Trespassing on the Railroad

Ian Savage
Department of Economics
Northwestern University
2001 Sheridan Road
Evanston, Illinois 60208, USA
Ph: +1-847-491-8241
Fax: +1-847-491-7001
E-mail: ipsavage@northwestern.edu

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Abstract

Greater than half of all the fatal injuries on United States railroads are sustained by trespassers. The paper provides a statistical analysis of the demographics of trespassers, the activities they were engaged in, and the causes of injury. It also analyzes trends over time. The paper finds that the risks of injury and death are particularly acute for males in their 20s and 30s. The annual casualty count has remained relatively stable in recent decades because growing affluence, which tends to reduce risk-taking behavior, has been balanced by increases in railroad activity and the size of the population.

1. Introduction

In 2005, 471 people died while trespassing on the railroads in the United States. Since 1970, the annual fatality count has fluctuated in a range between 376 and 543. The lack of a sustained improvement is in stark contrast to the considerable reduction in the risks faced by railroad employees and users of highway-rail grade crossings. In 2005, trespassers represented 53% of the 892 fatalities in railroad operations, whereas as recently as the late 1970s the proportion was only 25%.

A landmark year was 1997 when the number of trespasser fatalities exceeded the number killed in collisions at highway-rail grade crossings for the first time since 1941. In the late 1960s, crossing fatalities exceeded trespasser deaths by a ratio of three to one. Now there are 25% fewer crossing fatalities than trespassing deaths. A public outcry in the late 1960s led to a series of programs to improve crossing safety. These initiatives included making federal funds available to install gates and/or warning lights at a greater proportion of crossings, upgrading the lighting on the front of trains to improve conspicuity, closing little-used crossings, and starting a public education campaign called Operation Lifesaver. Taken together, these initiatives were and are remarkably successful in saving lives, and doing so in a cost-effective way (Mok and

Savage, 2005; Savage, 2006). In contrast, solutions to the trespassing problem have been far more elusive. With the public policy spotlight shifting in the past decade from grade crossings to trespassing, there is an increasing need for the professional community to understand the causes of trespassing and what can be done to reduce the annual casualty count.

2. Data

The analysis in this paper concerns mainline railroads. It does not deal with urban mass transit or streetcars, but it does include commuter railroads. Railroads are required to report deaths (excluding suicides) or injuries of all severities to the Federal Railroad Administration (FRA) on form 6180.55a. They have been required to do so since 1910. However, casualty data can be found for as far back as 1890. The data were published from 1901 to 1965 by the Interstate Commerce Commission (ICC), and since 1966 by the FRA. Throughout this paper "trespassers" will be defined as those people trespassing at locations other than grade crossings. (The term is also used to describe persons at grade crossings who pass through or around closed crossing gates, but the data are reported separately.)

3. Documented Suicides

Railroads are not supposed to report fatalities that are judged suicides by a coroner to the FRA. We will refer to these as "documented suicides." Coroners and local medical examiners do report suicides to the federal Centers for Disease Control and Prevention (CDC) for inclusion in the annual *National Vital Statistics Report* (see Hoyert et al, 2006, for the 2003 report). However, deaths are categorized using the World Health Organization's *International Statistical Classification of Diseases and Related Health Problems*, and suicides by railroad trespassers can be classified in a number of different ways. Therefore, it is difficult to accurately establish the annual fatality count. General professional opinion is that the number of documented trespasser suicides on mainline railroads is at least 100 per year, but that number may be higher, and perhaps is considerably higher. This means that the total number of trespasser fatalities is at least 20% higher than the approximately 500 deaths reported to the FRA.

While the number of documented suicides is substantial, the problem is much worse in Europe and Japan than it is in the United States. In Britain, documented suicides on the mainline railways are equal in number to the number of trespassing fatalities not deemed a suicide by a coroner (Rail Safety and Standards Board, 2005). Consistent with this, 2.6% of all documented suicides in Britain are by means of mainline trains, while the proportion in the United States based on an annual fatality count of 100 is 0.3%. The explanation for the different experience across countries is the greater density of rail lines and the higher frequency of trains in Europe and Japan, and the easier access to firearms in the United States (Hoyert et al, 2006, report that firearms are used in 54% of suicides in the United States).

4. Historical Perspective

While the annual fatality count has not changed much in recent decades, the situation is much improved compared with a century ago. A graph of the total number of trespassing casualties (deaths plus injuries) for each year from 1890 to the present is presented in Figure 1. The graph also distinguishes between deaths and injuries. Caution is required in comparing data over such a long period. In particular, documented suicides were included in the data at one time, and prior to1922 deaths that occurred more than 24 hours after an incident were classed as an injury rather than as a fatality.

Comparing 1905 and 2005, one is struck by the fact that fatalities were almost ten times more numerous (4,650 versus 471) at a time when the country was less than a third as populous (84 million versus 296 million). The fatality risk per head of population in 1905 was thirty-five times larger than it is today. Of course, part of the explanation is that there were 50% more train miles run over a much larger network, and in some cases the railroad literally ran down the middle of the main street of many towns. In addition, prior to the development of paved roads, the railroad right of way was used as an unofficial pathway (Aldrich, 2006).

Figure 2 plots the combined number of trespassing fatalities and injuries relative to two measures of exposure: population in millions, and line-haul train miles in tens of millions. (The latter measure excludes train miles in yard and switching operations, which have not been reported in a consistent manner over time. It should be noted that the majority of trespassing casualties occur on the main line.) Immediately noticeable from both Figures 1 and 2 is the very substantial decline in risk between 1915 and 1919, and again between 1939 and 1945. While some of this decline is understandable in that the segment of the population most likely to trespass (men in their 20s and 30s) was away in military service, the improvement persisted even after cessation of hostilities. One might well conclude that the wartime experience changed the risk-taking behavior of this segment of society.

There is also evidence of a spike in trespassing during the Great Depression of the early 1930s. The image in popular culture of people riding freight trains while looking for work during the dust bowl years is not that inaccurate. In the 1930s, a quarter of the trespasser casualties were described as “hoboes or tramps.” The proportion fell to about 20% in the 1950s and was less than 10% in the early 1970s when the published reports ceased using this description. Similarly, about a quarter of the casualties in the 1930s occurred onboard trains (albeit that this would include injuries sustained aboard passenger trains by people who had not purchased a ticket). This had fallen to about 12% in the 1950s, and today it is relatively rare despite the use of freight trains by illegal immigrants in the Southwest.

