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Rail Crossings: A Strategy to Select Countermeasure Improvements for Rail-Highway Crossings in California

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Rail crossing crashes have declined in the past 30 years, both nationally and in California. This is largely attributed to the closing of a large number of crossings as well as the deployment of a wide range of countermeasures, including signal systems, gating and grade separation programs. However, the number of crashes and subsequent injuries and deaths is still unacceptably high. Rail crossings provide different levels of warnings from four-quadrant gates down to stop signs. To understand how the state of California can best utilize state and federal funding available through SAFETEA-LU for making the state's 7,719 at-grade rail-highway crossings safer, this report presents an analysis of the effectiveness of different types of railroad crossing warning devices with a cost-benefit comparison.

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ABSTRACT

Rail crossing crashes have declined in the past 30 years, both nationally and in California. This is largely attributed to the closing of a large number of crossings as well as the deployment of a wide range of countermeasures, including signal systems, gating and grade separation programs. However, the number of crashes and subsequent injuries and deaths is still unacceptably high.

Rail crossings provide different levels of warnings from four-quadrant gates down to stop signs. To understand how the state of California can best utilize state and federal funding available through SAFETEA-LU for making the state's 7,719 at-grade rail-highway crossings safer, this report presents an analysis of the effectiveness of different types of railroad crossing warning devices with a cost-benefit comparison.

BACKGROUND

In response to a congressional directive, the U.S. Department of Transportation prepared a new national rail-highway at-grade crossing safety action plan that was issued on June 13, 1994. The results of this plan can be seen over the following ten years as the number of grade crossing crashes fell 35 percent, from 4,633 at the end of 1995 to 3,026 at the end of 2004. In California, during this same period, the number of crashes has decreased 23 percent from 201 to 154 (*1)*. The progress achieved under the 1994 action plan is primarily attributable to three factors: the closures of 41,070 public and private grade crossings, warning device upgrades at 3,985 public crossings with a high probability for incidents, and annual education campaigns by Operation Lifesaver, a nonprofit public education program on railroad crossing safety (*2*).

While these efforts have proven effective in reducing the annual number of rail-highway crashes, this number remains high. During the five year period from 2000 to 2004, there were 593 crashes between trains and motorized vehicles at California's public at-grade crossings that resulted in 99 deaths and 205 injuries (*1)*. While the majority of crossings with collisions had only one crash (72%) a significant number of crossings (28%) had multiple collisions, ranging from 2 to 12 in number. The 593 crashes exhibited a number of interesting characteristics, including:

- 73% occurred at crossings equipped with gates
- 26.8% involved vehicles that had driven around or through lowered gates.
- 59.2% involved vehicles that were still moving over the crossing
- 20.9% involved a vehicle running <u>into</u> the side of the train

A large proportion of these collisions were caused by drivers deliberately circumventing warning equipment, with devastating consequences. This behavior included ignoring flashing lights or other active warning devices, passing through descending barrier gates, or even driving around stopped traffic and already-lowered gates. Almost all of California's rail crossings provide some type of warning and/or barrier to prevent drivers of motor vehicles from crossing when a train is approaching. At the present time there are 7,719 public at-grade crossings in California of which 43% use passive warning devices (comprising static signage), and 57% use active warning devices (comprising train-activated warning devices such as 2-quad gates, flashing lights, and highway traffic signals) (*1*). The bulleted points above indicate that active warning signals, including conventional 2-quad gates, may not serve as a sufficient deterrent to drivers. At the same time, there is virtually nothing a train operator can do to avoid a collision. A 100-car freight train weighing approximately 12 million pounds and traveling at 55 mph may take over a mile to stop once the emergency brakes are applied. Given the difficulty in stopping trains and the potentially extremely severe consequences of a collision it is important to identify effective countermeasures.

The only way to absolutely prevent drivers from going around or through crossing gates is to make it physically impossible to do so. This can be accomplished by constructing a separation of grade, closing the crossing, or by deploying an impenetrable barrier, all of which carry a high monetary or social cost. There are a number of other approaches that, while not being 100% effective, can be used to find a middle ground that can prevent greater numbers of deaths and injuries while remaining economically feasible. These countermeasures are: long-arm gates, medians, four-quadrant gate systems and photo enforcement. These four approaches comprise the focus of this paper.

