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Driver Behavior at Rail Crossings: Cost-Effective Improvements to Increase Driver Safety at Public At-Grade Rail-Highway Crossings in California

Douglas L. Cooper, David R. Ragland

California PATH Research Report
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March 2009

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FINAL REPORT

DRIVER BEHAVIOR AT RAIL CROSSINGS

COST-EFFECTIVE IMPROVEMENTS TO INCREASE DRIVER SAFETY AT PUBLIC AT-GRADE RAIL-HIGHWAY CROSSINGS IN CALIFORNIA

PREPARED FOR

Caltrans

COOPERATIVE AGREEMENT
T.O. 5208

PREPARED BY

DOUGLAS L. COOPER
and
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Traffic Safety Center
Setting New Directions in Traffic Safety

CALIFORNIA PATH

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ABSTRACT

TITLE:
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This report examines driver behavior and conditions affecting vehicle-train collisions at rail crossings in California, and recommends effective countermeasures and implementation strategies. In doing so, the report helps meet California's goal of efficiently utilizing state and federal funding available through SAFETEA-LU for increasing the safety at public at-grade rail-highway crossings

KEYWORDS: automobile drivers; psychology; highway-railroad grade crossings; safety measures.

1. EXECUTIVE SUMMARY

In 1994, the U.S. Department of Transportation prepared a new national rail-highway crossing safety action plan. The plan succeeded in decreasing vehicle-train collisions, and over the last ten years the number of national crossing incidents fell 35 percent, while in California they decreased 23 percent. These decreases were due to a combination of railroad crossing closures, upgrading of warning devices, and the efforts of grassroots organizations such as Operation Lifesaver. However, despite decreasing numbers, crash counts remain undesirably high and ongoing efforts to improve rail crossing safety are a priority.

This report examines conditions affecting vehicle-train collisions at rail crossings in California, and recommends effective countermeasures and implementation strategies. In doing so, the report helps meet California's goal of efficiently utilizing state and federal funding available through SAFETEA-LU for increasing the safety at public at-grade rail-highway crossings.

At the present time there are 7,719 public at-grade rail-highway crossings in California. During the 5-year period from 2000 to 2004, there were 593 train-vehicle crashes at these crossings. While the majority of crossings with collisions had only one crash (72%) a significant number of crossings (28%) had multiple collisions, ranging from two to 12 in number. The crashes resulted in a total of 99 deaths and 205 injuries.

The 593 crashes exhibited a number of 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 into 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. Although the end-result of a collision is a relatively rare event, the behavior is widespread. Depending on the location, it appears that between 20% and 60% of drivers who are in the position to 'run' descending gates do so. The group of drivers who are not deterred by lowered gates are primarily male and mostly under 40 years old, which is the same profile seen for other risky driving behaviors. However, given the high proportion of drivers engaging in the behavior, it is clearly not limited to any one demographic segment.

Among this group of drivers, active warning signals such as descending gates and flashing lights do not cue the driver to stop. Rather, the active warning systems merely act as a signal that a decision must be made, and the driver uses his/her own judgment of train location and speed to decide whether or not to yield to the train. For those people, the 'problem' is determining the speed and proximity of the train, rather than establishing its presence. However, the interplay of perception, expectation, and human information processing that is required can easily lead to failures in judgment.

It has been shown that people's ability to accurately judge the speed and distance of an oncoming train is quite limited. In general, it is much more difficult to determine the speed of an object approaching the viewer than for an object traveling across the field of vision. Additionally, the *Leibowitz hypothesis* suggests that drivers underestimate the speed of trains because human vision underestimates the speed of large objects, such as locomotives.

Additionally, other disruptive factors—such as poor visibility, 'noisy' signage, or in-car distractions—may impede the driver's ability to make a sound judgment. Signal detection theory tells us that the decision to proceed or stop at a rail crossing is based on our ability to separate a meaningful signal from background noise. While measures exist that could further increase the conspicuity of trains (the 'signal') or decrease the background noise, these measures might actually encourage gate running by increasing driver confidence in his/her ability to judge train speed and distance. Given the physiological limitations that virtually preclude the driver from accurately judging the time remaining before an approaching train reaches the crossing, there appears to be no purpose served by giving the driver this additional information.

The best solution to rail crossing crashes is to remove the need for the driver to engage in a potentially faulty decision-making process by making it impossible, or at least very difficult, for the driver to bypass lowered gates. There are two low-technology, low-cost, low-maintenance methods that, while not 100% effective, have been deployed in many locations and shown to prevent deaths and injuries while remaining economically feasible. These are long-arm gates and median separators. Adding either long-arm gates or median separators has been estimated to have reduced collisions by 75%, compared to standard flashing lights and gates. The cost of long-arm gates is approximately $5,000 per crossing, but long-arm gates may not be appropriate in locations with significant truck or bus traffic, wide crossings, multiple rails, or high winds. Medians have a cost of $14,000 per crossing, and may be suitable for different locations than long-arm gates.

Where these technologies cannot be deployed, photo enforcement should also be considered as an option. Although the consequences of getting a traffic ticket are far less severe than being hit by a train, studies have shown that the threat of a traffic violation ticket is as effective in changing driver behavior as long-arm gates or medians. However, the cost for installation of cameras can be quite high.

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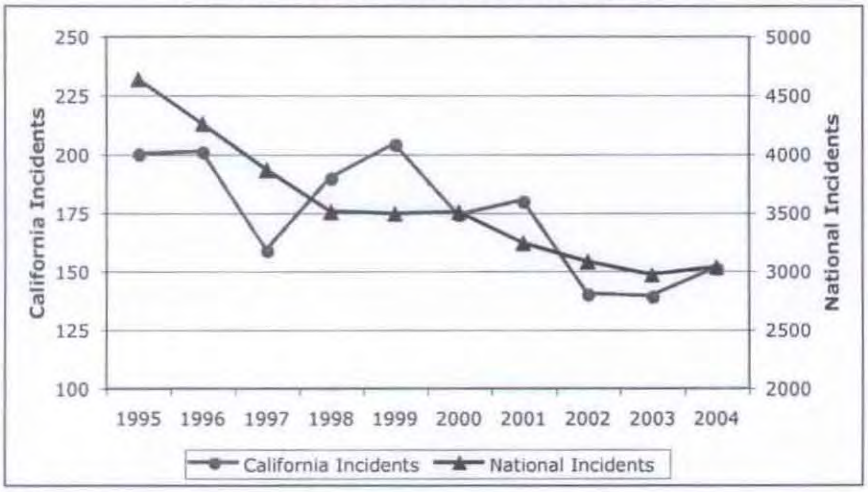
1. INTRODUCTION

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. Over the last ten years, the results of this plan can be seen as the number of grade crossing incidents has fallen 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 incidents has decreased 23 percent, from 201 to 154 (Figure 1).

For the most part, the progress achieved under the 1994 Action Plan is attributable to the closures of 41,070 public and private grade crossings, upgrades at 3,985 public crossings with a high probability for incidents with active warning devices, such as automatic gates, flashing lights, and highway traffic signals. The progress was also bolstered by annual education campaigns by Operation Lifesaver, a non-profit, international continuing public education program established to end collisions, deaths and injuries at places where roadways cross train tracks (Federal Railroad Administration (FRA, 2004).

Figure 1

TEN YEAR U.S. AND CALIFORNIA RAIL-HIGHWAY CROSSING INCIDENTS



SOURCE: FRA

While there is little doubt that upgrading crossings from passive to active significantly decreases the number of rail crossing incidents, a 2004 Federal Railroad Administration (FRA) report found that incidents continued to occur at public grade crossings equipped with active warning devices. In California, for the five-year period 2000 to 2004, 508 or 85.7 percent of the public at-grade crossing incidents occurred at crossings already equipped with automatic or active warning devices. Of these incidents, 434 occurred at public crossings with automatic gates, 69 had flashing lights, and 5 were equipped with wig-wags.

There are over 250,000 public and private at-grade highway-rail crossings in the United States which provided the backdrop for 3,026 reportable incidents in 2004 resulting in 368 deaths and 1,077 injuries in 2004. California's 12,784 at-grade crossings had 154 incidents in that same year with 34 deaths and 53 injuries.

The focus of this report will be California's 7,719 public at-grade crossings. During the five year from 2000 to 2004, there were a total of 593 crashes between trains and motorized vehicles at these crossings that resulted in 99 deaths and 205 injuries.

There are three primary sections of the California Vehicle Code that deal with motor vehicles at railway crossings:

PRIMA FACIE SPEED LIMITS

22352. (a) The prima facie limits are as follows and shall be applicable unless changed as authorized in this code and, if so changed, only when signs have been erected giving notice thereof:

(1) Fifteen miles per hour:

(A) When traversing a railway grade crossing, if during the last 100 feet of the approach to the crossing the driver does not have a clear and unobstructed view of the crossing and of any traffic on the railway for a distance of 400 feet in both directions along the railway. This subdivision does not apply in the case of any railway grade crossing where a human flagman is on duty or a clearly visible electrical or mechanical railway crossing signal device is installed but does not then indicate the immediate approach of a railway train or car.

RAILROAD OR RAIL TRANSIT GRADE CROSSINGS

22451.(a) The driver of any vehicle or pedestrian approaching a railroad or rail transit grade crossing shall stop not less than 15 feet from the nearest rail and shall not proceed until he or she can do so safely, whenever the following conditions exist:

(1) A clearly visible electric or mechanical signal device or a flagman gives warning of the approach or passage of a train or car.

(2) An approaching train or [rail] car is plainly visible or is emitting an audible signal and, by reason of its speed or nearness, is an immediate hazard.

(b) No driver or pedestrian shall proceed through, around, or under any railroad or rail transit crossing gate while the gate is closed.

PARKING UPON OR NEAR RAILROAD TRACK

22521. No person shall park a vehicle upon any railroad track or within 7 1/2 feet of the nearest rail.

2. BACKGROUND

Rail crossings provide different levels of warnings and/or barriers to alert drivers to the potential dangers presented by the at-grade crossing. These protective devices range from four-quadrant gates with medians to mere stop signs or crossbucks. Since some type of warning device is always present, crashes are caused either by people violating the signs/signals/gates or people not perceiving or mis-perceiving an approaching train's distance and speed.

In a 1999 study, Carlson and Fitzpatrick found that 60 percent of drivers at 19 sites in Texas equipped with lights and gates, crossed the track between the time the lights activated and two seconds after gate arms began to descend. In addition, violations occurring after the arms had been in motion more than 2 seconds and until the arms were horizontal, occurred during one-third of the gate-activations. Similarly, a 2004 FRA report found that accidents continued to occur at public grade crossings equipped with active warning devices. For the period 1994 to 2003, 51 percent of the public grade crossing accidents occurred at crossings already equipped with automatic or active warning devices[1] (FRA, 2004).

There is research to suggest that certain types of drivers may be more likely to ignore and violate such protective systems. Survey results of 891 randomly selected residents in Michigan found that the stronger a person's sensation seeking tendencies, the more likely they are to inflate their ability to judge train distance, train speed, and the ease with which they can get their car over the tracks before a train arrives. Additionally, the stronger the sensation seeking tendencies, the more likely people are to experience frustration while having to wait for a train, which appears to independently influence the judgment processes. Thus, the greater one's frustration, the more likely he or she is to make biased judgments which, in turn, can increase risky driving behavior (Witte and Donohue, 2000).

A study based on the reports from 85 consecutive fatal crashes involving motor vehicles and trains at all types of railway crossings in Victoria, Australia, on the other hand, concluded that, "...in most cases, the accident occurred to a law-abiding citizen going about his or her daily work and was attributable to human overload unrelated to any breach of regulation." Additionally, at least 86% of those killed were persons who lived locally and were therefore familiar with the existence of this crossing (Wigglesworth, 1979).

An important finding in a study by Meeker and Barr (1989) was that two thirds of the 57 drivers who approached a rural rail grade crossing in the presence of activated warning flashers crossed the tracks despite the warnings and the approaching train. This would appear to indicate that crossing an activated warning device is a widespread activity not limited to a small proportion of drivers. Clearly, the activated devices in their observations were *not* commonly perceived as a signal that the risk was too great and that the driver should not cross. Rather, the results are consistent with the view of Leibowitz (1985), who suggested that "active" warning systems merely cue drivers as to the need to make a decision whether or not to cross.

Meeker and Barr (1989) go on to say that "...it is not entirely satisfactory to conclude that two thirds of all drivers in our sample were engaging in life-threatening behavior when they decided to cross. One might argue that pedestrians regularly cross busy thoroughfares with a much smaller safety margin than the margin that drivers we observed allowed themselves."

Drivers crossing around barrier gates tended to stop or slow on approach significantly less than those crossing with flashers only. It was suggested that the gates themselves provided an impediment to crossing which forced drivers inclined to cross into making a hurried and sometimes perilous decision. Their behavior was seen as explaining the surprisingly high number of accidents that occur at barrier-gate crossings. Perhaps the only way that drivers at these

[1] Although no information is readily available on the role of warning equipment malfunctions in these incidents, a New York Times article from December 30, 2004, stated that a "computer analysis of government records found that from 1999 through 2003, there were at least 400 grade-crossing accidents in which signals either did not activate or were alleged to have malfunctioned...Proving that a signal malfunctioned can be difficult. In the more than 400 accidents in the Times analysis, 30 percent of the signal problems were listed as confirmed." This works out to 2.5% alleged and 0.7% confirmed.

barrier-gate crossings can achieve an acceptable safety margin is to make the decision to proceed through the crossing without stopping or slowing their vehicles early on. The fact that a substantial number of accidents tend to occur at these crossings is not surprising given this behavior. (Meeker et al., 1997)

A common driver error is misjudgment of the time remaining until the train arrives at the crossing (i.e., train speed and distance). Speed estimation can be influenced by a number of factors, including driving experience, visual cues available, light conditions, the presence of visual information in the background, and adaptation to previously encountered train speed levels (Dewar and Olson 2002). Additionally there are two perceptual problems associated with rail crossing decisions. First, humans have difficulty judging the approach speed of a vehicle when it is seen nearly head on, as their only indication of speed is the rate of change in the size of the object. Second, Leibowitz (1985) noted that there is the illusion that large object appear to move more slowly than small ones which are actually traveling at the same speed.

To assist the state of California in efficient utilization of state and federal funding available through SAFETEA-LU for increasing the safety at public at-grade rail-highway crossings, the results of this project aim to recommend effective countermeasures and an implementation strategy such that drivers are provided a sufficient level of warning and are motivated to comply with cues. This report first presents five and ten year crash data for California to assess the magnitude of the problem as well as driver and crossing factors that may be associated with vehicle-train collisions. This is followed by a discussion of various crossing warning equipment upgrades and a cost-benefit analysis of the most appropriate countermeasures for use in high-collision areas. Finally, a conceptual model of why drivers may make poor judgments at crossings is presented followed by a section on crossing observations at three locations.

3. FIVE AND TEN YEAR CALIFORNIA CRASH DATA

3.1. DESCRIPTION OF DATA SOURCES

The statistics used in this section were obtained from the FRA Office of Safety Analysis Web Site (http://safetydata.fra.dot.gov/officeofsafety/Default.asp – see Appendix C) 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 accidents and incidents, 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. The data are organized into the following nine categories (the complete list of headings and sub-headings can be seen in Appendix F):

1. Overview
2. Query Accident/Incident Trends
3. Train Accidents
4. Casualties
5. Highway-Rail Crossing Accidents
6. FRA Inspections
7. Downloads
8. Highway-Rail Crossing Inventory
9. FRA Safety Reporting

While these sources provide the best available and most complete information on railroad-related issues, there are a number of significant problems that undermine the reliability of the data. As noted in a number of reports (e.g., FRA, 2004, U.S. Government Accountability Office, 1996), both the inventory and accident/incident databases contain inaccurate as well as incomplete information. 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. Among the 593 public at-grade crashes that occurred between 2000 and 2004 examined for this report, 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. As noted by the FRA (2004), its Inventory Data File, a record of grade crossing location, physical, and operational characteristics, is dependent on voluntary state reporting.

Unlike aircraft accidents, which are investigated by the National Transportation Safety Board (NTSB) or the Federal Aviation Administration (FAA) unless only minor injury or property damage is involved, the FRA depends on the railroad involved in the incident to submit the report (the exceptions being if there are multiple deaths or a great deal of publicity). As will be seen later in this section, this leads to a general dearth of detailed information. Quoting from the FRA's Railroad Safety Statistics 2004 Annual Report:

> The completeness and accuracy of the information presented in this bulletin are primarily dependent upon the data collection and reporting processes of the nation's railroads. The FRA conducts routine audits of these procedures, but does not have sufficient resources to perform comprehensive reviews of each railroad's reporting procedures. We extensively review and edit the reports we receive and make inquiry when information is incomplete or inconsistent.

It is not possible to identify reportable events that were omitted from a railroad's submission. Likewise, there may be instances where incorrectly reported information passes all reviews and is accepted. Although we attempt to be as vigilant as possible in both the editing and presentation of the accident/incident data reported, errors do occasionally occur.

