%	0.17	-0.0648	-6%	0.17
New Hampshire	-1.0377	-65%	2.52	-1.6340	-80%	2.52
South Dakota	-1.0710	-66%	1.48	-0.8417	-57%	1.48
Vermont	-1.2820	-72%	2.26	-1.4435	-76%	2.26
North Dakota	-1.5179	-78%	0.34	0.1291	14%	0.34
Rhode Island	-1.5352	-78%	2.54	-2.6359	-93%	2.54
Montana	-1.6935	-82%	2.05	-0.8170	-56%	2.05
New Mexico	-1.7358	-82%	2.31	-1.1146	-67%	2.31
Nevada	-1.8835	-85%	2.30	-1.6339	-80%	2.30
Wyoming	-2.0838	-88%	3.53	-2.1239	-88%	3.53

Effect is calculated by ($e^{coefficient}$ - 1) and expressed as a percentage. -8% means 8% below Georgia, and 141% means 141% above Georgia.

TABLE 3: Decomposition of Change in Annual Totals

Totals may not add due to rounding	Incidents involving Motor Vehicles at Public Crossings	Fatalities from Incidents involving Motor Vehicles at Public Crossings
Actual Annual Totals		
1975	10,971	786
2001	2,695	315
Change	- 8,276	- 471
Changes Explained by Regressions		
Crossing Closures	- 1,040	- 60
Increased Highway AADT	+ 89*	+ 201
Increased Frequency of Trains	+ 556	+ 157
Increased Proportion of Active Warning Devices	- 1,786	- 115
Increased Safety Elsewhere on Highway	- 3,913	- 305
Operation Lifesaver	- 1,455	- 164
Locomotives with Ditch Lights	- 1,279	- 268
Sum of Crossproduct Terms	+ 259	- 12
Change Not Explained by Regressions		
	+ 294	+ 95

* = cannot be statistically distinguished from zero.

TABLE 4: Benefit-Cost Analysis of the Section 130 Program

	Present value $m
Benefits - accrue over 30 years discounted at 7% per annum[7]	
115[1] deaths averted per year @ $3m[2]	4,582
245[3] critical (AIS5) injuries averted per year @ $2.2875m[2]	7,453
250[3] moderate (AIS2) injuries averted per year @ $46,500[2]	154
1,746[1] incidents of highway vehicle damage averted per year @ $5,347[4]	127
1,746[1] incidents of railroad property damage averted per year @ $8,165[5]	194
Total Benefits	**12, 510**
Costs - incurred now	
Section 130 expenditures at current prices, including matching funds[6]	**8,475**
Benefit-Cost Ratio	**1.48**

Sources:

1 Estimated in this paper.

2 FRA (2003).

3 Analysis of the data base collected as part of this analysis indicates that for 1975 to 2001 the ratio of injuries to fatalities is 4.3:1. FRA (2003) suggests that collisions involving trains traveling at greater than 25 mph produce critical (Abbreviated Injury Scale 5) injuries, whereas those involving a train traveling at a speed of less than 25 mph will result in moderate (AIS2) injuries. Publicly available data only permits observing the proportion of injuries involving trains traveling at greater than or less than 30 mph. Based on this definition 49.6% of injuries will be critical and 50.4% will be moderate.

4 FRA (annual), year 2000 edition table 8-13.

5 FRA (annual), year 2000 edition table 5-6 indicates that for the 210 most serious incidents the average railroad property damage was $70,368. The other 2,685 incidents must have had levels of damage below the reporting threshold of $6,600. Assuming that these latter incidents average $3,300 in damages, the average damage for all incidents is $8,165.

6 Section 130 expenditures from 1975 to 2001, adjusted to reflect 10% non-federal matching funds, and adjusted to 2001 prices using the Consumer Price Index.

7 Office of Management and Budgets (1992).

FIGURE 1: Actual versus Predicted Annual Number of Incidents

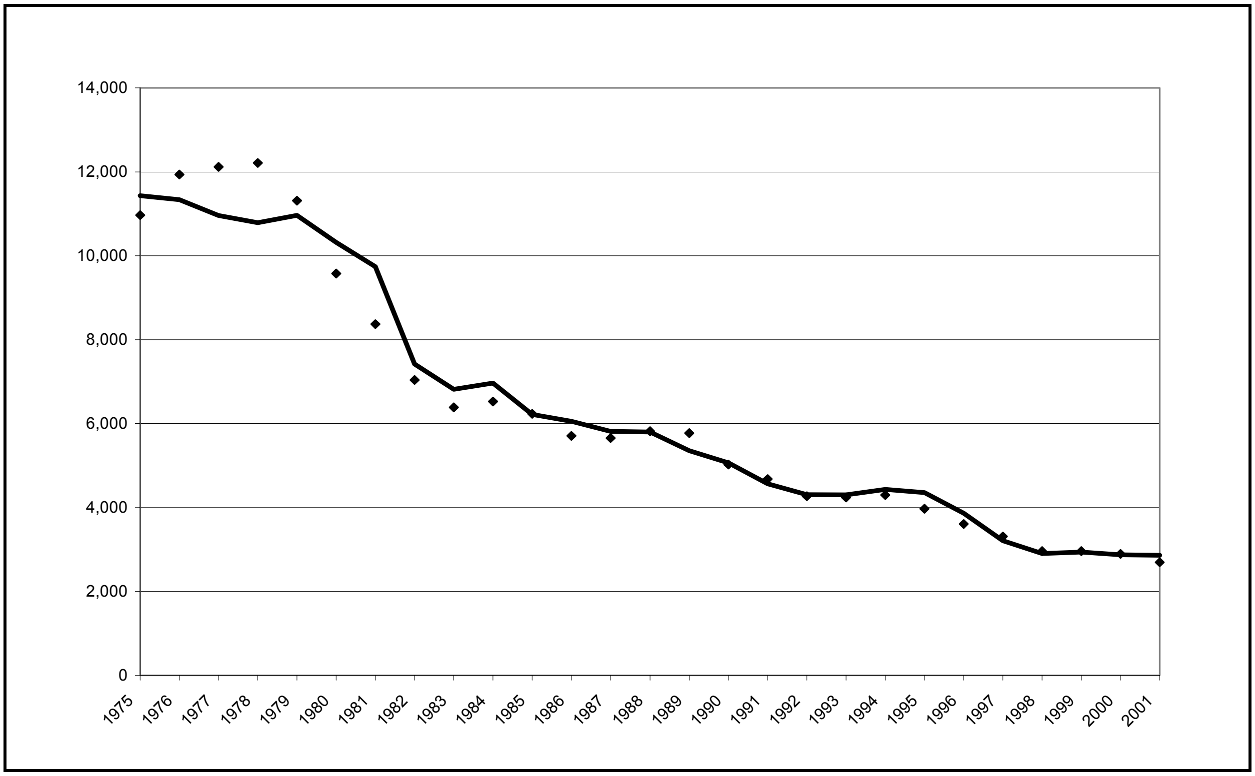

FIGURE 2: Actual versus Predicted Annual Number of Fatalities