As part of a larger study to examine driver behavior at public at-grade rail-highway crossings, this project conducted an examination of the effectiveness of various types of railroad crossing warning and protective devices with a cost-benefit comparison. The four approaches are described along with their associated costs and potential ability to reduce crashes when added to a 2-quad gate system. A cost-benefit approach is used to compare the relative value of installing these countermeasures across different categories of crossings. The results of this analysis can assist in and provide a strategy for efficient utilization of state and federal funding available through SAFETEA-LU to improve safety at California public rail-highway crossings.

METHODS

Review of Equipment /Countermeasures

A review of the literature on existing and currently deployed rail crossing countermeasures was conducted. The countermeasures were reviewed for: (i) typical application; (ii) presumed safety effectiveness, (iii) cost; (iv) limitations; and (v) maintenance requirements. Effectiveness refers to the expected reduction in collisions as a result of the installation of the device when compared to the same crossing equipped with conventional active warning systems of flashing lights and gates. A reduction of 75% means that a crossing that had previously had four collisions over a given time period would be expected to have only one collision over a similar time frame, once the countermeasure is installed. Limitations for implementation could be physical (e.g., traffic lanes are too narrow), legal (e.g., requirements for photo enforcement), or social (e.g., isolating businesses by closing a crossing).

California Crash and Crossing Equipment Data

Crash data were obtained from the Federal Railroad Administration (FRA) Office of Safety Analysis Web Site with supplementary data from the California Public Utilities Commission (CPUC) Crossing Inventory and California municipal and county personnel and websites. The FRA web site allows access to railroad safety information including crashes, inspections, and highway-rail crossing data. Users can run dynamic queries, download a variety of safety database files, publications and forms, and view current statistical information on railroad safety (*1*).

Cost Benefit Analysis

Costs are measured as dollars spent on upgrading (equipment and initial installation) the warning devices at a crossing while benefits are measured as the potential cost savings from lives saved and injuries and property damage prevented. The values used to define the potential benefit were:

Death - $3,052,000 (*4*).
Injury - $104,255 (*3*).
Vehicle Damage Only - $4,680 (*3*). This does not include damage to the train, track, or warning equipment.

The formula used to calculate the potential annual benefit for each site was:

Benefit = (AvgCrash x Eff) x AvgCrashCost.
Where:
AvgCrash = the average annual number of crashes at this site

Eff = the effectiveness of the upgrade
AvgCrashCost = the average cost of a crash at this type of crossing

In performing these calculations, two assumptions were made: (1) multiple treatments are multiplicative in effectiveness and (2) multiple treatment costs are additive.

The cost/benefit analysis was limited to sites with multiple crashes in the 10-year period 1995-2004. This constraint was imposed for several reasons. First, the cost to upgrade rail crossings can be quite high, and resources are limited. Thus, the cost of upgrading all public at-grade crossing, or even just those that experienced any collisions, would be prohibitively expensive. Even limiting upgrades to the 252 sites that experienced multiple crashes would require a large capital outlay. Second, the number of past crashes is often used in rail-highway crash prediction models (e.g., *5, 6*). Finally, other factors commonly used in crash prediction models such as average daily vehicle traffic, average daily train traffic, and maximum train speed are badly out of date in the FRA database (*1*).

The cost/benefit analysis itself provides only a general guideline as to the types of expenses and benefits that might be expected with specific countermeasure combinations. It is unlikely that all sites would receive the same upgrade, as each crossing has unique characteristics or conditions that dictate the most appropriate treatment.

RESULTS

Countermeasures are summarized in the following sections and include costs and potential crash reduction effectiveness when added to a 2-quad gate system.

Long-Arm Gates

Description and Typical Applications: Gate arms at gated crossings typically extend to the centerline of the road and are currently prohibited from extending further by the California Public Utility Commission's General Order 75-C. Where they are legal and have been deployed, longer gate arm systems, which cover at least 3/4 of the roadway, have been shown to be an effective means of discouraging gate "drive-arounds" (*7, 8*).