The California Public Utility Commission maintains its own incident and inventory database. Lack of funding has prevented the CPUC from keeping its inventory up to date, although some crossing information is more recent than that of the FRA database. The CPUC database was especially useful for analyzing the angle at which the highway crossed the railroad tracks for the crashes under review. The last time the CPUC issued its "Annual Report of Railroad Accidents Occurring in California" was 1999.

3.2. METHODS

Raw data for California was downloaded from the FRA site and categorized by vehicular and crossing factors. When possible, data was compared to information from other sources such as the CPUC. Because of the previously noted problems with the FRA data inventory, there was no way to insure that the crossing number listed in the accident report was actually where the crash occurred. Therefore, warning equipment at the crash site information was taken from the accident report rather than from the crossing inventory database.

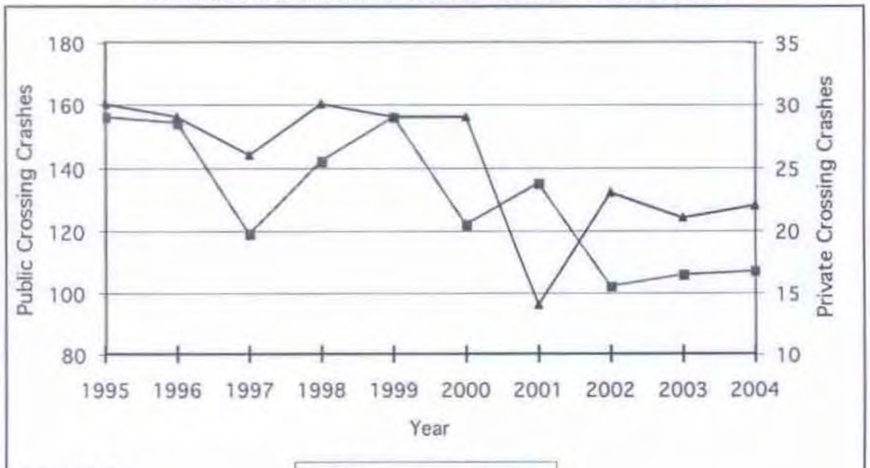
3.3. RESULTS

3.3.1. CALIFORNIA AND THE U.S.

FRA data show that rail accidents increased 14% from 2002 to 2004 (Figure 2 on page 7) and while many states have seen a decrease in rail related accidents, California is one of six states (along with Texas, Illinois, Indiana, Ohio, and

Figure 2

CALIFORNIA MOTOR VEHICLE/TRAIN CRASHES AT RAIL-HIGHWAY CROSSINGS 1995-2004



SOURCE: FRA

Table 1

CALIFORNIA PUBLIC AT-GRADE CROSSING WARNING EQUIPMENT (2005)[1]

Traffic Control Device Type	Number	Percentage
No Signs or Signals	172	2.2%
Other Signs or Signals	17	0.2%
Crossbucks	2805	36.3%
Stop Signs	307	4.0%
Special Signs or Warning	42	0.5%
Hwy Traffic Sig, Wigwags, or other Activated	270	3.5%
Flashing Lights	982	12.7%
All Other Gates	3124	40.5%
4 Quad	0	0.0%
Total Public At Grade	7719	100%

[1] The devices listed are the highest level of warning at a particular crossing.

SOURCE: FRA

Table 2

WARNING EQUIPMENT FOR CALIFORNIA PUBLIC CROSSINGS WITH CRASHES 2000-2004[1]

Control Device	# Train/Vehicle Crashes	Percentage of All Train/Vehicle Crashes	# Train/Pedestrian Crashes	Percentage of All Train/Pedestrian Crashes
Gates	434	73.2%	78	95.1%
Cantilever Flashing Lights	23	3.9%	0	0.0%
Std Flashing Lights	46	7.8%	4[2]	4.9%
Wig Wags	5	0.8%	0	0.0%
Hwy Traffic Sig	2	0.3%	0	0.0%
Audible	2	0.3%	0	0.0%
Cross Bucks	57	9.6%	0	0.0%
Stop Signs	20	3.4%	0	0.0%
Watchman	0	0%	0	0.0%
Flagged by Crew	0	0%	0	0.0%
Other	1	0.2%	0	0.0%
None	3	0.5%	0	0.0%
Total	593	100%	82	100%

[1] The devices listed are the highest level of warning at a particular crossing. Thus a crossing with gates and flashing lights would be listed only under the "Gates" category.

[2] The type of flashing lights was not given so all four crashes were arbitrarily placed in this category.

SOURCE: FRA

Table 3

ACTION AND POSITION OF MOTORIST AT GATED CROSSING CRASHES IN CALIFORNIA (2000-2004)

Driver Action/Driver Position	Action	Action Percentage	Position	Position Percentage
Drove Around Or Through Gates/	159	36.7%		
Moving Over Crossing			159	36.7%
Vehicle Stopped And Then Proceeded/	15	3.5%		
Moving Over Crossing			15	3.5%
Failed To Stop/	40	9.2%		
Moving Over Crossing			40	9.2%
Stopped On Crossing/	130	30.0%		
Stalled			29	6.7%
Stopped			87	20.0%
Trapped			14	3.2%
Other/	90	20.7%		
Stalled			19	4.4%
Stopped			57	13.1%
Moving Over Crossing			9	2.1%
Trapped			5	1.2%
Total	434	100.0%	434	100.0%

SOURCE: FRA

Table 4

FIVE YEAR CALIFORNIA PUBLIC HIGHWAY-RAIL AT-GRADE CROSSING STATISTICS 2000-2004

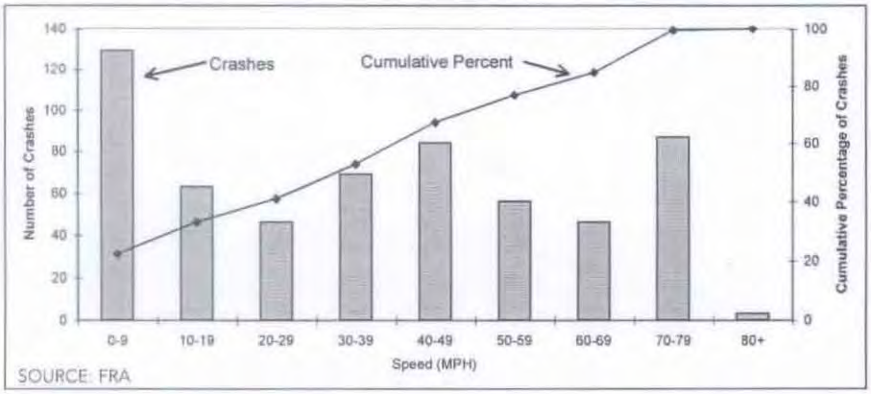
	2000	2001	2002	2003	2004	Total	% of Total	2000 Killed	Injured	2001 Killed	Injured	2002 Killed	Injured	2003 Killed	Injured	2004 Killed	Injured	Total Killed	Total Injured
Drove Behind Or In Front Of Passing Train, And Struck By Second Train	2	6	9	6	8	31		0	0	6	3	4	6	1	0	2	2	13	11
Passed Standing Vehicle	9	20	5	8	13	55		3	8	9	7	3	1	1	1	3	3	19	20
Train Hit Car	106	107	86	85	85	469	79.1%	11	32	28	25	14	26	18	45	14	30	85	158
Car Hit Train	20	34	19	24	27	124	20.9%	1	5	3	15	6	10	1	7	3	10	14	47
Total	**126**	**141**	**105**	**109**	**112**	**593**		**12**	**37**	**31**	**40**	**20**	**36**	**19**	**52**	**17**	**40**	**99**	**205**
Vehicle Stalled On Crossing	12	13	15	6	7	53	8.9%	1	4	0	2	0	3	0	0	0	2	1	11
Stopped On Crossing	37	27	31	38	36	169	28.5%	0	8	0	2	5	9	6	6	2	8	13	33
Moving Over Crossing	70	95	57	62	67	351	59.2%	10	24	31	35	15	24	12	46	15	29	83	158
Vehicle Trapped On Crossing	7	6	2	3	2	20	3.4%	1	1	0	1	0	0	1	0	0	1	2	3
Tot al	**126**	**141**	**105**	**109**	**112**	**593**	**100**	**12**	**37**	**31**	**40**	**20**	**36**	**19**	**52**	**17**	**40**	**99**	**205**
Drove Around Or Through Gates	32	39	26	27	35	159	26.8%	7	16	16	14	10	13	8	34	12	16	53	93
Vehicle Stopped And Then Proceeded	7	9	5	11	4	36	6.1%	1	2	9	4	1	0	1	2	0	2	12	10
Failed To Stop	29	42	24	26	28	149	25.1%	2	6	6	15	4	10	3	12	3	11	18	54
Stopped On Crossing	31	27	25	38	31	152	25.6%	1	6	0	5	5	8	6	4	2	8	14	31
Other	27	24	25	7	14	97	16.4%	1	7	0	2	0	5	1	0	0	3	2	17
Total	**126**	**141**	**105**	**109**	**112**	**593**		**12**	**37**	**31**	**40**	**20**	**36**	**19**	**52**	**17**	**40**	**99**	**205**
Crossings With Gates	95	99	77	80	83	434	73.2%	12	31	19	26	17	29	16	46	14	31	78	163

Note: Killed and Injured includes highway users, railroad employees, and railroad passengers

SOURCE: FRA

Figure 3

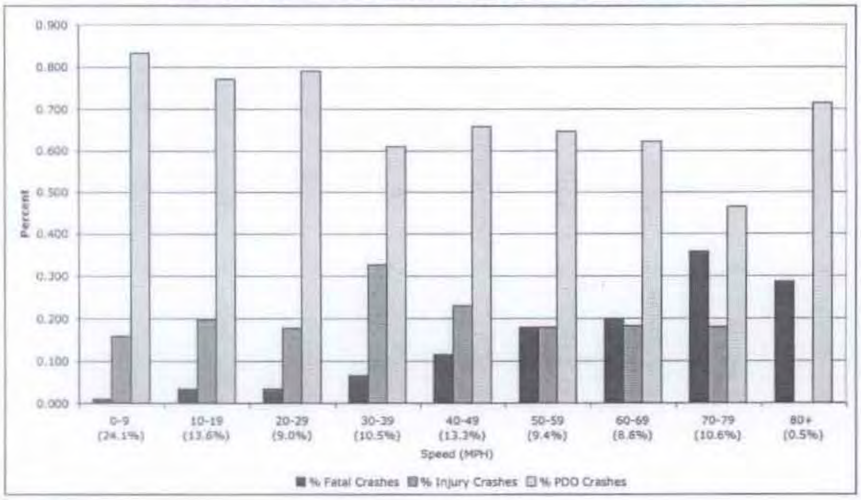
SPEED OF TRAINS INVOLVED IN CRASHES AT PUBLIC CROSSINGS IN CALIFORNIA (2000-2004)



SOURCE: FRA

Figure 4

CRASH SEVERITY BY TRAIN SPEED AT PUBLIC CROSSINGS IN CALIFORNIA (2000-2004)



SOURCE: FRA

Louisiana) that continue to rank as the worst in rail safety based on the **raw** number of accidents and fatalities at public grade crossings. Together, these six states account for 37% of the nation's reported public grade crossing accidents. By taking exposure (based on the number of public at-grade rail crossings in each state) into account, however, California's ranking improve from fourth worst to 22nd for total collisions and from second to seventh in fatalities.

3.3.2. CRASH CHARACTERISTICS: EQUIPMENT

At the present time there are 7,719 public at-grade crossings in California of which 43% are passive and 57% are active (Table 1). Most of the active crossings (71%) are equipped with gates and flashing lights. Equipment at public crossings where train-vehicle crashes occurred during 2000 through 2004 is shown in Table 2. Perhaps the most significant statistic from this table is that 434 crashes (73%) occurred at crossings equipped with gates, which would seem to indicate that, for some drivers, standard two-quadrant gates are not a deterrent.

3.3.3. CRASH CHARACTERISTICS: DRIVER BEHAVIOR

In California during the five years 2000 - 2004, there were 789 rail-highway crossing crashes, of which 675 were at public crossings. Eighty-two of the crashes involved pedestrians, leaving 593 train-vehicle crashes at public highway-rail crossings. Table 4 on page 9 shows these crashes broken out by year as well as type, and includes the number of people killed or injured. Three noteworthy statistics from this table are:

- 20.9% involved a vehicle running into a train.
- 59.2% involved vehicles that were moving over the crossing.
- 26.8% involved vehicles that had driven around or through lowered gates.

Of special interest are the 434 crashes that occurred at crossings equipped with gates. The motorist's actions prior to the crash and vehicle positions for each action at the time of the crash are shown in Table 3.

The crash records in the FRA database are often lacking in detail (See example record in Appendix C). While there is a narrative section that should describe the circumstances of the crash, this section appears to be constructed from checked boxes or short statements recorded elsewhere in the record. This makes interpreting the data difficult. For example, in Table 3 there are 40 crashes involving a vehicle that failed to stop and was hit as it moved over the crossing. Given that these are all gated crossings and that the gates must be down at least five seconds before the train arrives, how could these vehicles not have gone around or through the gates before being struck? The narratives shed no light on this question.

3.3.4. CRASH CHARACTERISTICS: TRAIN SPEED

Figure 3 shows the cumulative distribution of train speeds for the 593 train-vehicle crashes at public rail-highway crossings. The bars shows the actual number of crashes for each 10 MPH category, while the line shows the cumulative percentage of crashes at that speed or slower. As an example, 63 crashes occurred with trains traveling between ten and 19 MPH and nearly 33% of the total (192 out of 593) crashes involved trains moving at less than 20 MPH.

In Figure 4, the relationship between train speed and crash severity is shown. Within each speed grouping, the percentages for all three crash types sum to 100%. Thus, for example, for those crashes that occur with a train speed between 40 and 49 MPH (13.3% of all crashes), 65.7% are Property Damage Only (PDO), 22.9% involve injuries, and 11.4% involve fatalities. The injury and fatality categories are mutually exclusive in that a crash that has both injuries and at least one fatality is counted as a fatal crash. As can be seen, train speed plays a role in the number of fatalities.

Table 5

AGE AND GENDER OF DRIVERS INVOLVED IN CRASHES AT PUBLIC CROSSINGS IN CALIFORNIA (2000-2004)

Age Group	Number	% of Total	Male	% of Age Group	Female	% of Age Group
20 and younger	27	6.9%	20	74.1%	7	25.9%
21-25	36	9.2%	27	75.0%	9	25.0%
26-30	69	17.6%	62	89.9%	7	10.1%
31-35	55	14.0%	38	69.1%	17	30.9%
36-40	45	11.5%	33	73.3%	12	26.7%
41-45	35	8.9%	25	71.4%	10	28.6%
46-50	30	7.6%	24	80.0%	6	20.0%
51-55	27	6.9%	19	70.4%	7	25.9%
56-60	15	3.8%	9	60.0%	6	40.0%
61-65	19	4.8%	16	84.2%	3	15.8%
66-70	9	2.3%	7	77.8%	2	22.2%
71-75	8	2.0%	3	37.5%	5	62.5%
76 and Older	18	4.6%	11	61.1%	7	38.9%
Total	393[1]	100%	294[2]	74.8%	98[2]	25.2%

[1] 200 crossing crash records did not have drivers age
[2] One of the 393 crash records with driver age did not have driver gender

SOURCE: FRA

Table 6

CALIFORNIA MOTOR VEHICLE/TRAIN CRASH COUNTS PER PUBLIC CROSSING 1995-2004

Number of Crashes At Crossing	Number of Crossings
1	657
2	167
3	51
4	25
5	6
6	1
7	1
8	0
9	0
10	1
11	1
12	1
10 Year Total	911

SOURCE: FRA

3.3.5. CRASH CHARACTERISTICS: DRIVER AGE AND GENDER

Male drivers are over-represented in all but one of the 13 age categories shown in Table 5, with an overall average of nearly 75%.

3.3.6. CRASH CHARACTERISTICS: MULTIPLE CRASH SITES

Table 6 shows that most crashes (72%) occurred at sites with only one crash during the ten year period 1995-2004. The other 28% occurred at sites with 2 to 12 crashes. Table 7 is a listing of crossings with four or more crashes during this period, and includes information on the crash dates, crossing equipment, Average Annual Daily Traffic (AADT), collection year for AADT, average daily train counts, the angle at which the road and track intersect, the sightlines at each of the four corners of the intersection, and the crossing location. Of the 36 crossings listed, 25 had gates installed at the time the crashes occurred.