Figure 3 is an enlarged version of Figure 2 showing the post-Second World War years, with the rates per head of population and per line-haul train mile shown as indices with 1947 set equal to 100. The rate per head of population declined quite steadily until 1960. It then leveled out at about 35% of the rate in 1947. There was then a substantial decrease of about 25% between 1967 and 1975, followed by more than 20 years of stagnation. There is evidence of a reduced risk in the past five years, but it is too early to tell whether this will be a sustained improvement.

The rate per line-haul train mile improved between 1947 and 1955, but then fluctuated around a level that was 20% lower than in 1947 until the mid 1990s. Since the mid 1990s, there has been a considerable improvement of about 30% primarily because the number of train miles has increased but the number of trespasser casualties has not.

The improvement in casualty rates relative to both train miles and population size in recent years have been counterbalanced by the growth in both population and train miles (up by 25% and 60% respectively since the early 1980s). This explains why the absolute count of fatalities has remained relatively constant.

5. Who, Where, and What

A distinction needs to be made between the characteristics of trespassers in general, and the characteristics of the subset of trespassers who sustain fatal and non-fatal injuries. The total number of trespassers is clearly many orders of magnitude larger than the number of casualties. The BNSF Railway Company, the nation's second largest, reports that its police officers removed or arrested 23,200 trespassers in 2003. This compares with a total of 111 trespassers killed or injured in that year on the BNSF. Moreover, we can be certain that the vast majority of acts of trespass go unnoticed by BNSF police given that the railroad's network extends for 33,000 miles.

Information on the general trespassing problem can be obtained when cameras are set up along the right of way. In addition, some railroads have recently started installing cameras on the front of their locomotives with the primary intention of collecting evidence to use in law suits resulting from highway-rail grade crossing collisions. It would be possible to review a sample of the tapes to gain some idea of the locations of trespass, the nature of the persons involved and the activities they are engaged in.

I am not aware of any published research that has used photographic data to quantify trespass in general. (While daSilva et al, 2006, report on a camera installation on a bridge in Pittsford, New York, the purpose of their research was to test a deterrence system rather than to quantify the frequency and purpose of trespass). The increasing use of cameras on locomotives may make suitable data available in the future. In contrast, data on incidents in which an injury occurs can be obtained from the FRA database, and from reports filed by attending police officers and, in the case of fatalities, by coroners and medical examiners. Of course, society is most interested in obtaining information to prevent cases in which a fatal or non-fatal injury is sustained.

In Table 1, the 3,628 trespassing deaths and injuries that occurred between 2001 and 2004 are categorized by the event that caused the injury and the activity the trespasser was engaged in at the time. Three-quarters of the casualties occur when the trespasser is struck by a train. A further 10% of casualties result from slips, falls or striking a fixed object while on railroad land or on trains. The remaining 12% of casualties are due to a mixed bag of circumstances that include assault, exposure to the environment, and cases where the event and activity cannot be determined. Of course, those trespassers that are struck by a train are much more likely to sustain fatal injuries. Almost 90% of trespasser fatalities occur when the trespasser is struck by a

train, while almost 40% of non-fatal injuries occur in circumstances that do not involve being struck by a train.

Especially notable is that almost a third of all casualties involve a train striking a trespasser who was sitting or lying down. These data are often cited to support the contention that some of the entries in the FRA database represent suicidal people who do not leave notes or other evidence of their intentions. Consequently, coroners are unable to determine conclusively whether or not the fatality was a suicide. In addition, some fatalities are determined by coroners to be suicides subsequent to being reported to the FRA as a trespasser, and there is no formal system in place to reconcile the data at the end of the year. George (2006) matched up 61% of the 1,523 trespassing fatalities in the FRA database that occurred in 2002, 2003 or 2004 with the records held by local coroners and medical examiners. He found that in 164 of the 935 available cases (17.5%) the coroner had used the words "suicide" or "intentional" somewhere in their report. An additional 49 cases (5.2%) contained a written narrative that would suggest suicide as a motive. One might conclude from George's analysis that approximately 20% of the deaths in the FRA database are either "undocumented suicides" or documented suicides that were mistakenly reported. This proportion is far lower than in Europe. Railroad management in Britain investigated the circumstances of all trespasser deaths not deemed a suicide by a coroner, and found a strong suspicion of suicidal intent in 60% of cases (Rail Safety and Standards Board, 2005). Again, the ready access to firearms in the United States seems to reduce the popularity of trains as a method of suicide.

An analysis of casualty age is presented in Table 2. The age distribution of all the casualties occurring between 1999 and 2001 is shown in the middle column. A risk rate is shown in the final column. This is calculated by dividing the average annual casualty count in an age group by population data from the 2000 Census. There is a popular image in the press that children under the age of 10 are at particular risk. In reality, children in this age group represent only 2.2% of casualties and have a casualty rate that is smaller than that for senior citizens. People between the ages of 16 and 45 years old face the greatest risk. This age group represents 45% of the general population but 75% of the trespasser casualties whose age is known. People in their early twenties are particularly at risk, and face an annual casualty risk of 1 in 150,000.

While the FRA reporting form has a field for recording the victim's age, no additional demographic information is collected. There is not even a field for reporting gender. Consequently, additional insights on demographics have come from special studies that rely on police and/or coroners' reports. There has been just a handful of studies. The earliest of these was a National Transportation Safety Board (NTSB, 1978) study that looked at 280 fatalities that occurred between March 1976 and October 1977. A widely cited CDC study (Pelletier, 1997) examined coroners' reports for all of the 138 trespasser deaths in North Carolina for the years 1990-94. Another CDC study analyzed 132 fatalities and 156 injuries that occurred in Georgia between 1990 and 1996 (CDC, 1999). Finally, a recent consulting report to the FRA analyzed 935 deaths that occurred nationwide between 2002 and 2004 (George, 2006). There is also a small literature by medical examiners' (see Davis et al, 1997 and the references therein). The results of the studies are similar.

About 90% of victims are found to be adult males, with the vast majority between the ages of 20 and 49. Consequently, the risk rates shown in the final column of Table 2 considerably understate the risk to males. Eighty percent of the adult victims are unmarried. Pelletier's study found that for those adults whose education was known, only 45% had graduated from high school. Pelletier found that African-Americans were over-represented at 38% of the victims whereas they formed only 22% of the population of North Carolina. George also found that African-Americans were over-represented (16% of victims compared with 12% of the general population), and that Native Americans were even more over-represented at 5% of the victims while they only form 1% of the general population.