Limitations, Requirements, and Maintenance: Long-arm gates have been deployed successfully in the North Carolina sealed corridor between Charlotte and Raleigh. Lessons learned from that deployment include:

- At least 6' of shoulder are needed on each side of the road so that cars that go under a descending gate can go around the lowered arm after crossing the tracks.
- Long-arm gates should not be installed where there is a significant level of truck traffic since even trucks that cross legally (i.e., before the gates start down) can clip the gate as it starts down on the far side of the crossing.
- Long-arm gates should not be installed where there is a significant level of bus traffic for the same reason.
- The Norfolk Southern Railway, which is responsible for maintaining warning equipment along the corridor, has set a maximum length of 38' for the gate arms. At longer lengths, the arms become vulnerable to breakage during high winds.

Effectiveness and Cost: Long-arm gate estimated efficacy is 75% (*8*) and estimated cost is \$5,000 (*8*).

Median separators

Description and Typical Application: A median is a traffic control device that acts as a physical separator between opposing lanes of traffic. For this report, medians refer specifically to the mountable centerline type with channelization devices. These can be applied directly to the existing roadway or can be part of a more complex structure consisting of an island with reflectors mounted on the top. Such devices present drivers with a visual cue intended to impede crossing to the opposing traffic lane. The curbs are no more than six inches in height, usually less than twelve inches in width, and built with a rounded design to create minimal deflection upon impact. The reflectorized paddle delineators or tubes, typically 24-36 inches high, are built to be able to bounce back up after being hit or run over. These systems are designed to allow emergency vehicles to cross over into opposing lanes to go back in the opposite direction but not for the purpose of circumventing the traffic control devices at the crossing. Usually such a system can be placed on existing roads without the need to widen them.

Limitations, Requirements, and Maintenance: Medians are currently being used in a large number of locations including the North Carolina sealed corridor and in Washington state. The durability of these countermeasures has been good and maintenance requirements have been low. In Puyallup, WA, seven sites with annual average daily traffic (AADT) of 9,800, require replacement of three to four upright tubes per site per year. In North Carolina, with average AADTs of 12,000, approximately 16 uprights must be replaced per site per year.

Effectiveness and Cost: Median separator estimated efficacy is 75% (*9*) and estimated cost is $14,000 (*9*).

Four-Quadrant Gate Systems

Description and Typical Application: Four-Quadrant Gate Systems consist of a series of automatic flashing-light signals and gates where the gates extend across both the approach and departure side of roadway lanes where they cross the tracks. Unlike two-quadrant gate systems, four-quadrant gates provide additional visual constraint and inhibit nearly all traffic movements over the crossing after the gates have been lowered.

Limitations, Requirements, and Maintenance: Adding to both the initial cost as well as upkeep is the added circuitry required to prevent trapping vehicles on the crossing.

Effectiveness and Cost: Four-Quad gates estimated efficacy is 82% (*8*) and estimated cost ranges from $125,000 (*8*) to $300,000+. As with photo enforcement, costs for the installation of 4-quad gates vary widely. For a single track crossing, the cost to upgrade from a passive crossing or 2-quad gate to a four-quad gate was given by Burlington Northern Santa Fe Railroad (BNSF) as “well over $300,000.” In general, the upgrades from a 2-quad gate are complete upgrades due to the age of existing equipment and circuitry (Crakes, S., BNSF, unpublished data).

Photo Enforcement

Description and Typical Application: The California Vehicle Code, Section 21455.5 authorizes governments and law enforcement agencies to operate automated-enforcement systems at both traffic-light intersections and railroad grade crossings. In the event of a signal or gate violation, such systems are/can be designed to obtain a clear photograph of the violation, the vehicle's license plate, and the driver of the vehicle.

Photo enforcement, while not erecting a physical barrier, can still provide a very strong deterrent against inappropriate railway crossings. In Los Angeles, a 6-month demonstration project resulted in an 84% reduction in the number of violations (*10*). Considering what should already be a powerful incentive to stop at lowered gates, it is somewhat surprising that the threat of a fine would be an effective motivator of behavior. However, the past experience of a traffic ticket seems to carry more weight than the vague possibility of a crash, even though the consequences of a crash could be catastrophic.