3.3.7. CRASH CHARACTERISTICS: CROSSING ANGLE

It is plausible that crossing angle could play a significant role in crossing crashes, perhaps because this could require the driver to look back over his/her shoulder. To examine this hypothesis, crash records were examined for information on crossing angle. For the 5-year period 2000-2004, 508 of the 593 train-vehicle crashes had records that included crossing angle information. Table 8 describes the number of crashes in each ten degree crossing angle group. Column 1 describes the angle at which the road crosses the tracks, grouped into ten degree categories. Columns 2 and 3 list the total number and percentage of public railroad crossings in California in each crossing angle category, regardless of whether crashes occurred at the site or not. The data for Column 2 was taken from the CPUC Crossing Inventory database. Columns 4 and 5 present the total number and percentage of vehicle-rail crashes for each angle category. Columns 6 and 7 present the number and percentage of unique railroad crossings at which at least one crash occurred. In these two columns, only unique crossings are counted, regardless of the number of crashes that occurred at the site. Column 8 describes the percentage of all public California crossings in each angle category that had any crashes occur (Column 6 divided by Column 2).

A quick scan of the percentages in Columns 3, 5 and 7 shows that the distribution of total crashes and of unique crash sites both conform fairly closely to the distribution of all California crossings. Column 8 confirms that there does not appear to be any trend in crossing angle and crash rate. Overall, 6.6% of California crossings experienced a crash, and no single angle category deviates largely from this percentage.

It would appear, then, that crossing angle is unlikely to play a large role in vehicle-train crashes. This was confirmed by the use of chi-square tests on the crash data, which indicated no significant differences. However, these tests rely on an assumption of uniform vehicle exposure to crossing angles, that is, each angle category receives a proportionate amount of traffic.

Table 7

CALIFORNIA PUBLIC CROSSINGS WITH FOUR OR MORE CRASHES 1995-2004

Fed ID	# Crashes 1995-2004	Crash Dates	Crossing Equipment[1]	AADT	AADT Year & Source	Train Count Source & Year	Xing Angle	Views[2]	City	County
028688J	12	1/95, 6/98, 9/99, 1/00, 12/00, 12/00, 12/00, 3/01, 11/01, 1/02, 11/02, 11/04	12-G	9,500	PUC 2005	53	60	BBGG	Merced	Merced
027656A	11	10/96, 11/98, 9/99, 9/99, 2/00, 11/00, 12/00, 4/01, 5/01, 3/02, 9/03	11-G	30,900	FRA 1991	104 FRA 44 PUC 2000	50	RGFF	Santa Fe Springs	Los Angeles
765937U	10	8/95, 3/98, 3/99, 3/99, 10/99, 2/01, 8/01, 11/01, 1/02, 12/04	10-G	1,000	PUC NO DATE	20 FRA 12 PUC 2000	45	GGGG	Unincorporated	Merced
026517B	7	1/97, 11/01, 12/02, 12/03, 8/04, 11/04, 12/04	7-G	15,400	FRA 1989	77 PUC 2004	30	OROR	Unincorporated	Riverside
028553D	6	10/96, 10/96, 12/00, 3/01, 11/01, 2/02	6-G	8,023	City 2004	51 PUC 2005	80	OOFO	Fresno	Fresno
026572B	5	1/95, 8/97, 12/97, 9/01, 10/04	5-G	15,900	PUC 2001	81 PUC 2005	19	OpOOO	Anaheim	Orange
027650J	5	11/96, 5/98, 12/03, 12/03, 9/04	5-G s	12,000	1987 FRA	105 FRA	30		Santa Fe Springs	Los Angeles
028527N	5	1/95, 2/00, 8/02, 4/04, 5/04	FL	1,500	1990 FRA	53 PUC 2005	90	OOOO	Fresno	Fresno
745911M	5	8/95, 1/97, 8/00, 5/02, 3/04	5-G	21,600	1989 FRA	38 PUC 2000	90	OGOG	Simi Valley	Ventura
745997Y	5	6/96, 12/98, 5/99, 11/01, 11/02	5-G	21,000	2003 PUC	42 PUC 2003	80	OOOO	Van Nuys	Los Angeles
750703W	5	10/98, 12/98, 2/99, 2/02, 6/03	FL	2,742	1988 FRA	29 FRA	90	GGOO	Selma	Fresno
026476Y	4	05/96, 11/96, 01/00, 09/00	4-G	11,549	City 2003	105 PUC 2004	55	OOOO	Riverside	Riverside
026560G	4	11/95, 02/96, 02/98, 12/04	4-G	44,700	FRA 1991	93 PUC	90	OGCF	Anaheim	Orange
027657G	4	12/96, 12/99, 12/01, 10/04	4-G	30,000	PUC 2002	52 PUC 2002	55	GGGF	La Mirada	Los Angeles
028380R	4	01/95, 07/95, 06/02, 05/03	4-FL	1,450	PUC 2003	61 PUC 2005	45	GGGG	Shafter	Kern
028394Y	4	01/97, 04/97, 12/01, 03/02	4-FL	195	PUC 2003	61 PUC 2005	45	OOOO	Shafter	Kern
028517H	4	11/98, 08/99, 11/99, 10/03	4-FL	2,500	FRA 1990	53 PUC 2005	90	RPPF	Fresno	Fresno
028582N	4	03/99, 07/02, 03/03, 11/04	4-G	13,000	FRA 1970	45 FRA	40		Fresno	Fresno
028586R	4	04/95, 08/96, 07/98, 02/00	4-G	35,000	FRA 1990	39 FRA	45		Fresno	Fresno
745904C	4	02/97, 03/00, 05/00, 11/03	4-G	5000 4000	PUC 2004 FRA 1989	26 PUC 1999	45	OOO	Moorpark	Ventura
746052E	4	09/96, 10/96, 01/99, 03/02	4-G	24600 13300	PUC 2003 FRA 1997	32 PUC 2000	90	RCCC	Los Angeles	Los Angeles
746804B	4	04/93, 09/95, 10/98, 01/03	4-G	2,349	PUC 2001	91 PUC 2000	70	OpCCC	Glendale	Los Angeles
746903Y	4	08/95, 09/96, 10/02, 08/04	4-G	16,000	FRA 1987	32 PUC 2004	90	OpOOpO	Industry	Los Angeles
746919V	4	10/96, 07/97, 07/97, 12/99	4-G	12,076	PUC 2000	23 PUC 2003	90	OpROpR	Pomona	Los Angeles
746972G	4	02/98, 08/99, 09/00, 11/01	3-FL 1-G	5,200	FRA 1991	42 FRA	90	OOOO	Fontana	San Bernardino
749946C	4	05/95, 09/95, 11/99, 07/01	4-Xbucks	1,500	FRA 1991	10 FRA	80	FGGG	Newark	Alameda
752760S	4	02/96, 02/99, 04/01, 09/01	4-G	2,800	FRA 1988	12 PUC 2004	70	GGGG	Sacramento	Sacramento
757186J	4	10/98, 01/99, 01/99, 02/99	1-Fl 3-G	5,239	PUC 2000	18 PUC 1999	45	GGOO	Malaga	Fresno
757255P	4	12/97, 12/97, 01/98, 12/04	4-G	720	FRA 1991	44 PUC 2000	26	GGGG	Monolith	Kern
757316D	4	11/97, 09/98, 08/01, 01/03	4-G	37,372	PUC 2001	35 PUC 2001	48	GGGG	Fresno	Fresno
760732J	4	10/98, 02/03, 07/03, 02/04	4-G	8,573	PUC 2001	43 PUC 2004	90	OpRROp	Mecca	Riverside
761540V	4	12/97, 05/01, 03/04, 06/04	4-Stop	100	FRA 1988	74 FRA			Long Beach	Los Angeles
810913D	4	06/95, 10/99, 03/01, 04/02	4-G	19,515	PUC 2004	45 PUC 2004	70	RRRR	Ontario	San Bernardino
833921K	4	05/01, 06/01, 06/01, 11/01	4-G	3,600	FRA1991	13 FRA	90	PPGP	French Camp	San Joaquin
865221S	4	11/97, 01/98, 02/98, 03/98	FL	10,300	FRA 1986	6 FRA	90	GGGG	Modesto	Stanislaus

[1] Entries in this column are in the form: Number of Crashes-Equipment. FL-Flashing Lights, G-Gates, Stop-Stop sign
[2] G-Good, F-Fair, R-Restricted, O-Obstructed, B-Bad, Op-Open, C-Clear, P-Poor

SOURCE:

Table 8

CALIFORNIA PUBLIC CROSSING ANGLE DATA

1	2	3	4	5	6	7	8
Crossing Angle	# of CA crossings at this angle *	% of crossings in CA at this angle*	Total # of crashes at this angle	% of total crashes at this angle	# of unique crossings with one or more crashes	% of unique crossings with one or more crashes	% of public CA crossings at this angle that had one or more crashes
81-90°	3284	*54.7%*	261	*51.4%*	214	*54.2%*	6.5%
71-80°	803	*13.4%*	58	*11.4%*	46	*11.6%*	5.7%
61-70°	331	*5.5%*	34	*6.7%*	28	*7.1%*	8.5%
51-60°	503	*8.4%*	54	*10.6%*	40	*10.1%*	8.0%
41-50°	667	*11.1%*	64	*12.6%*	41	*10.4%*	6.1%
31-40°	86	*1.4%*	5	*1.0%*	4	*1.0%*	4.7%
<=30°	325	*5.4%*	32	*6.3%*	22	*5.6%*	6.8%
Totals	5999	*100.0%*	508	*100%*	395	*100.0%*	6.6%

SOURCE: California Public Utility Commission database

Additionally, the combination of the approach direction of both the train and the driver in relation to the intersection play a role in the viewing angle of the driver. In a non-perpendicular crossing, the tracks on one side of the driver will be difficult to see, and will require the driver to look back over his/her shoulder. However, the tracks on the other side of the driver will be very easily viewed. It may be that the increased visibility in one direction offsets poor visibility in the other direction. On the other hand, better visibility could lead to increased risk-taking if the driver feels overly confident about gauging the train's position and speed. This subject should be investigated further using viewing angle rather than intersection crossing angle.

4. CROSSING IMPROVEMENTS

Based on a review of the literature as well as our own observations of driver behavior at rail crossings, there exists a subset of drivers who will go around lowered gates if they think it is "safe" to do so. As will be demonstrated in Section 6 of this report, humans, in general, have an innate **in**ability to judge the speed and distance of an oncoming train. No amount of sight-line improvements, train conspicuity improvements, or warning system upgrades, will improve this situation.

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 (e.g., such as loss of convenience, slower response times for emergency vehicles, or loss of potential customers driving by a business) 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 deaths and injuries while remaining economically feasible. These will be briefly described in this section along with their associated costs and potential ability to reduce crashes when added to a 2-quad gate system.

4.1. POTENTIAL RAIL CROSSING UPGRADES

4.1.1. LONG-ARM GATES

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" (Caird et al. 2002; FRA, 2001).

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

Figure 5

LONG-ARM GATES

1 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.

2 Long-arm gates should not be installed where there is 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.

3 Long-arm gates should not be installed where there is significant level of bus traffic for the same reason as with trucks.

4 Long-arm gates should not be installed in locations with more than two tracks.

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. Longer than this, the arms become vulnerable to breakage due to high winds.

Long-Arm Gate Estimated Efficacy: 75% (FRA, 2001)
Estimated Cost Per Crossing: $5,000 (FRA, 2001)

4.1.2. MEDIANS

For this report, medians will be taken to mean mountable centerline medians with channelization devices. These can be applied directly to the existing roadway, as shown in Figure 6, or can be part of a more complex structure consisting of an island with reflectors mounted on the top, as shown in Figure 7. Such systems 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.

Medians are currently being used in a large number of locations including the North Carolina sealed corridor and in Washington state. The durability and maintenance experience in these locations has been good. In Puyallup, WA, seven sites, with average AADTs 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

Median Separators Estimated Efficacy:
75% (FRA, 2005) – 80% (FRA, 2001)
Estimated Cost:
$13,000 - $15,000 (FRA, 2005)

Figure 6

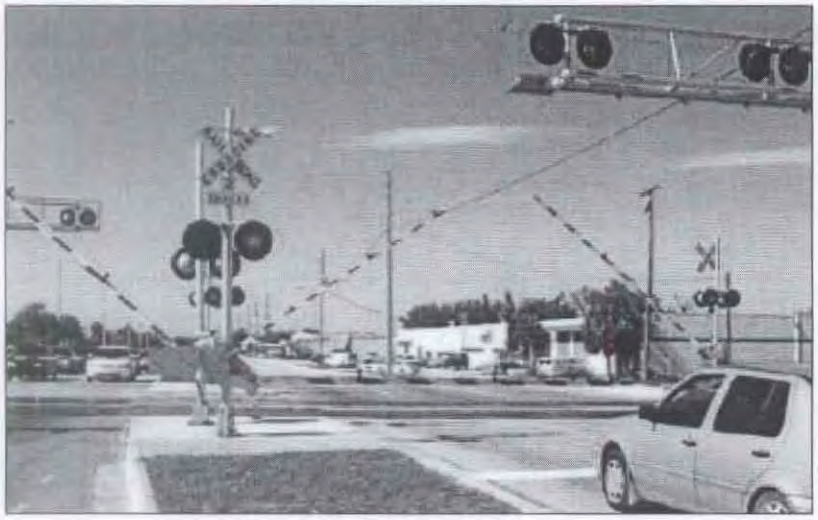
STREET MOUNTED CHANNELIZATION

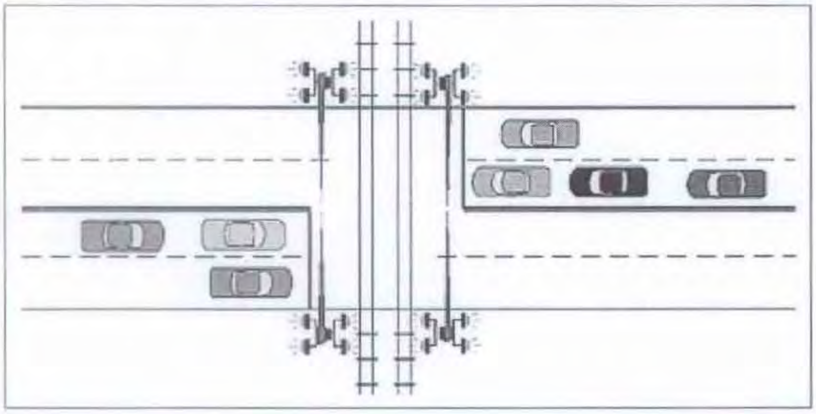
Figure 7

ISLAND MOUNTED CHANNELIZATION

Figure 8

FOUR-QUAD GATE SYSTEM PICTURE AND DIAGRAM





4.1.3. FOUR-QUADRANT GATE SYSTEMS

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. 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. At this time, only a small number of four-quadrant gate systems have been installed in California and incorporate different types of designs to prevent vehicles from being trapped between the gates.

Four-Quad Gates Estimated Efficacy: 82% (FRA, 2001) Estimated Cost: $125,000 (FRA, 2001) to $350,000

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).

4.1.4. PHOTO ENFORCEMENT

The California Vehicle Code, Section 21455.5: Traffic Signal Automated Enforcement (see Appendix H) 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 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 (Meadow,1994). 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.

Carroll and Warren, 2003, 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 four sites 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, is costing 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.

Photo Enforcement Estimated Efficacy - 72% (FRA, 2001)
Estimated Cost - $55,000 - $100,000 (Caird et al., 2002; FRA, 2001; Carroll and Warren, 2003)

4.2. SUMMARY

In Table 9, these methods are listed along with their estimated costs and relative effectiveness. The first column lists crossing equipment currently in use as listed in the FRA crossing inventory for California. While there may be some state crossings that have other equipment (e.g., four-quad gates), they are not listed in the inventory. The second column gives:

- Inventory: the number of state crossings with this type of equipment (crossings are listed by their highest level of warning device)
- Inc/K/Inj: the number of incidents/number killed/number injured at crossings of this type in California from 2000 to 2004
- Cost per Inc: the average cost of each crash incident at this type of crossing.
- Total Cost: the five-year total cost of all crashes at this type crossing

The next nine columns list the potential upgrades to the equipment listed in the first column. For each combination of old and new equipment, three numbers are given:

- "E" is the effectiveness of this upgrade. A rating of E-81% means that incidents would be reduced by 81% by upgrading to this type equipment.
- "C" is the cost to upgrade one crossing.
- "TC" is the total cost to upgrade all crossings of this type in the current inventory.