Contrary to the popular image of trespassers as “hoboes or tramps,” Pelletier found that only 10% of victims were transients, and 80% of deaths occurred within the victim's county of residence. Similarly, George found that only 9% were “homeless” or “transients.” The Georgia study found that 60% were injured in the city in which they resided, suggesting that trespassing occurs close to home. The trespasser problem appears to be an urban one with less than a quarter of fatalities occurring outside of city or town limits. The NTSB found that nearly all of the fatalities occurred on multiple-track mainlines (albeit that there is no indication that the NTSB selected a random sample of incidents). In 85% of the cases there was no fence erected to protect the right of way.

Alcohol would appear to be involved in most cases. A disproportionate number of fatalities occur at night on the weekends. Sixty percent of the victims in the NTSB study and 80% in Pelletier's study had been drinking heavily. The Georgia study found that 65% of victims tested positive for alcohol or drugs. George found that 57% of victims tested positive for alcohol and/or drugs, 30% tested negative for both, and the remainder were not tested. The average blood-alcohol content was 0.23mg/100mL in the NTSB study, and the median was 0.26 in the North Carolina study and 0.22 in the Georgia study. These are about three times the legal limits for driving, and according to the National Safety Council puts a person in a state of “confusion.” Twenty-eight percent of victims in the North Carolina study had previously received medical treatment for alcoholism.

Based on what we know at the moment, and at the risk of generalizing, one might conclude that about two-thirds of the trespasser casualties can be characterized as single adult males in their 20s and 30s under the influence of alcohol. It would appear that the railroad right of way is an attractive place for people to socialize and imbibe, or to sleep off the effects of alcohol or drugs. Almost a third of the trespasser casualties are sitting or lying in the right of way at the time of impact which clearly indicates considerable negligence on the trespasser's part or suicidal intentions.

That said, the other third represent people on railroad property for the purposes of theft, vandalism, thrill seeking, catching a ride on a freight rain, or taking a short cut over or along the right of way. The railroad is generally unfenced, and it bisects many small towns. Pedestrians are tempted to take a short cut rather than walk to the nearest grade crossing or bridge. In urban areas the temptation to take a short cut leads to the destruction of existing fencing. In rural areas, there is evidence that hunters, fishermen, and the operators of snowmobiles and all-terrain

vehicles use the railroad right of way. There is also evidence that residents of homes for senior citizens can become disoriented and wander onto neighboring railroad tracks.

6. Time Series Analysis 1947-2003

The stagnation in the number of annual trespasser casualties in the past 35 years has proved to be frustrating and mystifying to both railroads and the government. Some insights into the reasons for this stagnation can be found by conducting a time series analysis on the period since the end of the Second World War. Two different regression techniques will be used to analyze annual data from 1947 to 2003. Both techniques produce similar results

The first type of regression is a log-linear regression on the rate of trespasser casualties per head of population. The Prais and Winston (1954) AR(1) estimator is used to reduce the problems commonly found in time-series analysis caused by serial correlation. It does so by transforming both the dependent and explanatory variables in the regression by subtracting a proportion, Δ, of the variable's value in the previous period. Hence variables take the form:

$$X_t - \rho X_{t-1}$$

The Prais-Winsten method also ensures that the regression does not "lose" one observation in making this transformation.

The second is a negative binomial regression with the count of casualties as the dependent variable, population as the exposure variable, and the other explanatory variables expressed in logarithms. The negative binomial regression is a more generalized version of the Poisson regression. It assumes that the mean, E(Y), and variance, Var(Y), of the count of casualties for a group of years with identical values of the explanatory variables have the following relationship:

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

While the estimation algorithms of the two equations are very different, the functional form is very similar. The negative binomial equation can be usefully visualized as having the form:

$$\text{count of casualties} = \text{population} * e^{(\alpha + \sum \beta i \ln(Xi))} + \varepsilon$$

while the log-linear function is:

$$\ln(\text{count of casualties/population}) = \alpha + \sum \beta_i \ln(X_i) + \varepsilon$$

or

$$\text{count of casualties/population} = e^{(\alpha + \sum \beta i \ln(Xi))} + \varepsilon$$

Consequently the magnitudes of the estimated coefficients of the explanatory variables in the two equations can be directly compared. In effect, the log-linear regression and the negative binomial regression are two different estimation techniques for the same basic functional form for the variables. Moreover, as all but one of the explanatory variables are expressed in logarithms, the coefficients can be interpreted as elasticities. In both regressions, the dependent variable measures trespassing casualties, which is the combination of both fatal and non-fatal injuries. The use of this broader measure of victims is designed to overcome the problem of random year-to-year variation that is found in fatality data.

The regression results are shown in Table 3. The negative binomial regression has an alpha value significantly larger than zero, thereby rejecting the Poisson model. As the estimated value of $\forall$ is positive, the data are referred to as overdispersed. This model has a pseudo R^2 of 0.25. The pseudo R^2 is a measure, using the estimated log-likelihoods, of the explanatory power of the full regression compared with a regression with a constant as the sole explanatory variable. In the log-linear model, a Durbin-Watson test finds that a Prais-Winsten AR(1) estimator, with a value of Δ of 0.55, removes serial correlation. The adjusted R^2 of the equation is very high.

The overall goodness of fit of the equations can be seen in Figure 4 which shows the actual casualty rates per million population (shown as the dots) versus the predictions of the negative binomial (represented by the solid line) and log-linear AR(1) (dashed line) regressions. The two predicted regression lines are very similar, and track the actual data quite well, with the exception of the period between 1960 and 1967 when the actual rate reached a temporary plateau.

In interpreting the results, one should not forget that the size of the population is treated by both regressions as having a direct 1:1 effect on the number of casualties. The population has more than doubled from 143 million in 1947 to 291 million in 2003. Consequently, had nothing else changed, we would expect to have twice as many casualties in 2003 as there were in 1947. That said, there are some concerns with this variable. Fifty years ago, settlement patterns were heavily influenced by the rail network, and many, if not most, people had some interaction with railroads on a daily basis. Widespread automobile ownership has changed settlement patterns in such a way that new development has occurred in places remote from the railroad.

The first explanatory variable is the national railroad route length, known in the industry as "road miles." This was obtained from the ICC's annual statistical publication and later from the Association of American Railroad's *Railroad Facts.* The national network shrunk by 35% between 1947 and 2003, with most of the reduction occurring in the decade between 1974 and 1984. The 1976 *Railroad Revitalization and Regulatory Reform Act*, and the 1980 *Staggers Act* gave railroads more freedom to abandon unremunerative lines. A reduction in the network should reduce casualties as fewer people live in close proximity to the tracks. The estimated coefficient is very close to unity in both regressions. Indeed one cannot reject a null hypothesis that it is unity. Casualties change proportionately, all other things being equal, with the size of the network.