Limitations, Requirements, and Maintenance: Carroll and Warren (*11*), note that capital costs for photo enforcement can vary greatly depending on the requirements of the community served. These requirements can include the need for a picture of front and/or rear license plates, pictures of the driver's face, number of lanes, and location. One way to reduce the cost of photo enforcement is to move one camera among several sites without drivers knowing which ones are active at any given time. The authors list the following cost examples:

- The Insurance Institute for Highway Safety lists equipment costs of about $50,000 for a red-light camera and $5,000 for installation and sensors.
- In North Carolina, the cost for a prototype system at one intersection was $100,000 which included four cameras, two towers, loop detectors, infrared lighting units, software, controller and cabinet, printers and connections, and two advance-warning signs.
- In Florida, passive video monitoring at <u>four sites</u> with varying volume and numbers of tracks (including detection of vehicles, trains, and the status of gate arms and signal-crossing lights), using multiple cameras, costs nearly $400,000, with $200,000 attributed to equipment costs. The larger sum provides for site analysis and selection, all equipment, construction and installation, and reporting.
- In Illinois, the cost to install and maintain one installation site for 1 year averages $300,000, with the lower end at $263,000 and the high end at $344,000. Local police departments are also incurring costs in conjunction with this program. Both Naperville and Wood Dale indicate that they devote approximately 1 full day per week to process citations and appear in court. Naperville has one officer responsible, assisted by one technician, while Wood Dale has trained five officers to use the system.

Effectiveness and Cost: Photo enforcement estimated efficacy is 72% (*8*) and estimated cost ranges from $40,000 to $100,000 *(7, 8, 11)*. While there is a wide range in costs depending on site and legal requirements, the figure used for the benefit/cost analysis was $55,000.

Cost Benefit

Calculations for the benefits and costs of equipment upgrades at California public crossings with two or more crashes over the last ten years are shown in Table 1. Five different upgrade combinations are given. Because of the substantially higher costs involved, even at the low end of the cost range, four-quad gates were not included. The multi-crash sites have been grouped in two ways: the first includes only crossings with three or more crashes; the second includes all crossings with two or more crashes (including those in the first group). Costs and savings are totals across all crossings in the group.

TABLE 1 Benefits and Costs To Upgrade California Multi-Crash Crossings

Estimated Cost To Upgrade	2-Quad Gates + Photo	2 Quad Long-Arm Gates	2 Quad Long-Arm Gates + Photo	2-Quad Gates + Median Separator	2-Quad Gates + Median Separator + Photo
Upgrade Sites with 3 to 12 Crashes	$10,230,000	$5,930,000	$10,660,000	$6,704,000	$11,434,000
Upgrade Sites with 2 or More Crashes	$33,610,000	$21,010,000	$34,870,000	$23,278,000	$37,138,000
Estimated Annual Savings					
Upgrade Sites with 3 to 12 Crashes	$13,959,844	$14,459,172	$17,415,505	$15,291,108	$17,591,717
Upgrade Sites with 2 or More Crashes	$28,492,914	$29,460,869	$35,185,348	$31,079,117	$35,531,307
Estimated Benefit/Cost Ratio After 1 year For Sites With 2 Or More Crashes	0.85	1.40	1.01	1.34	0.96

As can be seen in Table 1, the highest benefit/cost ratio is achieved with the use of long-arm gates, followed closely by the addition of a median barrier to standard 2-quad gates. The application of either of these countermeasures to the spectrum of multiple crash sites would—in theory—pay for itself within one year. Photo enforcement performs more poorly, and would not be cost-effective in this short time frame. The addition of photo enforcement to either long-arm gates or medians thus appears to reduce the immediate benefit/cost ratio.

The most useful application of this table is to provide a relative valuation of these countermeasures in comparison with each other, and their possible compounding effects, for use across a large number of crossings. In practice, the choice of most appropriate countermeasure for a given crossing must be driven by a large number of other factors, including amount of train and vehicle traffic, siting, visibility, etc. Other countermeasures not included in the table above–such as 4-quad gates–may be appropriate in certain situations.