Table 9

COST AND EFFECTIVENESS OF HIGHWAY-RAIL CROSSING EQUIPMENT UPGRADES

		UPGRADE EQUIPMENT TO:								
CURRENT EQUIPMENT	Inventory Inc/K/Inj Cost per Inc Total Cost	Flashing Lights	2-Quad Gates	2-Quad Gates + Photo	2-Quad + Long-Arm Gates, FL	2-Quad + Long-Arm Gates + Photo	2-Quad Gates + Median Separators	2-Quad Gates + Median Separators + Long-Arm Gates	2-Quad Gates + Median Separators + Photo	4-Quadrant Gate System
No Signs or Signals	172 3/0/0 $4.7K $14.0K	E-64% C-$40K TC-$6.88M	E-88% C-$250K TC-$43M	E-97% C-$305K TC-$52.5M	E-97% C-$255K TC-$43.9M	E-99% C-$310K TC-$53.3M	E-98% C-$264K TC-$45.4M	E-99% C-$269K TC-$46.3M	E-99% C-$319K TC-$54.9M	E-98% C-$350K TC-$60.2M
Cross Buck	2805 57/7/16 $408.8K $23.30M	E-64% C-$40K TC-$112.2M	E-88% C-$250K TC-$701.3M	E-97% C-$305K TC-$855.5M	E-97% C-$255K TC-$715.3M	E-99% C-$310K TC-$869.6M	E-98% C-$264K TC-$740.5M	E-99% C-$269K TC-$754.5M	E-99% C-$319K TC-$894.8M	E-98% C-$350K TC-$981.8M
Stop Signs at Passive Crossing	307 20/0/5 $30.7K $614.9K		E-81% C-$250K TC-$76.8M	E-95% C-$305K TC-$93.6M	E-95% C-$255K TC-$78.3M	E-99% C-$310K TC-$95.2M	E-96% C-$264K TC-$81M	E-99% C-$269K TC-$82.6M	E-99% C-$319K TC-$97.9M	E-97% C-$350K TC-$107.5M
WigWags, Audible, Other Activated	270 7/2/4 $936.3K $6.55M		E-44% C-$250K TC-$67.5M	E-84% C-$305K TC-$82.4M	E-86% C-$255K TC-$68.9M	E-96% C-$310K TC-$83.7M	E-89% C-$264K TC-$71.3M	C-$269K TC-$72.6M	E-97% C-$319K TC-$86.1M	E-90% C-$350K TC-$94.5M
Flashing Lights	982 69/12/11 $552.1K $38.09M		E-44% C-$250K TC-$245.5M	E-84% C-$305K TC-$299.5M	E-86% C-$255K TC-$250.4M	E-96% C-$310K TC-$304.4M	E-89% C-$264K TC-$259.2M	E-97% C-$269K TC-$264.2M	E-97% C-$319K TC-$313.3M	E-90% C-$350K TC-$343.7M
2-Quad Gates	3124 434/78/163 $592.4K $257.08M			E-72% C-$55K TC-$171.8M	E-75% C-$5K TC-$15.6M	E-93% C-$60K TC-$187.4M	E-80% C-$14K TC-$43.7M	E-95% C-$19K TC-$59.4M	E-94% C-$69K TC-$215.6M	E-82% C-$350K TC-$1093.4M

These numbers are estimates and should be used as general indicators only in that each crossing may have unique characteristics and conditions. In constructing this matrix, two basic assumptions were made: (1) multiple treatments are multiplicative in effectiveness and (2) multiple treatment costs are additive.

The values and sources used for determining crash costs are:

Vehicle Damage: $4,680 (Lee 2004)
Death: $3,052,000 (California Highway Patrol [CHP], 2003)
Injury: $104,255 (Lee, 2004)

Calculations for the effectiveness of crossing equipment upgrades are given in Appendix D. To date, there have been no studies showing the effectiveness of upgrading from wigwags/audible warnings to 2-quad gates. In lieu of this information, the cost and effectiveness of upgrading from flashing lights to 2-quad gates will be used. The costs should be similar and the given effectiveness will be a conservative estimate for this type of upgrade.

4.3. BENEFIT VS. COST

Since the cost to upgrade all at-grade crossings would be prohibitive, this study attempts to determine which crossings would yield the greatest benefit from an upgrade. First, sites with multiple crashes were examined using ten-year crash data. Out of a total of 911 crossings which had crashes between 1995 and 2004, 252 had two or more, and 87 had at least three (Table 5). The complete list of the 252 multiple crash crossings is presented in Appendix E. The warning equipment components at these sites are:

Gates: 69%
Flashing Lights: 17%
Other Active Devices: 2%
Passive Warning: 12%

Next, the cost and potential benefit of upgrading the 252 sites with multiple crashes was calculated. The minimum upgrades considered for both passive and active sites were to include 2-quad gates plus one of the following: photo enforcement, long-arm gates, or median separators. Four-quad gates were not included due to their substantially higher cost. 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

As an example, to upgrade from a 2-quad gate to 2-quad + median separators at crossing number 026476Y in Riverside, which had four crashes in the ten years from 1995 to 2004:

Annual Benefit = (0.4 x 0.8) x $592,352 = $189,553

The cost to add median separators is $14,000. The potential annual benefit benefit/cost ratio is: $189,553/$14,000 = 13.5. The same ratio for a similar site with two crashes in the ten year period rather than four, would be: $94,776/$14,000 = 6.8.

These methods were applied to all multi-crash sites. Although it is unlikely that all sites would have the same upgrade, there are too many possible combinations to list here. As such, it was assumed that all sites will receive the same final equipment. The results are shown in Table 10.

Table 10

BENEFITS AND COSTS TO UPGRADE CALIFORNIA MULTI-CRASH CROSSINGS

	2-Quad Gates + Photo	2 Quad + Long-Arm Gates	2 Quad + Long-Arm Gates + Photo	2-Quad Gates + Median Separators	2-Quad Gates + Median Separators + Photo
Costs To Upgrade to These Levels					
Upgrade Sites with 3 to 12 Crashes	$8,030,000	$3,730,000	$8,460,000	$4,504,000	$9,234,000
Upgrade Sites with 2 or More Crashes	$25,710,000	$13,110,000	$26,970,000	$15,378,000	$29,238,000
Expected Annual Upgrade 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
Expected Benefit/Cost Ratio	1.1	2.2	1.3	2.0	1.2

It should be remembered that the values of this section are based on property damage, injury, and death cost **estimates**. The results, therefore, show an unrealistic degree of precision that should be, at the least, rounded to the nearest thousand. These results could change greatly if the assumptions underlying the cost estimates are altered.

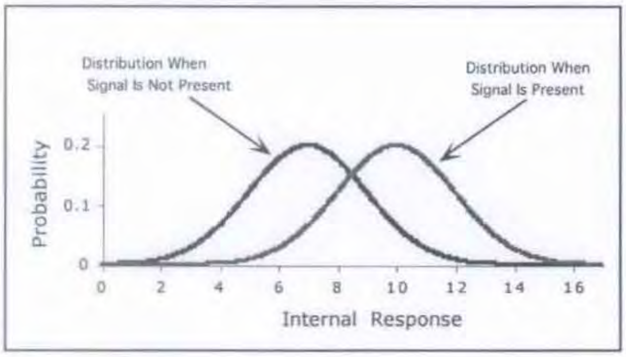
5. DRIVER DECISIONS AT RAIL CROSSINGS: A CONCEPTUAL MODEL

What failures in perception or judgment would cause 503 drivers (2000-2004) to ignore active warnings (gates and/ or flashing lights) and become involved in crashes with trains and, even more incredibly, would cause 84 of them to drive around or through gates **INTO** the side of a train? This section aims to provide insight into the interplay of perception, expectation, and human information processing which can assist in the development of strategies for grade crossing crash prevention.

5.1. SIGNAL DETECTION THEORY

Figure 9

INTERNAL RESPONSE PROBABILITIES FOR NOISE WITH SIGNAL AND NOISE ONLY



Signal detection theory (SDT) has been used by a number of researchers as a means of analyzing and predicting railroad crashes (e.g., Raslear, 1995, Rapoza and Fleming, 2002). "The starting point for signal detection theory is that nearly all reasoning and decision making takes place in the presence of some uncertainty" (Heeger, 1997). Thus, someone at a party trying to determine if they have previously met someone, a radiologist looking for evidence of a tumor, and a motorist at a rail highway crossing are all in the same situation of trying to detect a signal in a background of noise. In all of these situations, it is often difficult to distinguish signal from noise, and a decision will be made which is not solely dependent upon the sensory information alone.

In the SDT model, both the signal and the noise are represented as a single internal response continuum which varies in magnitude. Even if all of the sensory inputs to an individual are identical, signals, such as the locomotive, are capable of producing perceptual magnitudes which vary between encounters. This produces a

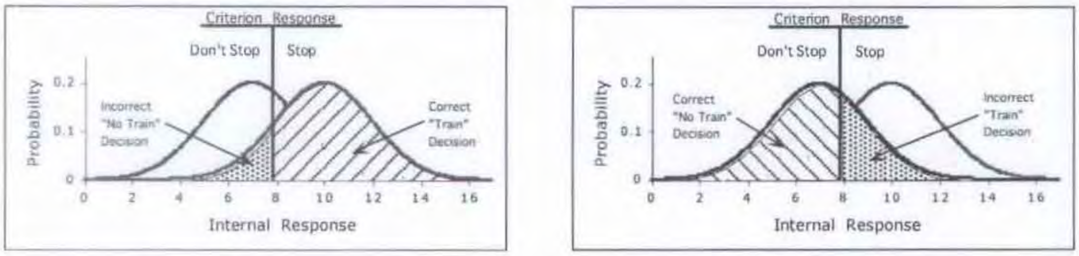
> "...probability distribution of internal response which is associated with a particular locomotive configuration (e.g., size, loudness, color, brightness, etc.). This distribution of perceptual magnitudes has a mean and variance which can be used to specify the perceptual magnitude of the locomotive as a signal. Similarly, the background noise also has a distribution of perceptual magnitudes which can also be specified by a mean and a variance. For the sake of simplicity it is often assumed that the distribution of perceptual magnitudes for noise and signal are normal. Additionally, the basic SDT model assumes that the variances of signal and noise distributions are equal, although this assumption is not critical to the theory" (Raslear, 1995).

A typical representation of noise and signal plus noise only distributions are shown in Figure 9.

A key point to note is that the distributions overlap. Thus there are times when it is not possible to distinguish between signal and noise, necessitating the adoption of some other means to decide which it is and what action to take. This is the criterion and the point on the internal response axis at which this criterion is set is the criterion line (see Figure 10).

Figure 10

INTERNAL RESPONSE PROBABILITY CURVES



(a) Signal (Train) Present

(b) Signal (Train) Not Present

In the case of the motorist at a crossing, the criterion line provides the basis for the decision to stop (all points to the right of the line) or continue crossing (all points to the left of the line). There are four potential outcomes for the decision as shown in Table 11. There are two response categories: "Stop (the train is too close)" and "Don't Stop (the train is not too close)." And there are two possible events: a train is close to the crossing and a train is not too close to the crossing (or not present).

These outcomes can be seen in Figure 10 where the train is close in diagram (a) and not close or absent in diagram (b). For our purposes, the more important question is not whether or not the train is perceived as present but rather is it perceived as close enough and moving fast enough to represent a threat to the driver's crossing the tracks ahead of it.

In diagram (a), where the train is close, the striped area to the right of the criterion represents the correct decision to stop. The shaded area to the left of the line is the incorrect decision to proceed, resulting in a crash. In diagram (b), the striped area represents the correct decision to proceed, while the shaded area is the decision to stop unnecessarily.

Table 11

POTENTIAL OUTCOME MATRIX

	Stop	Don't Stop
Train Is Close	Valid Stop	Crash
Train Is Not Close, or No Train	False Stop (driver stops unnecessarily)	Correct Crossing (driver crosses safely)

For any given level of detectability of the signal, moving the criterion response line will change the probabilities of the potential outcomes. By choosing a low criterion, the driver could be assured a very low probability of crashes but at the cost of a large number of unnecessary stops. The effects of shifting the criterion response line are shown in Figure 11. It is important to note that the criterion for detection is not consciously set, but rather corresponds to the amount of visual "evidence" required for detection, which itself can be heavily influenced "by the observer's expectations (probability of signal, probability of noise), motivation (values of each of the decision outcomes), and other cognitive functions (e.g., memory, attention, decision strategy). For instance, a driver who is familiar with a particular grade crossing has an expectation regarding the frequency of trains at that crossing" (Raslear,1995).

Note that changes in the criterion do not change the distribution of the detectability of the proximity of the train. The only means in this model of altering detectability is to move the signal and noise distributions further apart, thus lessening the area of overlap. There are three ways to achieve this: (1) decrease the level of background noise (Figure 12a), (2) increase the level of the signal (Figure 12b), and (3) change the variance of one or both distributions.

Mathematically, how detectable the signal is from no-signal can be expressed as:

$$d' = \frac{separation}{spread} = \frac{\mu_s - \mu_n}{\sigma}$$

Again, changes in the criterion only affect the probabilities of the outcomes, while changes in the distributions can effect a change in both detectability and the probabilities of the outcomes (Raslear, 1995).

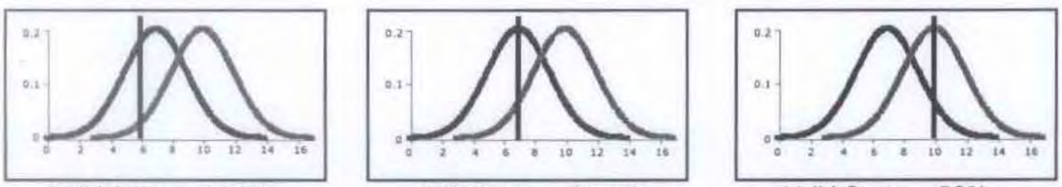
Given that over 86% of the 593 crashes that occurred between 2000 and 2004 took place at crossings with active warning devices, it would appear that knowledge of the presence of a train is not sufficient reason to stop for some people. For them, the problem is determining the speed and proximity of the train, rather than its presence.

SDT indicates that there are two classes of variables which can be manipulated to prevent crashes: (1) variables which increase the Signal/Noise Ratio and (2) variables which increase the bias to stop. An approaching train gives off a large signal, with visual, auditory, and physical characteristics. While there are several signal boosting strategies available to further the detectability of trains (e.g., enhancing locomotive conspicuity, reflectorization of freight cars, and altering the train horn), this strategy does not appear to be especially promising given that determining train speed and proximity are the problem, rather than just train presence.

A more promising strategy might be to increase the S/N ration by decreasing noise, thus allowing more effort to be spent on speed and distance judgments. Raslear (1996) noted that grade crossings with active devices actually have lower train detectability values than crossings with passive or no devices. This could be due to the fact that the warning equipment is not part of the train, so the increases in light and sound at the crossing acts as a distraction,

Figure 11

EFFECTS OF SHIFTING CRITERION RESPONSE LINE



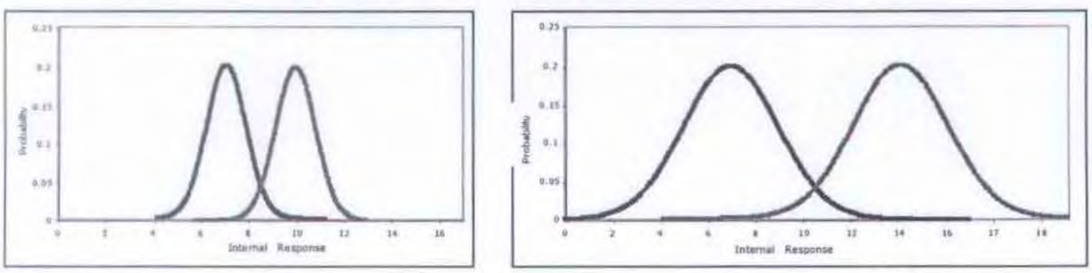
Valid Stops = 97.7%
False Stops = 69.2%

Valid Stops = 84.1%
False Stops = 50%

Valid Stops = 50%
False Stops = 16.7%

Figure 12

CHANGES IN PERCEPTUAL DISTRIBUTION

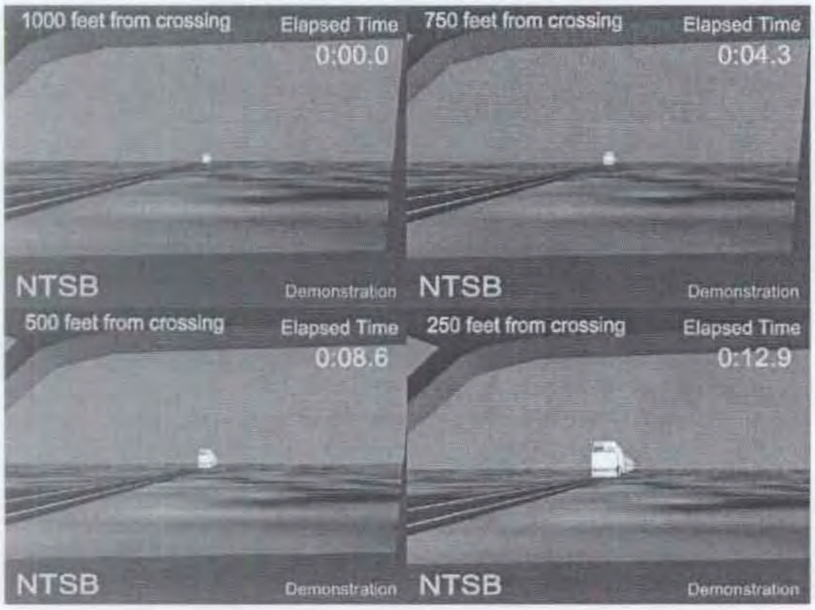


(a) Lower Noise

(b) Stronger Signal

Figure 13

VIEW OF APPROACHING TRAIN FROM VEHICLE STOPPED AT CROSSING



decreasing the S/N ratio. Interestingly, SDT predicts that automated horns and illumination of grade crossings should increase the accident rates at grade crossings for the same reason (Raslear, 1996). Following this line of reasoning, one possible crossing enhancement might be to change the flashing lights to steady red and stop the bells once the gates are fully down. The motorist at this point is aware of the presence of the train and can concentrate on speed and location.