In an ideal world, one might want to use an exposure measure that incorporates population increases, changes in settlement patterns and line abandonment. Perhaps the most appropriate exposure measure would be the number of people who live, work or go to school within, say, a mile of the tracks. Nowadays such data are available in geographic information systems, based on Census Bureau data and a digitized representation of the rail network. Such information is used to model the population exposed to movements of hazardous materials (see for example, Han et al, 2006). However a time series of such data is not available, especially when one wishes to track changes back to the 1940s.

Of course, the lines that were abandoned were those with the least amount of rail traffic. The effect of closing little-used lines, along with general trends in rail traffic are captured by a second explanatory variable measuring the average daily line-haul trains per mile of network. The number of national train miles was obtained from the ICC's annual statistical publication and later from the FRA's annual safety publication. The variable representing the average daily trains is calculated as:

$$\text{Daily Trains} = \frac{\text{Annual Line - Haul Train Miles}}{\text{Road Miles} * \text{Days in Year}}$$

The average daily number of trains fell from 13 a day in 1947 to 8 in 1960. It then fluctuated around this number until 1991. Rail traffic density then started to increase, and by 2003 the number of daily trains had almost returned to its 1947 level. The estimated coefficient is in the range of 0.85 to 0.9, implying that casualties change slightly less than proportionately with rail activity. This is to be expected given that a quarter of all casualties result from slips and falls rather than from being struck by a moving train.

The third variable measures the proportion of the population that is between the ages of 15 and 44 (U.S. Census Bureau, 2002). Table 2 indicates that persons in this age range have a disproportionate involvement in trespassing incidents. As the post-World War II "baby boom" generation has aged, the proportion of 15 to 44 year olds has followed a wave pattern. It decreased from 0.46 in 1947 to a low of 0.39 in 1961, increased to a high of 0.48 in 1986/7, and has subsequently fallen to 0.43 in 2003. This variable is found to have a very strong effect on the number and rate of casualties.

The fourth variable measures the real per capita Gross Domestic Product. GDP data from the Bureau of Economic Analysis were converted to 2003 dollars using the Consumer Price Index, and expressed as a per capita rate. Real GDP per capita has increased from $14,000 in 1947 to $38,000 in 2003. Standard economic theory suggests that citizens demand more lifesaving activities as a country becomes richer. This manifests itself in increased health care expenditures, a demand for more product safety features, and perhaps a reduction in undertaking risky activities such as trespassing on the railroad. Consistent with this theory, the National Safety Council (annual) reports that the rate of non-work-related unintentional deaths in the United States fell from about 55 per 100,000 people in 1947 to 33 per 100,000 in 2003. In

addition, increased wealth reduces the prevalence of transients who hop trains while traveling to find work. The regressions find that the increase in wealth has the expected negative effect on casualties and casualty rates, with an elasticity close to unity.

The final variable measures a technological change that was found by Mok and Savage (2005) to be particularly effective in improving safety at grade crossings. A 1995 federal rule required increased lighting of trains. The traditional single headlight had 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 trespassers with a greater perception of an approaching train's speed and how far it is away. Assuming that locomotives were fitted with these additional lights at a constant rate between the announcement of the rule in September 1995 and 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. Unlike the other variables, this is not expressed in logarithms. Also, unlike the other variables, the regressions suggest a weaker statistical relationship with the number of casualties. The negative binomial regression suggests that installing ditch lights reduced casualties by 13%. This relationship is marginally significant at the 95% confidence interval. The relationship is statistically insignificant in the log-linear equation, which estimates that ditch lights reduced casualties by 7.5%.

There were two other variables that were tested but were found to be less satisfactory and were dropped from the analysis. The first was the implementation of Operation Lifesaver. The public outcry concerning grade crossing safety in the late 1960s led to the formation, starting in Idaho in 1972, of state-based nonprofit organizations to promote education and awareness of railroad-related hazards. The program spread state by state across the nation between 1972 and 1986. A variable was constructed indicating the proportion of the population in a given year who resided in a state in which Operation Lifesaver had been established. Unfortunately from an analytical perspective, the growth in Operation Lifesaver coincided with the peak period for railroad abandonment. A high correlation between these variables made it impossible to include both in the regressions. Subsequent discussions with officers of Operation Lifesaver revealed that the organization primarily focused on the risks at grade crossings in its early years, and only since 1997 have activities also been directed toward trespassing and suicide prevention.

With an eye to examining possible trends in the portion of reported casualties who are undocumented suicides, data were obtained on the national rate of suicide (National Center for Health Statistics, annual). The rate has fluctuated over the years between 97 and 131 per million population. The rate was particularly low between 1951 and 1961, and in the period since 1999. It was particularly high between 1975 and 1978, and again between 1984 and 1988. If a large proportion of reported trespasser casualties are really undocumented suicides then one would expect a strong positive correlation between the national suicide rate and the trespassing casualty rate. In fact, the correlation is a counterintuitive -0.36. This would lend additional support to the notion that undocumented suicides are a smaller proportion of the reported trespasser fatalities in the United States compared with the situation overseas.

7. Decomposition of Time-Series Trends

From 1947 to 2003 the number of annual trespassing casualties fell by 1,594 from 2,490 to 896. The regressions can be used to estimate the contribution of the various causes to the decline. Using the negative binomial regression results, the change in the predicted number of casualties from year t to year t+1, can be decomposed into its constituent parts. The theory of the decomposition methodology can be explained by considering a simple function where Z = A*B. The change in Z from one period to the next can be defined as:

$$Z_{t+1} - Z_t = A_{t+1}*B_{t+1} - A_t*B_t = A_t*(B_{t+1}-B_t) + B_t*(A_{t+1}-A_t) + (A_{t+1}-A_t)*(B_{t+1}-B_t)$$

The analysis in this paper has many more variables, and the decomposition will take the following form:

$$\begin{aligned}\text{Casualties}_{t+1} - \text{Casualties}_t = {} & \left[\text{Population}_{t+1} - \text{Population}_t\right] e^{a} e^{b_1 \ln(\text{RoadMiles}_t)} \\ & e^{b_2 \ln(\text{Trains}_t)} e^{b_3 \ln(\text{Age15-44}_t)} e^{b_4 \ln(\text{Wealth}_t)} e^{b_5 \text{Ditch Lights}_t} \\ & + \text{Population}_t \; e^{a}\left[e^{b_1 \ln(\text{RoadMiles}_t)} - e^{b_1 \ln(\text{RoadMiles}_{t-1})}\right] e^{b_2 \ln(\text{Trains}_t)} \\ & e^{b_3 \ln(\text{Age15-44}_t)} e^{b_4 \ln(\text{Wealth}_t)} e^{b_5 \text{Ditch Lights}_t} + \ldots + \varepsilon_t - \varepsilon_{t-1}\end{aligned}$$

The equation will also include (in place of the ellipses) similar terms to the first two that involve changes from year t to t+1 for the variables Trains, Age 15-44, Wealth and Ditch Lights. In addition there will be cross-product terms involving every possible combination of the value of variables in period t and changes in variables. There will be 63 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 cross-product terms will be positive and some negative, and will tend to cancel each other out.