The expected benefits shown, and therefore the expected benefit/cost ratio, are idealized in that they are based on the assumption that the 252 sites with multiple crashes over the last ten years would, without equipment upgrades, continue to have crashes at their historic rate over the ensuing years, which, of course, is highly unlikely. Nevertheless, even if the benefits shown by this relatively crude method of choosing sites are substantially overstated, the improvements would pay for themselves in a reasonably short period.

CONCLUSIONS

Strategy

Given the number of competing needs and limited resources for traffic safety improvements, it is important to know what the likely outcomes and costs are for specific countermeasures and for these countermeasures at specific types of locations. It is important for both effective allocation of existing funds and for planning for future improvements. This study offers a strategy for selecting countermeasures by conducting a cost-benefit analysis.

Limitations

Better data are needed for future rail crossing research as well as equipment upgrade site selection. Both the inventory and crash/incident databases used for this study are limited by inaccurate as well as incomplete information (*1*). As an example, highway traffic information for the 7,719 open, at-grade public crossings in California is often out of date with 16% of the vehicular traffic counts dating from the 1970s, 67% from the 1980s, and 17% from the 1990s. Also, of the 593 at-grade public crossing crashes that occurred between 2000 and 2004, 100 had either a crossing number with a location that did not match the information in the rest of the incident report or else the latitude and longitude listed for the crossing in the FRA inventory yielded a location that did not match the rest of the information in the inventory or incident report. The California Public Utility Commission maintains its own incident and inventory database. However, lack of funding has prevented the CPUC from keeping its inventory up to date.

This cost/benefit analysis is restricted to the estimation of costs and benefits associated with changing only large classes of crossings. In selecting appropriate countermeasures for individual crossings, or for identifying which crossings are most likely to benefit from additional treatments, numerous additional factors will have to be taken into account.

Recommendations

Updating the state's rail crossing vehicular and rail traffic is of the utmost importance. Once this task is accomplished, more precise estimates of true costs and benefits can be estimated through the use of more sophisticated methods for choosing sites.

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REFERENCES

1. Federal Railroad Administration Office of Safety Analysis Web Site. Federal Railroad Administration. http://safetydata.fra.dot.gov/officeofsafety/Default.asp. Accessed July 26, 2006.
2. Ritt, D.S., M.E. Goldstein, B.R. James, W.M. Harris, N.K. Adusei, J.E. Bates, H.H. Larson, M.A. Stiglitz, P. Rose, and H. Lambert. *Audit of the Highway-Rail Grade Crossing Safety Program.* Report Number MH-2004-065. Federal Railroad Administration, Federal Highway Administration, Federal Transit Administration, 2004.
3. Lee, D., K. Gay, A. Carroll, A. Hellman and S. Sposato. *Benefit-Cost Evaluation of a Highway-Railroad Intermodal Control System*. U.S. Department of Transportation, Volpe National Transportation Systems Center, 2004.
4. California Highway Patrol. *2003 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions*. California Highway Patrol, 2003.
5. Behrens, M.W. Allocations of State Transportation Resources. Testimony before the Senate Finance Committee and Senate Transportation and Homeland Security Committee, Washington, D.C., 2006.
6. Farr, E. H. *Summary of the DOT Rail-Highway Crossing Resource allocation Procedure – Revised*. U.S. Department of Transportation, 1987
7. Caird, J.K., J.I. Creaser, C.J. Edwards, and R.E. Dewar. *A Human Factors Analysis of Highway-Railway Grade Crossing Accidents in Canada*. Transportation Development Centre Transport Canada, 2002.
8. Federal Railroad Administration. *North Carolina "Sealed Corridor" Phase I.* U.S. DOT Assessment Report: Report to Congress. Federal Railroad Administration, U.S. Department of Transportation, 2001.
9. Federal Railroad Administration, Use of Locomotive Horns at Highway-Rail Grade Crossings: Final Rule, 49 CFR Parts 222 and 229, Federal Register, Vol. 70, No. 80, 2005.
10. Meadow, L. Los Angeles Metro Blue Line Light Rail Safety Issues. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1433,* TRB, National Research Council, Washington, D.C., 1994, pp. 123-133.
11. Carroll, A.A. and J.D. Warren. *Photo Enforcement at Highway–Rail Grade Crossings in the United States, July 2000–July 2001*, Transportation Research Record 1801 Paper No. 02-2517, 2002