Another method to increase S/N, is to improve the line of sight of the motorist at the crossing and reduce visual clutter (e.g., other traffic, traffic signs and signals, street lights, etc.). Obviously, visual information is extremely important when compared to other sensory information for determining speed and proximity, so any improvements could have a large effect on reducing noise and strengthening the signal.

Raslear (1996) quotes a recent FRA study of 56 grade crossings with an average of more than one accident per year that found that 97% of these crossings had visual obstructions, 95% had a large number of driveways and intersecting roadways, and 80% had visual clutter on the approach.

Finally, directing a driver's attention toward the train may serve to enhance the S/N ratio. Signs which indicate where motorists should look could function to enhance both detectability and bias to stop. Signals and other changes in the sensory stimulation provided by grade crossing devices should be more focused on causing motorists to orient toward the train rather than just indicating the train's presence (Raslear, 1996). Care must be taken, however, that the indicator cannot be misinterpreted. A lighted arrow, for example, could be interpreted as pointing to where the train is OR the direction it is traveling.

In addition to changing the S/N ratio, increasing a motorist's bias to stop should also reduce rail-highway grade crossings. This bias has been shown to be strongly influenced by expectation and motivation. The first of these is best illustrated by the fact that accident rates vary inversely with train frequency. While this at first seems counterintuitive, the key word here is "rates." As Lerner et al. (1990) reported, "If the driver assigns a low probability to the presence of a train...he will adopt a higher criterion for detecting the train, and this will increase his chances of [not seeing it]. It is important to note that the criterion for detection is not consciously set, but rather corresponds to the amount of visual 'evidence' required for detection."

One method of increasing the bias to stop is through the use of enforcement. In Los Angeles, a photo enforcement demonstration project was conducted in 1992 that began with the un-announced installation of cameras at two locations where counts were made over a two month period to serve as a baseline for evaluation of the system. Following this, a press conference was held and signs were installed at the crossings. After two months of sending out warnings only to violators, ticketing began and continued for four months. The demonstration project resulted in an 84% reduction in the number of violations (Meadow, 1994).

Considering what should be an already powerful incentive to stop at lowered gates, it is somewhat surprising that the threat of a $50 or $100 fine would be an effective motivator of behavior. As Raslear (1996) points out, however, there are other costs associated with fines including inconvenience and loss of time, embarrassment caused by publicly receiving a fine and the possibility of losing one's license due to the points that might be added to the driver's record. Another possible reason for the effectiveness of photo enforcement is that most people have firsthand knowledge of receiving a ticket whereas very few have been hit by a train. Thus, the certainty and past experience of a ticket seem to carry more weight than the vague possibility of a crash, even though the consequences of a crash could be catastrophic.

Table 12

APPROACH SPEEDS OF THE LARGE (10') SPHERE

Speed (mph)	# Trials (Out of 270)
25	40
35	40
45	40
55	50
65	50
75	50

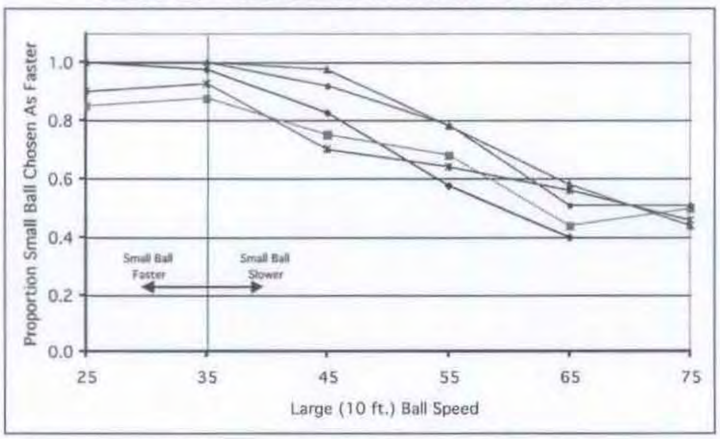
5.2. PERCEPTION OF TRAIN SPEED AND DISTANCE

Between 2000 and 2004, 73% of drivers involved in crashes had been made aware of the approaching train by the presence of lowered gates. If we assume that a driver ignores this warning and decides to proceed across the tracks because he or she believes there is enough time to do so safely, there must be some perceptual problems that affect an individual's ability to make this judgment correctly.

Detecting speed or time to collision from changes in an object's size has been shown to be relatively difficult (Leibowitz, 1985). In addition to problems associated with judging speeds of large objects (discussed in greater detail in the next section), as an object approaches, the growth in size is not linear but hyperbolic, with the apparent rate of growth of a distant object being quite slow and then accelerating as the object gets closer (See Figure G3 in Appendix G). The result is that drivers tend to be effective at estimating the speed of the train when it is closest because the change in visual angle is rapid, but when the train is at greater distances, at the time when drivers tend to decide on the safety of proceeding across the tracks, the change in visual angle is slow and they are more likely to underestimate the train's speed (NTSB, 1998).

Figure 14

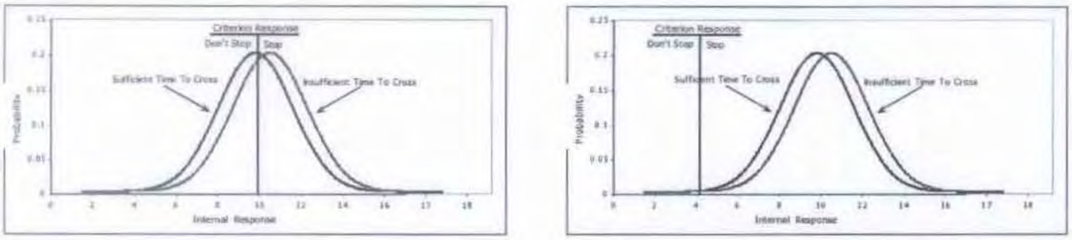
TEST OF THE LEIBOWITZ HYPOTHESIS



This phenomenon can be seen in Figure 13, taken from an NTSB simulation of a train approaching a stationary car at 40 MPH from a distance of 1,000 feet. Each frame represents the movement of the train covering one quarter of the original distance. Half of the distance is covered before any appreciable difference in the size of the train can be noted and the remaining time to collision is only 8.5 seconds.

Figure 15

OVERLAPPING SIGNAL AND SIGNAL-PLUS-NOISE CURVES



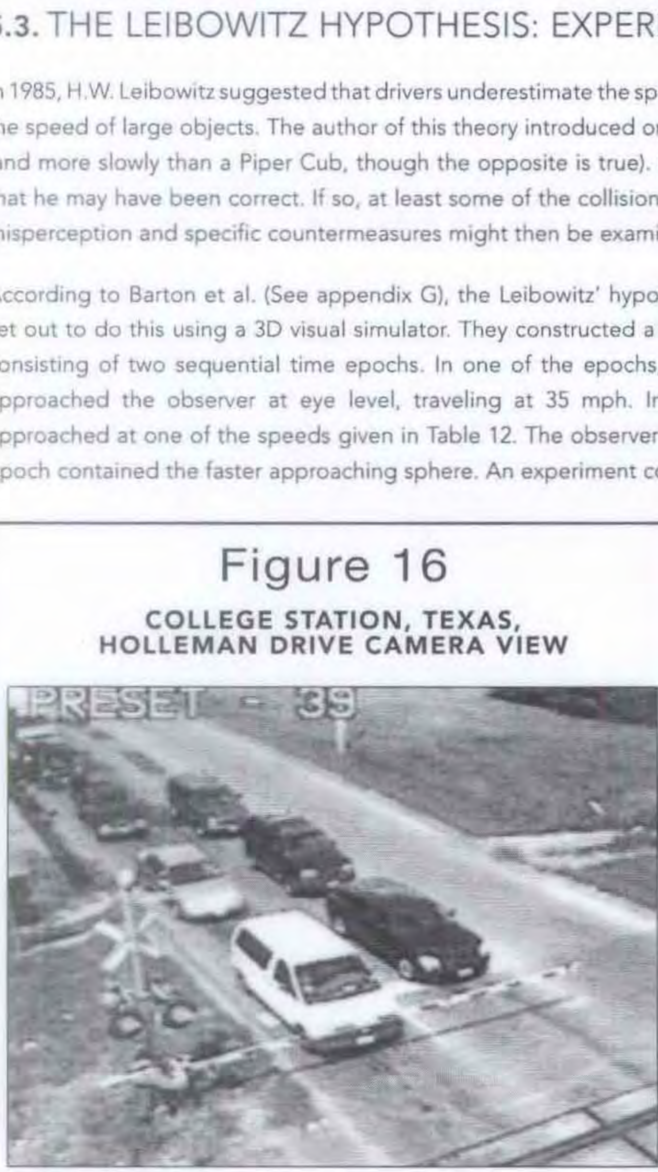
5.3. THE LEIBOWITZ HYPOTHESIS: EXPERIMENTAL RESULTS

In 1985, H.W. Leibowitz suggested that drivers underestimate the speed of trains because human vision underestimates the speed of large objects. The author of this theory introduced only anecdotal evidence in its favor (a 747 seems to land more slowly than a Piper Cub, though the opposite is true). Cohn and Nguyen (2003) found indirect evidence that he may have been correct. If so, at least some of the collisions at rail crossings might be due to a simple driver misperception and specific countermeasures might then be examined.

According to Barton et al. (See appendix G), the Leibowitz' hypothesis has never been tested, and so the authors set out to do this using a 3D visual simulator. They constructed a two alternative, forced choice (2AFC) experiment consisting of two sequential time epochs. In one of the epochs, chosen at random, a five foot diameter sphere approached the observer at eye level, traveling at 35 mph. In the other epoch, a ten foot diameter sphere approached at one of the speeds given in Table 12. The observer's task was to indicate by pressing a button which epoch contained the faster approaching sphere. An experiment consisted of 270 such trials.

Figure 16

COLLEGE STATION, TEXAS, HOLLEMAN DRIVE CAMERA VIEW



The authors tested the ability of five males, ranging in age from the early 20s to the mid 50s, with corrected normal eyesight to identify the faster of two different sized approaching spheres. The results of these tests are summarized in Figure 14, which plots, for each subject, the proportion of times the 5 ft diameter sphere was judged to be faster (P5) as a function of 10 ft sphere speed (V10). This shows a strong tendency to judge the smaller sphere as the faster, even when the actual approach speed of the larger sphere is 20 mph greater (V10=55 mph). Only when V10 reaches speeds of 65-75 mph (twice that of the smaller sphere) does the observer become unsure as to which is approaching faster (P5≈0.5).

The experimental data, then, show a strong tendency to judge the smaller ball to be the faster, even when the opposite is the case, and often by a considerable margin. The plots in Figure 14 suggest that experimenters would have to include trials in which the large ball approaches in excess of 95 mph (2.7 times faster than the small ball) before subjects would unambiguously pick the large ball as the faster approaching.

5.4. DRIVER DECISIONS CONCLUSION

From both signal detection theory and the tests of the Leibowitz hypothesis, it is apparent that, in general, humans have a great deal of difficulty in judging the speed and distance of an oncoming train as depicted in the nearly overlapping signal and signal-plus-noise curves in Figure 15. Since no amount of sight-line improvements, train conspicuity improvements, or warning system upgrades will improve this situation, the solution to rail crossing crashes must be found by removing the need to make such a decision (i.e., driving the criterion response point all the way to the left) by making it impossible, or at least very difficult, for the driver to bypass the lowered gates.

6. CROSSING OBSERVATIONS

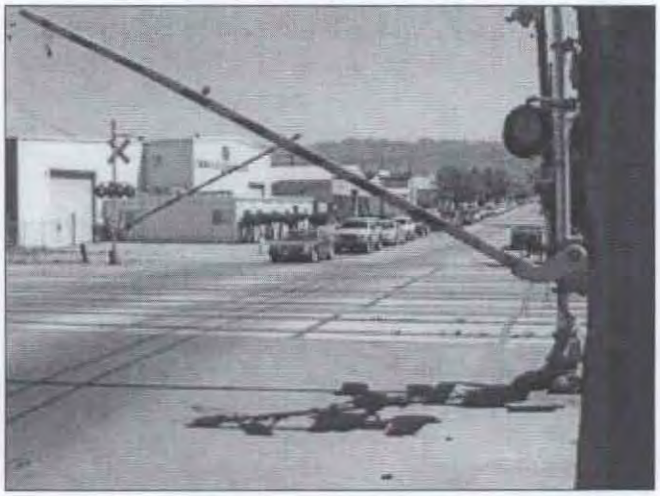
Observation of drivers at rail crossings provides a valuable tool for understanding their behavior under different combinations of grade crossing equipment and train frequencies and speeds. Three different methods were examined: a crossing camera in College Station, Texas, a crossing camera in Berkeley, California, and a train engine based camera in Napa, California. This section presents the results of these observations. A complete description of the sites, procedures, setups, and results can be found in Appendix I.

6.1. COLLEGE STATION, TEXAS

College Station, Texas, population of 70,000, is located 90 miles northwest of Houston. It has a rail monitoring system, The College Station ITS Integration Project (CSIP), set up along the Wellborn Road Corridor which is a major north-south arterial in College Station. The system was set up to provide the City's Fire Station #4 with grade crossing status and travel time prediction information for trains traveling in both directions in the project corridor to aid station personnel in making route decisions when servicing an emergency call.

Figure 17

GILMAN AVENUE CROSSING BERKELEY, CALIFORNIA



Adjacent to Wellborn Road lies the Union Pacific Railroad's Fort Worth Subdivision mainline which carries approximately 20 to 25 trains per day, varying from 1/2 mile to 11/2 miles in length. Train speed through the corridor can be as low as 15 to 20 mph in the northern end of the corridor and as high as 50 mph at the southern end. Trains in the corridor do not travel on a fixed time schedule, but arrive randomly throughout the day, depending on train traffic (Texas Transportation Institute, 2005).

PROCEDURE

Approximately 300 hours of live video feed from the College Station Holleman Avenue camera was downloaded from the internet and stored over a total of 24 weekdays between June 22, 2005 and September 2, 2005. Train speed information was also recorded during this period

RESULTS

During the observation period, 116 gate cycles during which cars were present, were recorded. During 45 of those, cars were present in the storage area beyond the tracks, preventing approaching traffic on Holleman from crossing the tracks. In the remaining 71 cycles, 48 cars had the opportunity (defined as arriving at the crossing before the road was blocked by the gate) to go under the descending gate and 28 cars (58%) did so. One of the 28 cars went around stopped traffic and one car was hit by the gate.

Also during the 71 unblocked cycles, nine cars went around a lowered gate. Six of these took place after the train had passed and the gate did not go up. Two of the remaining three occurred in front of a train traveling at seven miles-per-hour and the last one in front of a train traveling at 26 miles-per-hour. In the case of the slow train, 35 seconds passed from the time the second car cleared the tracks until the train arrived. In the third case, the train arrived at the crossing nine seconds after the car had cleared.

6.2. BERKELEY, CALIFORNIA

The Gilman street crossing in Berkeley, California, has two lanes of traffic crossing three sets of tracks, of which only two are used (Figure 17). The crossing is equipped with two quadrant gates, bells and flashing lights. There are up to 70 trains per day including 24 operated by Amtrak's Capitol Corridor, consisting of an engine and four passenger cars traveling at speeds up to 60 MPH.

Observations at this location were recorded using two cameras, each located in the back of a van parked along Gilman Avenue. Each camera was set up so as to shoot traffic coming at it diagonally across the tracks.

RESULTS

Over a period of four days, there were a total 114 gate cycles with vehicles present (eastern and western gate cycles counted separately). There were 86 opportunities for a vehicle to go under a descending gate — 17 vehicles (19.8%) did so. No cars went around fully descended gates.

6.3. NAPA, CALIFORNIA

The Napa Valley Wine Train provides a 3-hour round-trip covering the 36- miles beginning in the town of Napa, through the village of St. Helena, and back. The train consists of nine rail cars and a double-sided Alco Diesel Engine. The data collected from this train comes from a camera mounted in the engine and operated by the engineers. The resulting tapes were obtained from the Napa Valley Railroad Police Department. While the data are anecdotal in nature they provide valuable insight into the public's general lack of knowledge of both the law regarding rail crossings and the basic laws of physics. One person, for example, a passenger in a car that had stalled on the tracks, got out of her car and stood between the car and the oncoming train, waving for the engineer to stop. Fortunately, a woman in another car got out and dragged the first woman to safety just before the train hit her car.

7. CONCLUSIONS & RECOMMENDATIONS

Rail-Highway grade crossing collisions fall under the category of bilateral accidents in that the probability of their occurrence is affected by both the railroad and the other involved party (Savage, 1998). Between 2000 and 2004, there were 99 people killed and 205 injured due to collisions between motor vehicles and trains at rail highway crossings in California, virtually all the fault of the highway user.