The decomposition was carried out for each of the annual changes, starting with the predicted change from 1947 to 1948 and concluding with the predicted change from 2002 to 2003. The annual changes are then added together to produce a predicted decomposition over the entire 57 year period. This is shown in the final column of Table 4. The first-order effects are shown explicitly, while the cross-product terms are summed together. Over the entire period, the regression predicts that increases in population should have increased casualties by 904 a year. However, this was counteracted by abandonment of parts of the network (reducing casualties by 498), reductions in the number of average daily trains (369), changes in the age distribution of the population (232), installation of ditch lights (136), and increases in wealth which promote less risk-taking behavior (1,133). The cross-product terms produce a further reduction of 62 casualties a year. The sum of the error terms, which is to say the changes not explained by the regression, total a net decrease of 68 casualties. As inspection of Figure 4 would suggest, the

explanation for the latter is that the actual number of casualties in 2003 was somewhat below the predicted value, whereas in 1947 the actual and predicted numbers are much closer.

While the decomposition of the changes over the entire period is interesting, breaking down the decomposition into four sub-periods provides even more insight. The sub-periods chosen are 1947-1960 (that is to say, the sum of the predicted changes from 1947 to 1948 through 1959 to 1960), 1960-1974, 1974-1988 and 1988-2003. The break points were chosen because of observed changes in the trend of one, or more, of the explanatory variables. The decompositions are shown in the middle columns of Table 4. In interpreting the table, there are a number of notable features. Increases in population and wealth have affected casualties in all four time periods. However, the numerical size of both the population and wealth effects are much larger in the earlier time periods because trespassing risks (as explained by the other variables) were much higher fifty years ago. The reduction in the railroad network size had its primary effect in the 1974-1988 period. The aging of the baby boom generation is reflected in the high proportion of people between the ages of 15 and 44 in the period from 1960 to 1988. The reduction in the average number of daily trains in the 1950s had a particularly large negative effect. The reverse is true when train traffic density started to increase rapidly after 1988.

The decomposition suggests that the perception that there has not been any discernable change in trespassing in the past few decades is incorrect. There have been some strong trends, but they have tended to counteract each other. Increases in train traffic coupled with an increase in population have been almost exactly balanced by factors that tend to reduce trespassing, such as line abandonment, increasing wealth, the installation of ditch lights and an aging population.

8. The Way Forward

Trespassing on the railroad is a problem that does not seem to be going away. The lack of success is disheartening to all involved in attempting to improve the situation. In charting out future public policy initiatives, it may be useful to think of trespassers as falling into four broad categories: people who are loitering near the tracks, suicides, those looking for transportation, and everyone else. Such a classification is useful, as the applicability of potential countermeasures will vary depending on the nature of the trespasser.

By far the largest group of trespassers casualties, probably representing about half of all casualties, are males in their 20s and 30s who are socializing or loitering on or near the tracks. From what we know from the CDC studies, many of these trespassers are under the influence of alcohol, have a history of alcohol abuse, are unmarried, and have a low level of educational attainment. It would be probably fair to say that these persons probably engage in risky behaviors of many types in addition to trespassing on the railroad. Consequently, the most productive public policy responses would probably fall into the realm of public health, rather than being specific to the railroad.

That said, there is presumably some reason why this segment of society decides to congregate along the right of way. In the absence of any relevant studies, let me suggest that the most likely explanation is that one can engage in things on the railroad that one could not do in a public park

or a parking lot. Persons drinking in a public park would be in full view of the street, and it would likely result in citizen complaints and an intervention by the city police or county sheriff. In contrast, the railroad right of way is what sociologists would call a quasi public-private place. It is technically private property, yet access is easy and the probability of enforcement by railroad police is very low. Moreover, vegetation shields activities on the right of way from public view, and the local police have no jurisdiction and little interest in removing trespassers (albeit that the latter may be changing since the terrorist attacks of September 2001). For this type of trespasser, deterrence in the form of fencing the right of way may actually prove to be counterproductive as it may further shield the tracks from public view, and this type of trespasser values privacy. Clear cutting the vegetation, and where appropriate installing some lighting, might be far more productive.

Because all evidence suggests that these trespassers exist on the fringe of society, mainstream activities such as public service announcements and the current program of Operation Lifesaver presentations may be an ineffective way of communicating the dangers. It may be productive for Operation Lifesaver to redirect some of its activities away from presentations to schools and civic groups toward activities in soup kitchens and taverns that are located close to the tracks.

The second group is suicides. While the number of coroner-determined suicides is not known for sure, the number is thought to be at least 100 a year. It may be much higher than this number. In addition, George (2006) reports that about 23% of the FRA database of trespasser casualties, which in theory should exclude suicides, are most likely also suicides, which would represent another 100 suicides a year. Taken together, perhaps a third of the persons who died on the tracks away from grade crossings are actual or probable suicides. There is a small literature on suicides on railroads, primarily dealing with urban transit systems, and mainline railways in Europe (see Mishara, 1999 and the references cited therein). The FRA in cooperation with Transport Canada have recently commissioned a research study that will investigate and provide detailed background information on 60 cases of suicide over the course of the next few years. This study will provide demographic information, the medical background and information on why the railroad was chosen as a method of suicide.

Possible countermeasures include posting the phone number of suicide help lines at intervals along the right-of-way and at stations, and instructing staff to be aware of antecedent behavior. Suicidal people often reconnoiter the site of the proposed suicide in advance. Because many suicidal persons have lapsed from a program of psychiatric treatment and a drug regimen, an intervention can get them back into their programs and deter a suicide attempt. Evidence from Britain suggests that fencing of the right of way has relocated suicide attempts to station platforms and other places of public access such as highway-rail grade crossings.