There is a group of drivers, more than half less than 40 years old, and male by a ratio of three to one, who are not deterred by lowered gates and have a misplaced confidence in their ability to judge train location and speed. Signal detection theory tells us that the decision to proceed or stop at a rail crossing is a function of our ability to separate signal from noise (both external and internal), and the criterion point, which is itself a function of expectation, prior experience, and personality.

It would seem, then, that to cut the crash rate at grade crossings, we could begin by finding a means to increase the S/N ratio. This might consist of increasing signal strength by increasing train conspicuity (although this would be difficult to accomplish during daylight hours), installing some form of indicator of where to look for the train, and/or decreasing noise by improving viewing angles and switching to a steady red light instead of flashing red light and quieting the bells once the arms are fully down.

But at a fully functioning gated crossing, where 73% of California's crashes occurred, the driver has been fully informed, by means of lowered gates, that a train is near. Should we be concerned about providing better information to the driver in order to facilitate a more informed decision to run the gates? In fact, could every effort we make to increase the SDT signal (train conspicuity, louder horns, etc.) and decrease noise (better sight lines, turning off flashing lights once the gate is down) actually encourage gate running by increasing driver confidence in his/her ability to judge train speed and distance?

From both signal detection theory and the tests of the Leibowitz hypothesis, it is apparent in general, that humans have difficulty judging the speed and distance of an oncoming train. Since no amount of sight-line improvements, train conspicuity improvements, or warning system upgrades will improve this situation, the solution to rail crossing crashes must be found by removing the need to make such a decision. This translates to making it impossible, or at least very difficult, for the driver to bypass the lowered gates.

While making it impossible to violate a crossing can be accomplished in a number of ways, including constructing a separation of grade, closing the crossing, or by deploying an impenetrable barrier, this solution tends to be relatively expensive. There are, however, two low technology, low cost, and low maintenance methods that while not being 100% effective, have been deployed in many locations and shown to prevent deaths and injuries while remaining economically feasible. These are long-arm gates and median separators.

8. SUGGESTIONS FOR FURTHER RESEARCH

There appears to be widely held belief among public agency decision makers that implementation of safety related measures can, unless universally applied, expose the agency to liability lawsuits. The feeling is that public plaintiffs will argue that the addition of a safety device (e.g., upgrading a rail-highway crossing) is a tacit admission of the existence of a dangerous condition and putting it one place and not another constitutes negligence on the part of the agency. The question to be answered is whether or not lawsuits of this type actually occur and, if so, are they being won by the plaintiffs?

The second area for future study involves those sites with multiple crashes. Specifically, do these sites differ in some significant way from other rail-highway crossings?

Finally, as previously discussed in the section on crossing angles (Section 4.3.7), while **crossing** angle appears to play no part in crash rates, it may very well be that **viewing** angle does. This needs to be investigated further.

9. REFERENCES

Caird, J.K., Creaser, J.I. , Edwards, C. J., Dewar (2002), A Human Factors Analysis Of Highway-Railway Grade Crossing Accidents In Canada, Transportation Development Centre Transport Canada

California Highway Patrol (2003), 2003 Annual Report Of Fatal And Injury Motor Vehicle Traffic Collisions, Sacramento CA

Carlson, Paul J., Fitzpatrick, Kay (1999), Violations at Gated Highway-Railroad Grade Crossings, Transportation Research Record 1692

Carroll, Anya A. and Warren, Judith D. (2002), Photo Enforcement at Highway–Rail Grade Crossings in the United States, July 2000–July 2001, Transportation Research Record 1801 Paper No. 02-2517

Cohn, T. E., Nguyen , T. (2003), A Sensory Cause of Railroad Grade-Crossing Collisions: Test of the Leibowitz Hypothesis, Transportation research record. No. 1843 (2003)

Dewar , Robert E., Olson , Paul L., Editors (2002), Human Factors In Traffic Safety, Lawyers & Judges Pub Co., Tucson, AZ

Farr, E.H. and Hitz, J.S. (1985), Effectiveness of Motorist Warning Devices at Rail-Highway Crossings, Publication No. FHWA-RD-85-015. Federal Highway Administration, Washington, D.C.

Federal Railroad Administration (2001), North Carolina "Sealed Corridor" Phase I, U.S. DOT Assessment Report: Report to Congress

Federal Railroad Administration, (2004), Audit Of The Highway-Rail Grade Crossing Safety Program, Federal Highway Administration, Federal Transit Administration, Report Number: MH-2004-065 Date Issued: June 16, 2004

Federal Railroad Administration (2005), Use of Locomotive Horns at Highway-Rail Grade Crossings: Final Rule, 49 CFR Parts 222 and 229, Federal Register, Vol. 70, No. 80

Lee, Douglass Jr., Gay, Kevin, Carroll, Anya, Hellman. Adrian, Sposato. Suzanne (2004), Benefit-Cost Evaluation of a Highway-Railroad Intermodal Control System (ICS) Final Report, U. S. DOT, Volpe National Transportation Systems Center, Cambridge, MA

Leibowitz, H. W., (1985), Grade Crossing Accidents and Human Factors Engineering, American Scientist. Vol.73, pp. 558-562.

Lerner, N., Ratte, D., and Walker, J., (1990), Driver Behavior At Rail-Highway Crossings (Report No. FHWA-SA-90-008). Washington, DC: Federal Highway Administration, U. S. Department of Transportation.

Meadow, Linda (1994), Los Angeles Metro Blue Line Light Rail Safety Issues, Transportation Research Record. No. 1433

Meeker, Frank L., Barr, Robin A. (1989) An Observational Study Of Driver Behavior At A Protected Railroad Grade Crossing As Trains Approach, Accid. Anal & Prey. Vol. 21, No. 3, pp. 255-262, 1989

Meeker, Frank, Fox, Daniel, and Weber, Christopher. (1997), A Comparison Of Driver Behavior At Railroad Grade Crossings With Two Different Protection Systems, Accident Analysis & Prevention., Vol. 29, No. I, pp. 16, 1997

National Transportation Safety Board, (1998) Safety At Passive Grade Crossings. Volume 1: Analysis, Safety Study NTSB/SS-98/02. Washington, DC.

Rapoza, Amanda S., Fleming, Gregg G. (2002), Determination of a Sound Level for Railroad Horn Regulatory Compliance, U.S. Department of Transportation, Federal Railroad Administration, Washington, D.C.

Raslear, T.G. (1995). "Driver Behavior at Rail-Highway Grade Crossings: A Signal Detection Theory Analysis," In: Safety of Highway-Railroad Grade Crossings, Research Needs Workshop, Volume II-- Appendices, Caroll, A.A. and Helser, J.L. (Eds.). Report No. DOT/FRA/ORD/14.2, DOT-VNTSC-FRA-95-12.2, pp. F9-F56. U.S. Department of Transportation, Washington, D.C

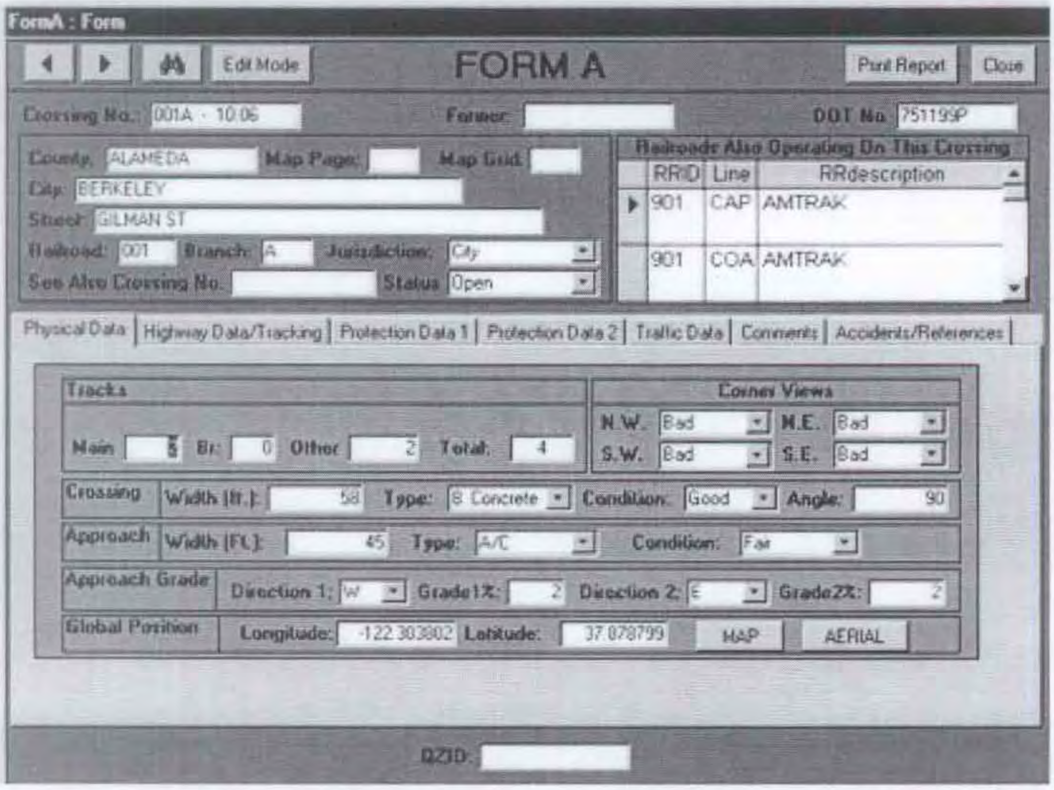
Texas Transportation Institute (2005), Evaluation and Lessons Learned From The College Station Integration Project, College Station, TX

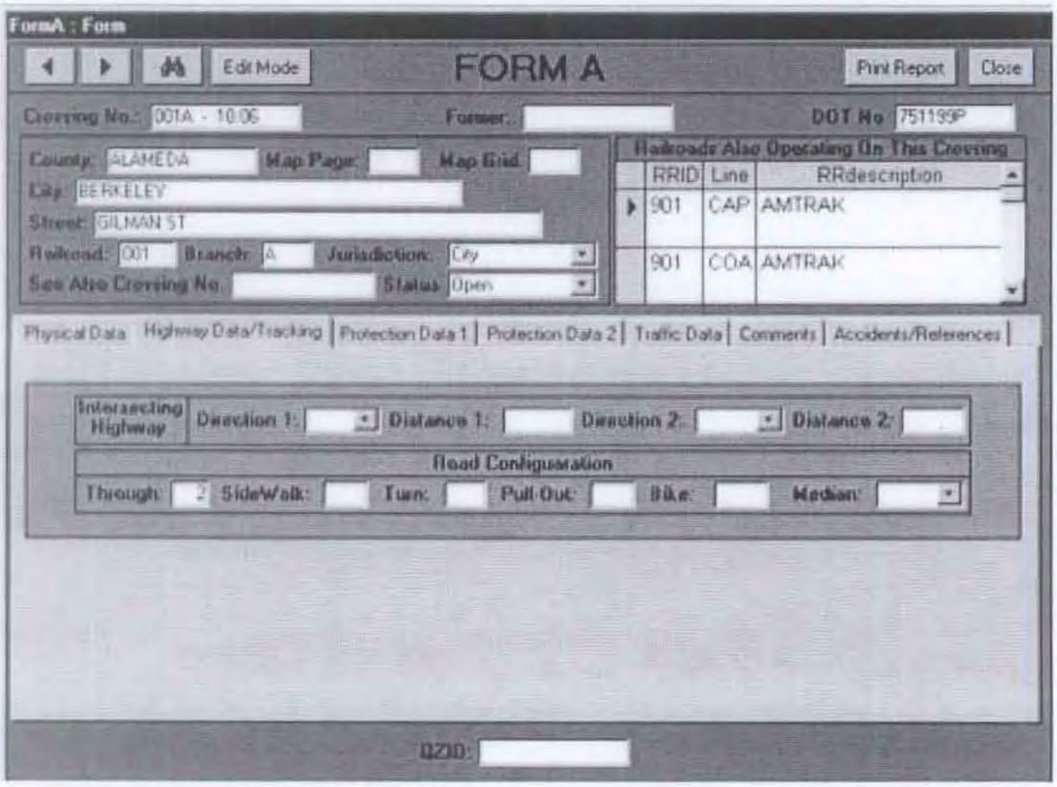
Wigglesworth, E.C. (1979), Epidemiology of road-rail crossings in Victoria. Journal of Safety Research 11, 162.

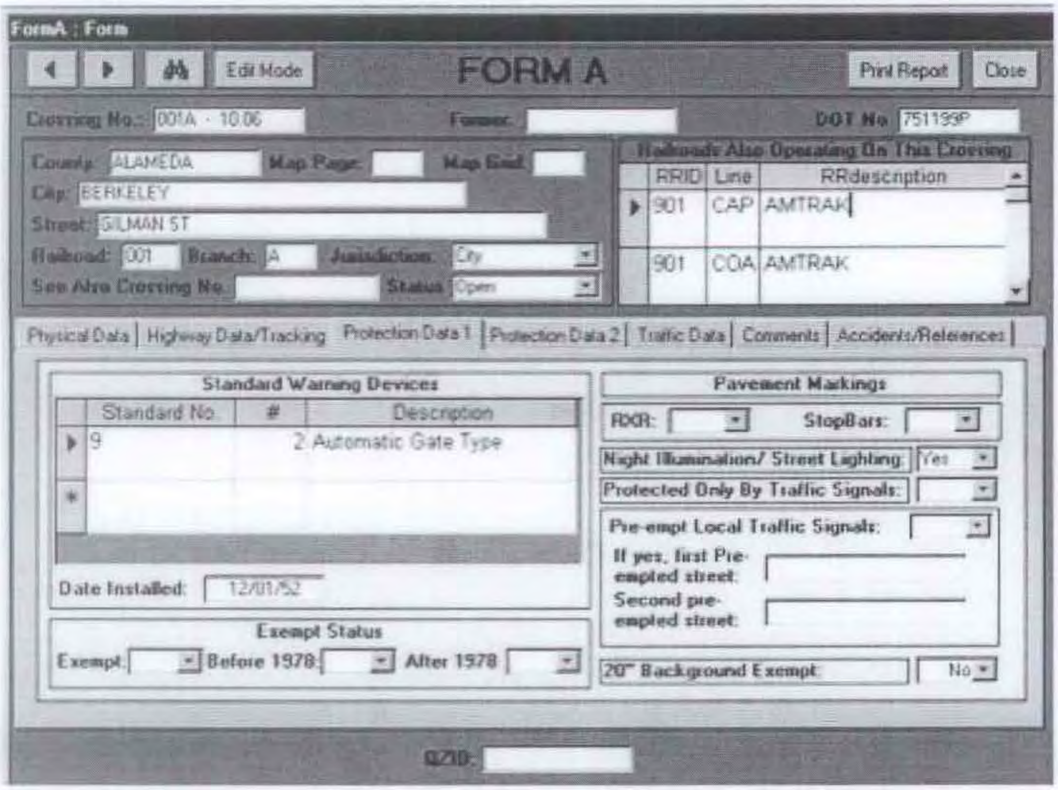
Witte , Kim and Donohue , William (2000), Preventing Vehicle Crashes With Trains At Grade Crossings: The Risk Seeker Challenge, Accident Analysis and Prevention 32 (2000) 127–139

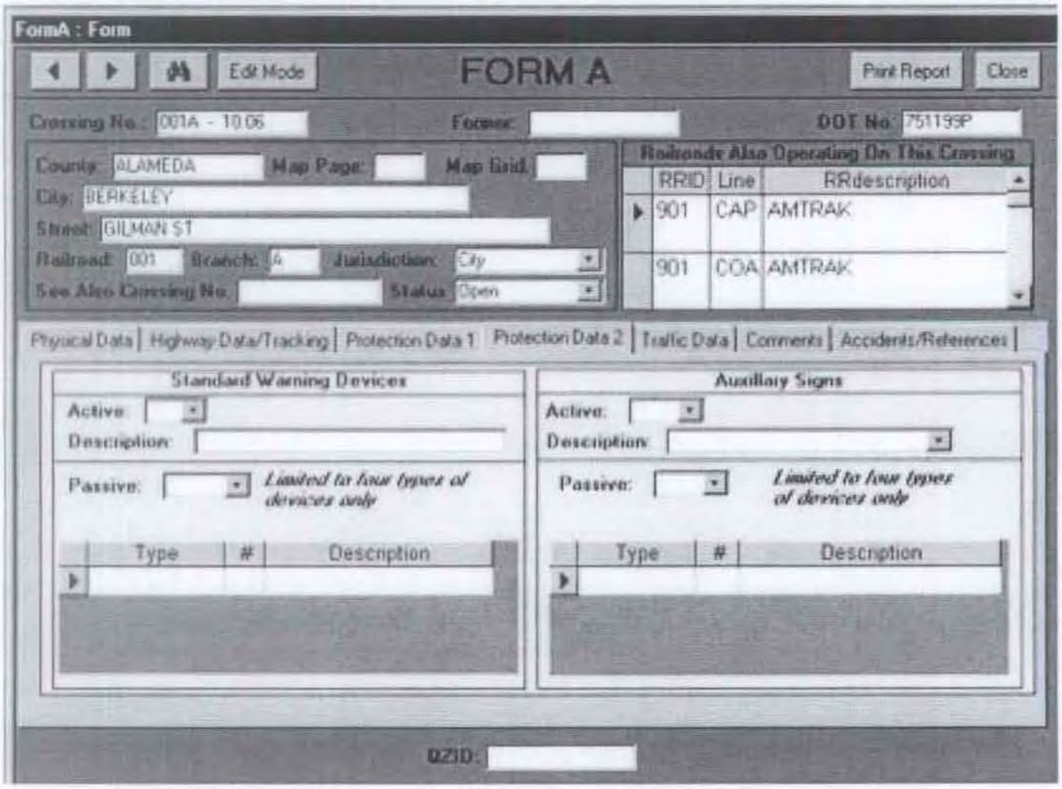
10.1 APPENDIX A:

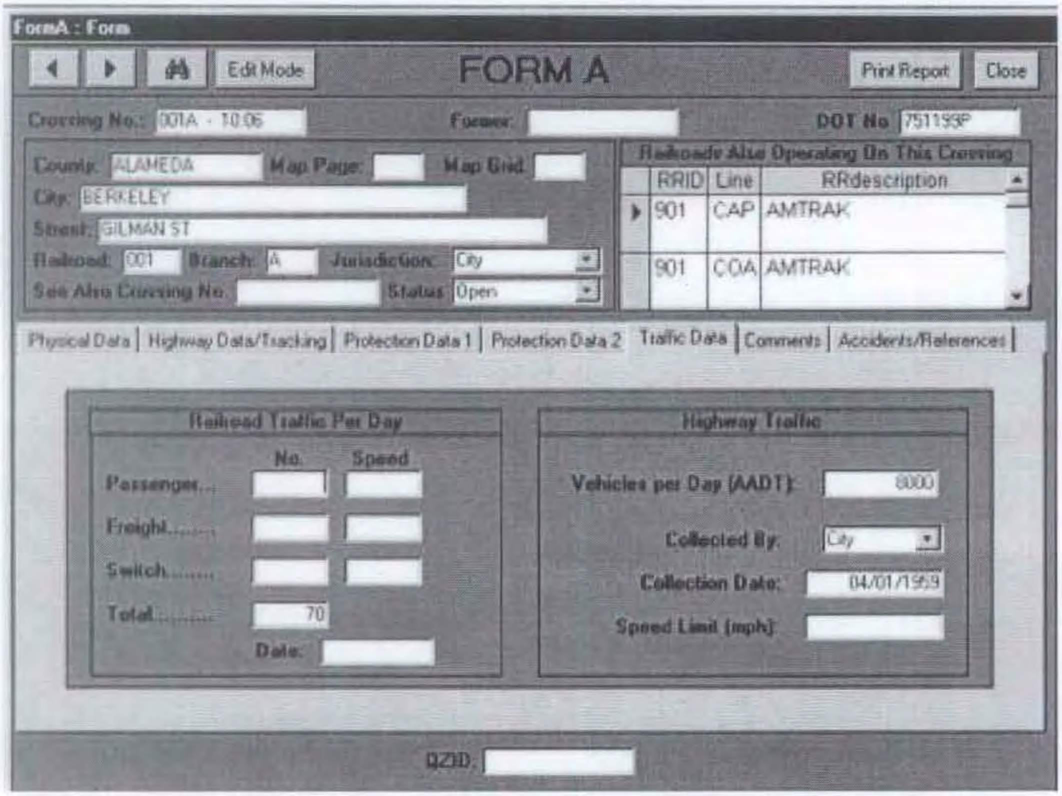
CALIFORNIA PUC SAMPLE FORM A CROSSING INVENTORY ENTRY

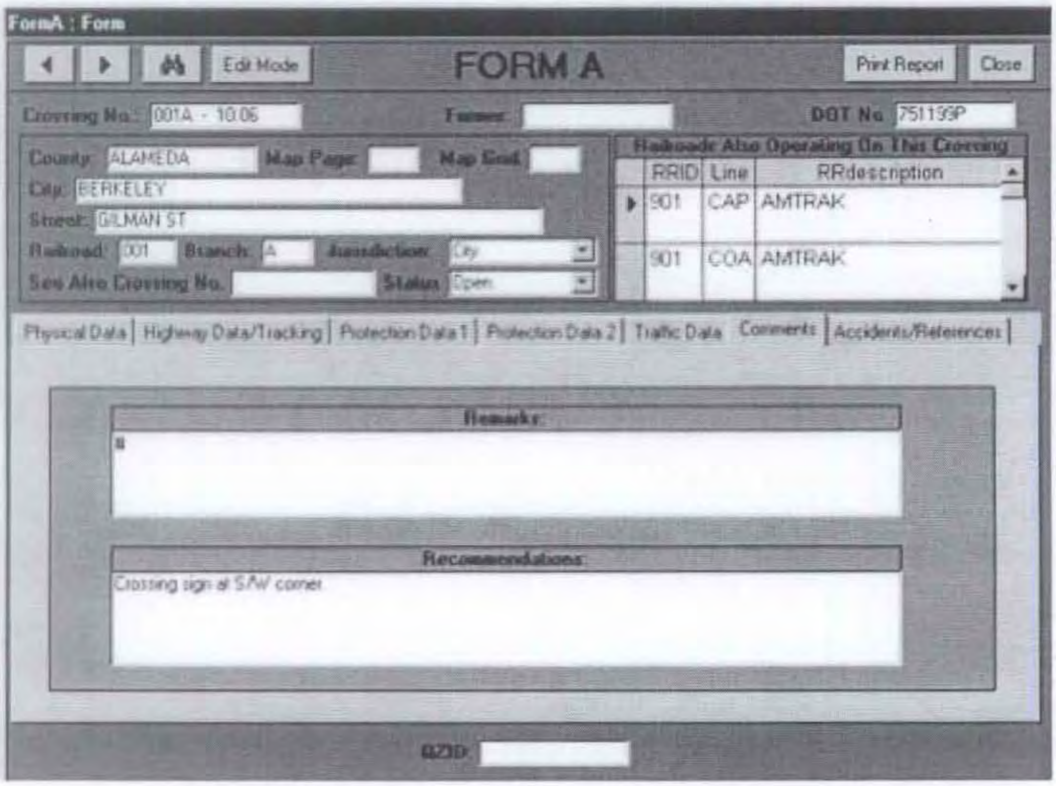





FormA : Form
Edit Mode
FORM A
Print Report
Close
Crossing No.: 001A - 10.06
Former
DOT No 751199P
County: ALAMEDA
Map Page
Map Grid
City: BERKELEY
Street: GILMAN ST
Railroad: 001
Branch: A
Jurisdiction: City
See Also Crossing No.
Status: Open
Railroads Also Operating On This Crossing
RRID
Line
RRdescription
901 CAP AMTRAK
901 COA AMTRAK
Physical Data
Highway Data/Tracking
Protection Data 1
Protection Data 2
Traffic Data
Comments
Accidents/References
Standard Warning Devices
Standard No.
#
Description
9
2 Automatic Gate Type
Date Installed: 12/01/52
Exempt Status
Exempt:
Before 1978:
After 1978
Pavement Markings
RXR:
StopBars:
Night Illumination/ Street Lighting: Yes
Protected Only By Traffic Signals:
Pre-empt Local Traffic Signals:
If yes, first Pre-empted street:
Second pre-empted street:
20" Background Exempt: No
QZID:


FormA : Form
Edit Mode
FORM A
Print Report
Close
Crossing No.: 001A - 10.06
Former
DOT No: 751199P
County: ALAMEDA
Map Page
Map Grid
City: BERKELEY
Street: GILMAN ST
Railroad: 001
Branch: A
Jurisdiction: City
See Also Crossing No.
Status: Open
Railroads Also Operating On This Crossing
RRID
Line
RRdescription
901 CAP AMTRAK
901 COA AMTRAK
Physical Data
Highway Data/Tracking
Protection Data 1
Protection Data 2
Traffic Data
Comments
Accidents/References
Standard Warning Devices
Active:
Description:
Passive:
Limited to four types of devices only
Type
#
Description
Auxiliary Signs
Active:
Description:
Passive:
Limited to four types of devices only
Type
#
Description
QZID:


FormA : Form
Edit Mode
FORM A
Print Report
Close
Crossing No.: 001A - 10.06
Former:
DOT No 751199P
County: ALAMEDA
Map Page:
Map Grid:
City: BERKELEY
Street: GILMAN ST
Railroad: 001
Branch: A
Jurisdiction: City
See Also Crossing No:
Status: Open
Railroads Also Operating On This Crossing
RRID Line RRdescription
901 CAP AMTRAK
901 COA AMTRAK
Physical Data | Highway Data/Tracking | Protection Data 1 | Protection Data 2 | Traffic Data | Comments | Accidents/References
Railroad Traffic Per Day
No. Speed
Passenger...
Freight........
Switch........
Total.......... 70
Date:
Highway Traffic
Vehicles per Day (AADT): 8000
Collected By: City
Collection Date: 04/01/1959
Speed Limit (mph):
QZID:


FormA : Form
Edit Mode
FORM A
Print Report
Close
Crossing No.: 001A - 10.06
Former:
DOT No 751199P
County: ALAMEDA
Map Page:
Map Grid:
City: BERKELEY
Street: GILMAN ST
Railroad: 001
Branch: A
Jurisdiction: City
See Also Crossing No.
Status: Open
Railroads Also Operating On This Crossing
RRID Line RRdescription
901 CAP AMTRAK
901 COA AMTRAK
Physical Data | Highway Data/Tracking | Protection Data 1 | Protection Data 2 | Traffic Data | Comments | Accidents/References
Remarks:
Recommendations:
Crossing sign at S/W corner
QZID:

10.2. APPENDIX B:
FRA CROSSING INVENTORY EXAMPLE

U.S. DOT - CROSSING INVENTORY INFORMATION
AS OF 4/6/2005

Crossing No.: 751199P   Update Reason: Changed Crossing   Effective Begin-Date of Record: 03/28/88
Railroad: UP Union Pacific RR Co. [UP]   Current Record
Initiating Agency Railroad   Type and Position: Public At Grade

Part I Location and Classification of Crossing

Division:	WESTERN	State:	CA
Subdivision:	MARTINEZ	County:	ALAMEDA
Branch or Line Name:	OVERLAND ROUTE	City: In	BERKELEY
Railroad Milepost:	0010.06	Street or Road Name:	GILMAN ST
RailRoad I.D. No.:	A 10.60	Highway Type & No.:	CITY
Nearest RR Timetable Stn:	BERKELEY	HSR Corridor ID:	
Parent Railroad:		County Map Ref. No.:	5L12
Crossing Owner:		Latitude:	37.8786959
ENS Sign Installed:		Longitude:	-122.3045800
Passenger Service:		Lat/Long Source:	Actual
Avg Passenger Trian Count:	0	Quiet Zone:	
Adjacent Crossing with Separate Number:			

Private Crossing Information:

Category: Public Access:
Specify Signs: Specify Signals:

	ST/RR A	ST/RR B	ST/RR C	ST/RR D
Railroad Use:				
State Use:				

Narrative:

Emergency Contact: (800)848-8715   Railroad Contact: State Contact:

Part II Railroad Information

Number of Daily Train Movements: Less Than One Movement Per Day: No
Total Trains: 29   Total Switching: 6   Day Thru: 16
Typical Speed Range Over Crossing: From 1 to 60 mph   Maximum Time Table Speed: 60
Type and Number of Tracks: Main: 2   Other 4   Specify: DRILL&SPUR

Does Another RR Operate a Separate Track at Crossing? No
Does Another RR Operate Over Your Track at Crossing? Yes: ATSF

U.S. DOT - CROSSING INVENTORY INFORMATION
Continued

Crossing 751199P

Effective Begin-Date of Record: 03/28/88

Current Record

Part III: Traffic Control Device Information

Signs:

Crossbucks:	0	Highway Stop Signs:	0
Advanced Warning:	Yes	Hump Crossing Sign:	
Pavement Markings:	Stop Lines and RR Xing Symbols	Other Signs:	0 Specify: 0

Train Activated Devices:

Gates:	2	4 Quad or Full Barrier:	
Mast Mounted FL:	2	Total Number FL Pairs:	0
Cantilevered FL (Over):	0	Cantilevered FL (Not over):	0
Other Flashing Lights:	0	Specify Other Flashing Lights:	
Highway Traffic Signals:	0	Wigwags:	0 Bells: 2
Other Train Activated Warning Devices:		Special Warning Devices Not Train Activated:	
Channelization:		Type of Train Detection:	Constant Warning Time
Track Equipped with Train Signals?	Yes	Traffic Light Interconnection/Preemption:	

Part IV: Physical Characteristics

Type of Development:	Industrial	Smallest Crossing Angle:	60 to 90 Degrees
Number of Traffic Lanes Crossing Railroad:	2	Are Truck Pullout Lanes Present?	No
Is Highway Paved?	Yes		
Crossing Surface:	Timber	If Other:	
Nearby Intersecting Highway?	Less than 75 feet	Is it Signalized?	
Does Track Run Down a Street?	No	Is Crossing Illuminated?	
Is Commercial Power Available?	Yes		

Part V: Highway Information

Highway System:	Non-Federal-aid	Functional Classification of Road at Crossing:	Urban Other Principal
Is Crossing on State Highway System:	No		
Annual Average Daily Traffic (AADT):	011000	AADT Year:	1988
Estimated Percent Trucks:	15	Avg. No of School Buses per Day:	0
Posted Highway Speed:	0		

10.3. APPENDIX C:
SAMPLE ACCIDENT REPORT AND NARRATIVE

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING
ACCIDENT/INCIDENT REPORT

OMB Approval No. 2130-0500

Name Of		Alphabetic Code	RR Accident/Incident No.
1. Reporting Railroad	Amtrak	1a. ATK	1b. 065621
2. Other Railroad Involved in Train Accident/Incident		2a.	2b.
3. Railroad Responsible for Track Maintenance	Union Pacific RR Co.	3a. UP	3b. XXX

4. U.S. DOT-AAR Grade Crossing ID No. 751183T | 5. Date of Accident/Incident 12/06/00 | 6. Time of Accident/Incident 5:43 PM

7. Nearest Railroad Station: BERKELEY | 8. Division: WTR | 9. County: ALAMEDA | 10. State Abbr. CA, Code 06

11. City (if in a city): BERKELEY | 12. Highway Name or No. CITY ; CEDAR ST | ☑ Public ☐ Private

Highway User Involved

13. Type: A. Auto B. Truck C. Truck-trailer D. Pick-up truck E. Van F. Bus G. School Bus H. Motorcycle J. Other Motor Vehicle K. Pedestrian M. Other (specify) — Code: B

14. Vehicle Speed (est. mph at impact): 10

15. Direction (geographical): 1. North 2. South 3. East 4. West — Code: 3

16. Position: 1. Stalled on crossing 2. Stopped on Crossing 3. Moving over crossing 4. Trapped — Code: 3

Rail Equipment Involved

17. Equipment: 1. Train (units pulling) 2. Train (units pushing) 3. Train (standing) 4. Car(s) (moving) 5. Car(s) (standing) 6. Light loco(s) (moving) 7. Light loco(s) (standing) 8. Other (specify) — Code: 1

18. Position of Car Unit in Train: 1

19. Circumstance: 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code: 1

20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20b. Was there a hazardous materials release by 1. Highway User 2. Rail Equipment 3. Both 4. Neither — Code: 4

20c. State the name and quantity of the hazardous materials released, if any

21. Temperature (specify if minus): 60 °F

22. Visibility (single entry): 1. Dawn 2. Day 3. Dusk 4. Dark — Code: 4

23. Weather (single entry): 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code: 1

24. Type of Equipment Consist (single entry): 1. Freight train 2. Passenger train 3. Commuter train 4. Work train 5. Single car 6. Cut of cars 7. Yard/Switching 8. Light loco(s) 9. Other (specify) — Code: 2

25. Track Type Used by Rail Equipment Involved: 1. Main 2. Yard 3. Siding 4. Industry — Code: 1

26. Track Number or Name: NO.#1

27. FRA Track Class (1-6,X): 3

28. Number of Locomotive Units: 3

29. Number of Cars: 10

30. Consist Speed (Recorded if available) R. Recorded E. Estimated: 45 mph — Code: R

31. Time Table Direction: 1. North 2. South 3. East 4. West — Code: 4

32. Type of Crossing Warning: 1. Gates 2. Cantilever FLS 3. Standard FLS 4. Wig wags 5. Hwy. traffic signals 6. Audible 7. Crossbucks 8. Stop signs 9. Watchman 10. Flagged by crew 11. Other (specify) 12. None — Code(s): 01, 06, 07

33. Signaled Crossing Warning: 1 — * See continuation of Form

34. Whistle Ban: 1. Yes 2. No 3. Unknown — Code: 2

35. Location of Warning: 1. Both Sides 2. Side of Vehicle Approach 3. Opposite Side of Vehicle Approach — Code: 1

36. Crossing Warning Interconnected with Highway Signals: 1. Yes 2. No 3. Unknown — Code: 3

37. Crossing Illuminated by Street Lights or Special Lights: 1. Yes 2. No 3. Unknown — Code: 3

38. Driver's Age: 50

39. Driver's Gender: 1. Male 2. Female — Code: 1

40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train: 1. Yes 2. No 3. Unknown — Code: 2

41. Driver: 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other (specify) — Code: 1

42. Driver Passed Standing Highway Vehicle: 1. Yes 2. No 3. Unknown — Code: 2

43. View of Track Obscured by (primary obstruction): 1. Permanent Structure 2. Standing railroad equipment 3. Passing Train 4. Topography 5. Vegetation 6. Highway Vehicles 7. Other (specify) 8. Not Obstructed — Code: 8

Casualties to:	Killed	Injured
48. Highway-Rail Crossing Users	0	1
49. Railroad Employees	0	0
52. Passengers on Train	0	0

44. Driver was: 1. Killed 2. Injured 3. Uninjured — Code: 2

45. Was Driver in the Vehicle? 1. Yes 2. No — Code: 1

47. Highway Vehicle Property Damage (est. dollar damage): $15,000

48. Total Number of Highway-Rail Crossing Users (include driver): 1

50. Total Number of People on Train (include passengers and crew): 87

51. Is a Rail Equipment Accident / Incident Report Being Filed: 1. Yes 2. No — Code: 2

53a. Special Study Block | 53b. Special Study Block

54. Narrative Description
TRAIN NO.#5 WITH ENGS 121/122/77 AND 10 CARS STRUCK A TRUCK AT MP6.8, CEDAR ST AND SECOND AVE CROSSING.