Perhaps the first step in addressing the suicide problem is to obtain a clear picture of its magnitude. By not requiring the reporting of suicides, the FRA is sweeping the problem out of public sight. It should be required that all deaths on the railroad are reported to the FRA, and procedures put in place to cross check the reports to the verdicts of coroners and medical examiners. It is clear from George (2006) that even the current reporting requirements are not being followed consistently with some coroner-confirmed suicides entering the FRA trespasser

database. In the proposed regime, suicides would be shown as a separate line item in the FRA safety data. I suspect that the outcome of such a change in reporting requirements will be so shocking as to spur public policy. The government and railroad management might wish to go even further and classify other trespasser deaths as "suspected suicides" based on evidence from police reports and coroners' enquiries. The objective of such an analysis would not be to allow the railroad to evade legal or moral responsibility for a trespasser's death, but to inform public policy because the countermeasures that should be adopted to prevent suicides are different from those that are appropriate to prevent other types of trespass.

The third group is transients using the railroad for purposes of illicit transportation. While the era of the hobo from popular imagery has long since passed into history, there is a problem of illegal immigrants in the Southwestern states hopping freight trains, and using the right of way as a pathway. Clearly, the magnitude of this railroad problem is related to the prevalence of illegal immigration, which is a topic of national debate.

The final group is a mixed bag of thieves, vandals, thrill seekers, and those taking a short cut across or along the tracks. While members of this group probably represent the vast majority of incidents of trespass, they are a minority of those killed and injured. Alcohol-fueled loiterers, suicidal people, and people hopping freight trains are much more likely to sustain an injury while on railroad property than people taking a short cut. Savage (1998, see chapter 9) discusses the legal duty of care that railroads have in preventing this final type of trespass. In general, courts in the United States have held that the mere existence of a railroad track is sufficient to warn adults of the dangers of trespass, and that neither a fence nor warning signs are necessary.

However, for children under the age of twelve a higher standard of care is required, especially because the law has long recognized that children may be attracted to playing on the railroad. This is formally known as the "attractive nuisance doctrine" and more commonly referred to as the "turntable doctrine" as an early case involved a child injured while he was trespassing on a railroad turntable. The actual conduct expected of the railroad is somewhat unclear. In areas where there are very young children a fence may be required, whereas for older children Operation Lifesaver presentations in neighboring schools warning of the dangers may be sufficient.

A more contentious issue is how the railroad should act when it is aware that trespass takes place repeatedly at certain locations. Some courts have taken the view that railroads have a duty to "anticipate future trespass" at locations where trespass occurs regularly, and to react to a "well-worn path" crossing the railroad. In situations where a landowner is aware of repeated trespass but has taken no action to prevent access, courts may regard the trespasser as a "licensee." In general, landowners are held to a higher standard of care in warning licensees of the dangers than they would be for trespassers. In general the posting of signs by the railroad is regarded as a sufficient action. Railroads do take further actions such as conducting patrols and working with local authorities and police departments. Where there appears to be a well-used informal foot crossing then the railroad might be expected to provide a regular crossing, a footbridge, or erect fencing to make people use nearby formal crossings.

In North America, as in continental Europe and many other parts of the world, the railroad is generally unfenced. The NTSB (1978) study indicated that 85% of trespasser fatalities occurred at unfenced locations. At various times Congress has raised the issue of imposing regulations to require railroads to erect fences along sections of their right of way that pass through populated areas. Savage (1998) made some calculations on the economics of fencing approximately 10,000 miles of right of way that pass through areas with population densities of greater than 800 persons per square mile. He estimated that installing and maintaining urban fencing would cost about $300 million a year, and would reduce trespassing fatalities by a maximum of 100 persons a year. At this level of fatalities averted, fencing would be marginally justified in a cost-benefit analysis given commonly used values of a statistical life saved. However, Savage points out that this calculation is based on the most optimistic assumptions about the effectiveness of fencing. Fencing is routinely destroyed, and may not be effective against persons who value privacy while loitering on the right of way, or potential suicides who relocate to accessing the tracks at grade crossings and stations. From a public policy point of view, Savage argues that society would be much better off if the money was spent on installing flashing lights and gates at the large number of highway-rail grade crossings that currently do not have them. At these locations, the payoff in terms of lives saved is larger and much more predictable.

9. Conclusions

The good news is that the nation's increasing affluence has reduced the propensity for people to expose themselves to the risks of trespassing on the railroad. The bad news is that increases in train traffic and the size of the population conspire to ensure that the annual toll of injuries and fatalities has remained reasonably constant for the past three decades.

There is a strong epidemiological aspect to the trespassing problem, with the risks concentrated on males in their 20s and 30s. Consequently the amount of trespassing will be directly related to the demographic trends affecting the size of the population in the target group. While the baby boom generation has aged, lowering the proportion of the population in this high-risk group, the total size of the population is increasing, meaning that the absolute number of 15-44 year olds is still rising. Absent any innovative countermeasures, there is little prospect that the annual casualty count will be reduced anytime soon.

A hurdle to designing effective countermeasures is that we are only now developing an understanding of the demographics of trespassers and their motivation for being on the tracks. The 1990s studies by the CDC (Pelletier, 1997; CDC, 1999), and the recent work by George (2006), which was envisioned by the FRA as a pilot study, point in the right direction. There is a great need for a nationwide comprehensive study that combines FRA data with information that can be gained from coroners and local police reports, supplemented by interviews with those suffering non-fatal injuries, and relatives and friends of the deceased.

Insights from more detailed studies are essential, as the effectiveness of possible countermeasures will vary depending on the nature of the trespassing. It is clear that innovative thinking is necessary if society wishes to see a reduction in the annual casualty toll, but without a

good understanding of the problem we risk wasting resources or, even worse, doing things that may be counterproductive.

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Table 1: Proportion of 3,628 Trespassing Casualties by Event and Activity 2001-2004

Activity	Event			**Total**
	Struck by On-track Equipment	Slips, Falls, Electric Shock, Crushed, Striking Object	Other	
Walking or Running	29.8%	1.7%	0.5%	**31.9%**
Standing, Bending or Stooping	7.5%	0%	0%	**7.5%**
Sitting	7.4%	0%	0%	**7.4%**
Laying, Lying Down, Sleeping	22.9%	0%	0.9%	**23.7%**
Jumping, Climbing, Crawling, Boarding	5.2%	3.5%	0%	**8.7%**
Driving or Riding or Operating (bicycle, snowmobile etc.)	3.5%	4.8%	0%	**8.3%**
Other activities	0.7%	0%	11.9%	**12.5%**
Total	**76.8%**	**10.0%**	**13.2%**	**100%**

Source: FRA downloadable database (note that data are rounded, so columns and rows may not add up exactly).

Table 2: Distribution of Trespasser Casualties and Casualty Rates by Age

Age Range (years)	% of Total Trespasser Casualties 1999-2001	Annual Rate per million population
0-5	0.7%	0.27
6-10	1.5%	0.67
11-15	5.2%	2.33
16 - 20	10.6%	4.74
21 - 25	14.0%	6.77
26 - 30	11.0%	5.00
31 - 35	9.4%	4.08
36 - 40	11.5%	4.54
41 - 45	9.5%	3.90
46 - 50	6.6%	3.05
51 - 55	3.9%	2.15
56 - 60	1.5%	1.03
61 - 65	1.2%	1.01
66 - 70	1.0%	1.00
71 - 75	0.8%	0.81
76 - 80	0.8%	1.00
>= 81	0.9%	1.00
Not Given	10.0%	

Sources: Trespassing casualties from downloadable FRA database for 1999-2001. Rate calculated as the average annual count 1999-2001 divided by population data from the 2000 U.S. Census.

Table 3: Time Series Regression Results

	Negative Binomial		Prais-Winsten AR(1)	
	Coefficient	t	Coefficient	t
Dependent Variable	Count of Trespassing Casualties		Trespassing Casualties per Head of Population	
Constant	-15.6171	3.78	-13.7662	2.29
United States Population	Exposure		part of Dependent Variable	
Log of Railroad Road Miles	1.0070	4.08	0.9364	2.51
Log of Average Daily Number of Trains	0.9180	8.55	0.8547	6.33
Log of Proportion of Population between Ages 15 and 44	1.1888	4.24	1.2904	3.01
Log of Real Gross Domestic Product per Capita	-0.9633	8.08	-1.0408	6.12
Proportion of Locomotives with Ditch Lights	-0.1360	2.02	-0.0780	0.85
alpha	0.0041	4.35		
Observations	57		57	
Constant-only Log Likelihood	-442.26			
Log Likelihood	-331.37			
rho			0.5555	
Original Durbin-Watson Statistic			0.9318	
Transformed Durbin-Watson Statistic			2.0157	
Pseudo R^2 / Adjusted R^2	0.2508		0.9852	

Table 4: Decomposition of Change in Annual Totals

Totals may not add due to rounding	Sub-Periods				Overall 1947-2003
	1947-1960	1960-1974	1974-1988	1988-2003	
Actual Annual Totals					
Start of period	2,490	1,088	1,004	1,010	**2,490**
End of Period	1,088	1,004	1,010	896	**896**
Change	-1,402	-84	+6	-114	**-1,594**
Changes Explained by Regression					
Increased Population	+415	+184	+135	+170	**+904**
Decreased Road Miles	-68	-84	-218	-128	**-498**
Changes in Average Daily Trains	-806	-1	+65	+374	**-369**
Changes in Proportion of Population between 15 and 44	-338	+110	+109	-114	**-232**
Increased per Capita Real Gross Domestic Product	-436	-373	-181	-142	**-1,133**
Locomotives with Ditch Lights	0	0	0	-136	**-136**
Sum of Cross Product Terms	-15	-9	-27	-11	**-62**
Changes Not Explained by Regression					
	-154	+89	+123	-127	**-68**

Figure 1: Annual Trespasser Casualties by Type

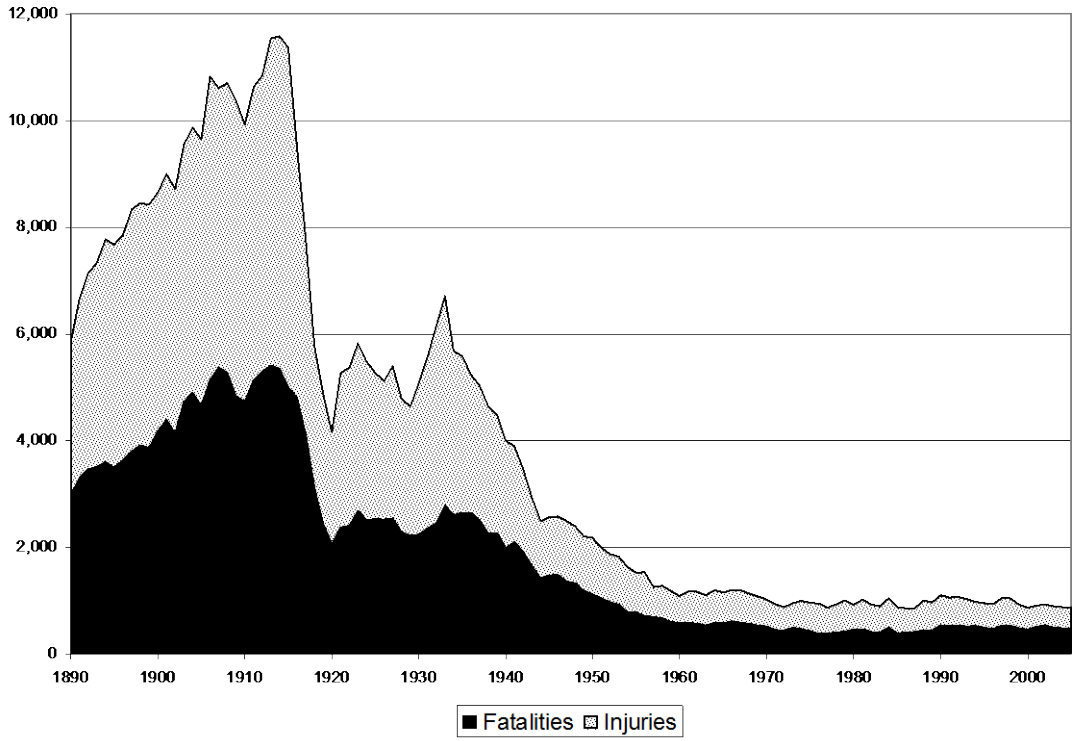

Figure 2: Trespasser Casualty Rates

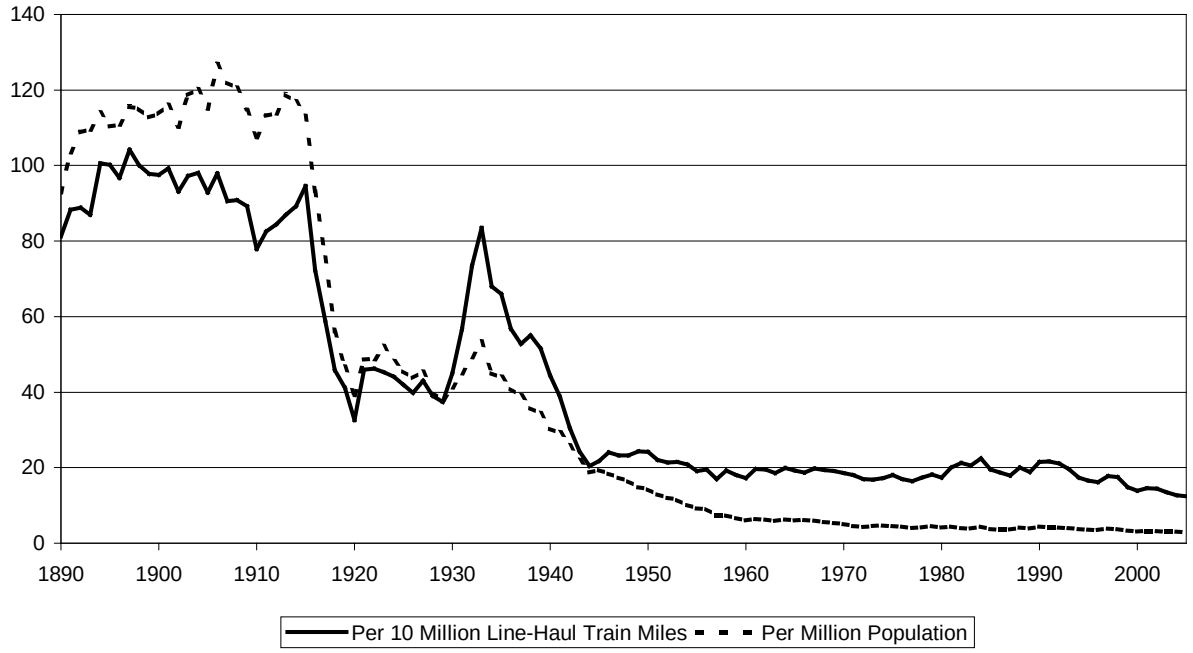

Figure 3: Index of Trespasser Casualty Rates Since 1947 (1947=100)

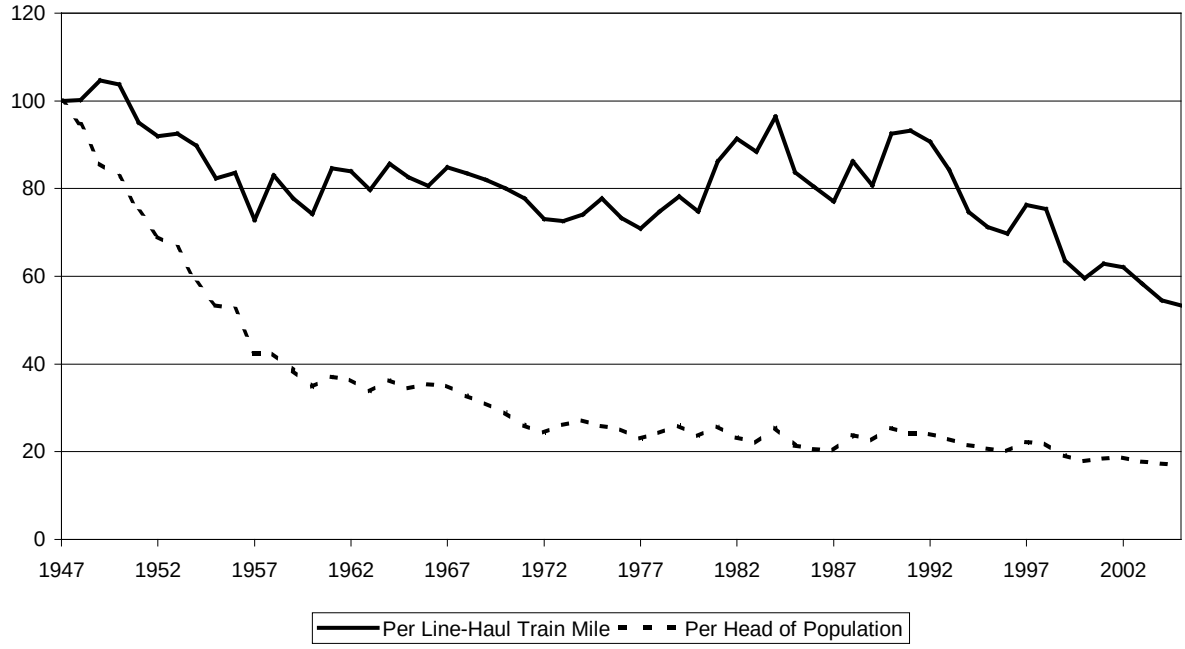
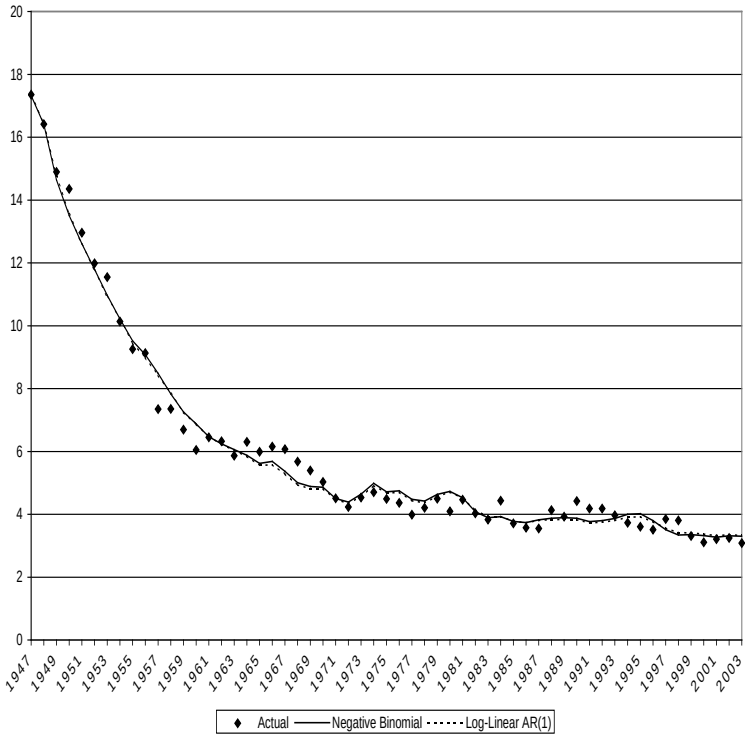
Figure 4: Actual versus Predicted Trespasser Casualty Rates per Million Population