55. Typed Name and Title | 56. Signature | 57. Date

FORM FRA F 6180.57 — * NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

===== RR report 065621 ===== Crossing ID 751183T =====
On Dec 06, 2000 a PASSENGER TRAIN operated by Amtrak [ATK] hit a TRUCK at approximately 5:43PM in California in ALAMEDA county on CITY; CEDAR ST road. The incident occurred in/near BERKELEY city. The rail equipment was reported to have been traveling at 045 Mph with 3 locomotive(s) and 10 cars(s). The TRUCK had been traveling in an easternly direction at 010 Mph.

The railroad was operating on main line track over a public road crossing. It was clear, at night and the temperature was 60. There were 0 death(s) and 1 injured in this incident and a Railroad Injury/Illness Report (form FRA-55a) was also filed. The 50 year old male driver was moving on the crossing and was reported to have driven around or thru gate. There were 1 occupant(s) in the vehicle. The view of the track was not obstructed. Hazardous material was not being transported by rail or highway vehicle.

The crossing was protected by: Gates, Bells (audible), Crossbucks

TRAIN NO.#5 WITH ENGS 121/122/77 AND 10 CARS STRUCK A TRUCK AT MP6.8, CEDAR ST AND SECOND AVE CROSSING.

10.4. APPENDIX D:

UPGRADE EFFECTIVENESS CALCULATION AND SOURCES

	Stop Signs	Flashing Lights	2-Quad Gates	2-Quad Gates + Photo	2-Quad Long-Arm Gates, FL	2-Quad Long-Arm Gates + Photo	2-Quad Gates + Median Separator	2-Quad Gates + Median Separator + Photo	4-Quad Gate System	4-Quad Gate System + Photo	4-Quad Gate System+ Median Separator	4-Quad Gate System + Median Separator + Photo
No Signs or Signals		64% (3)	88% (3)	0.97	0.97	0.99	0.98	0.99	0.98	0.99	0.99	0.99
Cross buck	35% (4)	64% (3)	88% (3)	0.97	0.97	0.99	0.98	0.99	0.98	0.99	0.99	0.99
Stop Signs at Passive Crossings			81%*	0.95	0.95	0.99	0.96	0.99	0.97	0.99	0.98	0.99
WigWags, Audible, Other Activated												
Flashing Lights			44% (3)	0.84	0.86	0.96	0.89	0.97	0.90	0.97	0.96	0.99
2-Quad Gates				72% (1)	75% (1)	0.93	75% (2) 80% (3)	0.94	82% (1)	0.95	92% (1) (2)	0.98
4-Quadrant Gate System											56%**	

* FHWA 1985 - Stop signs 35% effective. Xbuck to 2-quad = 88%, so stop sign to 2 quad = 81%

** 2-quad to 4-quad is 82%, 2-quad to 4-quad+median is 92%, therefore 4-quad to 4-quad+median is 56%

1. Federal Railroad Administration (2001), North Carolina "Sealed Corridor" Phase I, U.S. DOT Assessment Report: Report to Congress

2. Federal Railroad Administration (2005), Use of Locomotive Horns at Highway-Rail Grade Crossings: Final Rule, 49 CFR Parts 222 and 229, Federal Register, Vol. 70, No. 80

3. Caird, J.K., Creaser , J.I. , Edwards , C. J., Dewar, 2002, A Human Factors Analysis Of Highway-Railway Grade Crossing Accidents In Canada

4. Farr, E.H. and Hitz, J.S. (1985), Effectiveness of Motorist Warning Devices at Rail-Highway Crossings, Publication No. FHWA-RD-85-015. Federal Highway Administration, Washington, D.C.

FRA (2005) "Effectiveness rate" means a number between zero and one which represents the reduction of the likelihood of a collision at a public highway-rail grade crossing as a result of the installation of an SSM or ASM when compared to the same crossing equipped with conventional active warning systems of flashing lights and gates.

10.5. APPENDIX E:

CRASH SITES WITH MULTIPLE CRASHES 1995-2004

Fed ID	# Crashes 1995-2004	Crash Dates	Equipment	City	County
028688J	12	1/95, 6/98, 9/99, 1/00, 12/00, 12/00, 12/00, 3/01, 11/01, 1/02, 11/02, 11/04	Gates	Merced	Merced
027656A	11	10/96, 11/98, 9/99, 9/99, 2/00, 11/00, 12/00, 4/01, 5/01, 3/02, 9/03	Gates	Santa Fe Springs	Los Angeles
765937U	10	8/95, 3/98, 3/99, 3/99, 10/99, 2/01, 8/01, 11/01, 1/02, 12/04	Gates	Unincorporated	Merced
026517B	7	1/97, 11/01, 12/02, 12/03, 8/04, 11/04, 12/04	Gates	Unincorporated	Riverside
028553D	6	10/96, 10/96, 12/00, 3/01, 11/01, 2/02	Gates	Fresno	Fresno
026572B	5	1/95, 8/97, 12/97, 9/01, 10/04	Gates	Anaheim	Orange
027650J	5	11/96, 5/98, 12/03, 12/03, 9/04	Gates	Santa Fe Springs	Los Angeles
028527N	5	1/95, 2/00, 8/02, 4/04, 5/04	Flashing Lights	Fresno	Fresno
745911M	5	8/95, 1/97, 8/00, 5/02, 3/04	Gates	Simi Valley	Ventura
745997Y	5	6/96, 12/98, 5/99, 11/01, 11/02	Gates	Van Nuys	Los Angeles
750703W	5	10/98, 12/98, 2/99, 2/02, 6/03	Flashing Lights	Selma	Fresno
026476Y	4	05/96, 11/96, 01/00, 09/00	Gates	Riverside	Riverside
026560G	4	11/95, 02/96, 02/98, 12/04	Gates	Anaheim	Orange
027657G	4	12/96, 12/99, 12/01, 10/04	Gates	La Mirada	Los Angeles
028380R	4	01/95, 07/95, 06/02, 05/03	Flashing Lights	Shafter	Kern
028394Y	4	01/97, 04/97, 12/01, 03/02	Flashing Lights	Shafter	Kern
028517H	4	11/98, 08/99, 11/99, 10/03	Flashing Lights	Fresno	Fresno
028582N	4	03/99, 07/02, 03/03, 11/04	Gates	Fresno	Fresno
028586R	4	04/95, 08/96, 07/98, 02/00	Gates	Fresno	Fresno
745904C	4	02/97, 03/00, 05/00, 11/03	Gates	Moorpark	Ventura
746052E	4	09/96, 10/96, 01/99, 03/02	Gates	Los Angeles	Los Angeles
746804B	4	04/95, 09/95, 10/98, 01/03	Gates	Glendale	Los Angeles
746903Y	4	08/95, 09/96, 10/02, 08/04	Gates	Industry	Los Angeles
746919V	4	10/96, 07/97, 07/97, 12/99	Gates	Pomona	Los Angeles
746972G	4	02/98, 08/99, 09/00, 11/01	Flashing Lights	Fontana	San Bernardino
749946C	4	05/95, 09/95, 11/99, 07/01	Crossbucks	Newark	Alameda
752760S	4	02/96, 02/99, 04/01, 09/01	Gates	Sacramento	Sacramento
757186J	4	10/98, 01/99, 01/99, 02/99	Gates	Malaga	Fresno
757255P	4	12/97, 12/97, 01/98, 12/04	Gates	Monolith	Kern
757316D	4	11/97, 09/98, 08/01, 01/03	Gates	Fresno	Fresno
760732J	4	10/98, 02/03, 07/03, 02/04	Gates	Mecca	Riverside
761540V	4	12/97, 05/01, 03/04, 06/04	Crossbucks	Long Beach	Los Angeles
810913D	4	06/95, 10/99, 03/01, 04/02	Gates	Ontario	San Bernardino
833921K	4	05/01, 06/01, 06/01, 11/01	Gates	French Camp	San Joaquin
865221S	4	11/97, 01/98, 02/98, 03/98	Flashing Lights	Modesto	Stanislaus
026567E	3	05/97, 01/99, 01/00	Gates	Placentia	Orange
026578S	3	10/00, 12/01, 01/02	Flashing Lights	Placentia	Orange
028002V	3	02/97, 03/98, 12/00	Flashing Lights	Inglewood	Los Angeles
028209C	3	03/97, 11/02, 06/04	Gates	Boron	San Bernardino
028379W	3	04/99, 01/02, 03/04	Gates	Shafter	Kern
028397U	3	12/00, 06/02, 11/04	Gates	Wasco	Kern

Fed ID	# Crashes	Crash Dates	Equipment	City	County
028400A	3	02/95, 11/96, 11/01	Gates	Hanford	Kings
028432F	3	02/95, 01/97, 01/98	Gates	Hanford	Kings
028478U	3	03/96, 10/96, 03/01	Gates	Fresno	Fresno
028512Y	3	12/95, 06/03, 12/04	Gates	Fresno	Fresno
028569A	3	11/97, 10/00, 10/01	Gates	Fresno	Fresno
028601R	3	01/99, 07/99, 11/01	Gates	Madera	Madera
028647E	3	10/99, 12/00, 05/01	Gates	Planada	Merced
028673U	3	06/95, 02/04, 05/04	Gates	Merced	Merced
028743G	3	10/97, 04/00, 09/00	Gates	Empire	Stanislaus
028767V	3	02/98, 07/98, 08/98	Gates	Riverbank	Stanislaus
028781R	3	06/99, 10/00, 06/03	Gates	Escalon	San Joaquin
029896N	3	04/01, 11/02, 09/03	Crossbucks	Richmond	Contra Costa
745651W	3	09/95, 12/96, 01/03	Gates	Ventura	Ventura
745855H	3	06/95, 03/98, 03/98	Gates	Oxnard	Ventura
745890W	3	01/95, 07/98, 07/98	Gates	Moorpark	Ventura
746061D	3	06/98, 02/00, 03/01	Gates	Los Angeles	Los Angeles
746064Y	3	02/97, 03/00, 06/04	Gates	Los Angeles	Los Angeles
746880U	3	04/95, 08/99, 04/02	Gates	San Gabriel	Los Angeles
746936L	3	03/00, 07/02, 08/04	Gates	Montclair	San Bernardino
747253Y	3	08/02, 07/03, 10/04	Crossbucks	Chino	San Bernardino
747594S	3	03/99, 10/99, 10/99	Crossbucks	Los Angeles	Los Angeles
747660C	3	07/95, 11/96, 01/97	Flashing Lights	South Gate	Los Angeles
749929L	3	04/98, 06/99, 08/00	Gates	Union City	Alameda
750098A	3	04/96, 06/96, 12/96	Flashing Lights	San Jose	Santa Clara
750503M	3	10/98, 01/00, 11/04	Gates	Redding	Shasta
750643P	3	12/96, 03/99, 11/03	Gates	Palmdale	Los Angeles
751177P	3	07/99, 08/01, 05/02	Other Active	Berkeley	Alameda
751198H	3	01/01, 09/01, 10/02	Gates	Berkeley	Alameda
751678U	3	11/99, 04/00, 10/00	Gates	Richmond	Contra Costa
752434N	3	10/95, 04/00, 05/01	Gates	Manteca	San Joaquin
752746W	3	04/96, 06/00, 08/04	Gates	Elk Grove	Sacramento
752855A	3	10/00, 05/03, 07/03	Gates	Modesto	Stanislaus
752868B	3	07/95, 11/99, 12/99	Gates	Modesto	Stanislaus
755151B	3	12/97, 03/98, 08/99	Flashing Lights	San Jose	Santa Clara
757420X	3	03/99, 12/02, 08/04	Crossbucks	Edison	Kern
760602M	3	01/03, 03/04, 03/04	Flashing Lights	Hawthorne	Los Angeles
766159L	3	05/96, 07/97, 11/04	Gates	Livingston	Merced
810871U	3	06/01, 01/03, 07/03	Gates	Los Angeles	Los Angeles
810893U	3	07/97, 07/97, 07/00	Gates	Ontario	San Bernardino
810977P	3	11/95, 10/96, 05/99	Gates	Riverside	Riverside
810979D	3	02/97, 09/98, 12/99	Gates	Riverside	Riverside
833920D	3	07/98, 12/02, 12/02	Gates	Lathrop	San Joaquin
834259D	3	08/96, 10/96, 01/97	Gates	San Leandro	Alameda

Fed ID	# Crashes	Crash Dates	Equipment	City	County
865219R	3	03/96, 10/98, 03/99	Stop Sign	Modesto	Stanislaus
865259N	3	08/96, 11/99, 03/00	Crossbucks	Escalon	San Joaquin
026006R	2	12/96, 02/99	Gates	San Bernardino	Needles
026070P	2	09/01, 10/01	Crossbucks	San Bernardino	Helendale
026140C	2	12/00, 01/03	Gates	San Bernardino	Rialto
026177S	2	02/01, 06/02	Gates	San Bernardino	Montclair
026475S	2	11/96, 07/98	Gates	Riverside	Riverside
026480N	2	02/96, 08/04	Gates	Riverside	Riverside
026501E	2	09/99, 02/03	Gates	Riverside	Riverside
026519P	2	02/01, 05/01	Gates	Riverside	Corona
026570M	2	08/98, 12/98	Gates	Orange	Placentia
026581A	2	02/98, 11/99	Gates	Orange	Fullerton
026584V	2	01/95, 08/98	Gates	Orange	Fullerton
026697B	2	11/99, 06/04	Gates	Orange	Santa Ana
026699P	2	03/95, 03/01	Gates	Orange	Santa Ana
026742T	2	11/02, 09/03	Gates	Orange	Santa Ana
026743A	2	01/95, 02/95	Gates	Orange	Santa Ana
026765A	2	11/00, 11/01	Gates	Orange	Irvine
026785L	2	11/00, 12/03	Gates	Orange	San Juan Capistrano
026827V	2	07/01, 01/03	Gates	San Diego	Encinitas
026852D	2	11/96, 12/97	Gates	San Diego	San Diego
026866L	2	06/95, 06/97	Gates	San Diego	San Diego
027138E	2	10/01, 03/04	Crossbucks	San Bernardino	Hesperia
027583S	2	05/95, 06/99	Crossbucks	San Diego	San Marcos
027643Y	2	10/95, 11/01	Gates	Los Angeles	Pico Rivera
027647B	2	02/96, 05/96	Gates	Los Angeles	Santa Fe Springs
027837E	2	08/96, 02/00	Flashing Lights	Los Angeles	Santa Fe Springs
027907S	2	10/01, 01/03	Crossbucks	Los Angeles	Vernon
027945B	2	06/96, 09/01	Gates	Los Angeles	Vernon
027950X	2	09/99, 12/99	Gates	Los Angeles	Huntington Park
027963Y	2	07/95, 07/01	Gates	Los Angeles	Los Angeles
028072K	2	04/95, 02/00	Gates	Los Angeles	Redondo Beach
028310B	2	10/95, 04/01	Flashing Lights	Kern	Wasco
028343N	2	08/95, 12/03	Gates	Kings	Corcoran
028386G	2	09/98, 11/00	Gates	Kern	Shafter
028409L	2	07/04, 07/04	Gates	Kings	Hanford
028442L	2	01/99, 12/00	Gates	Fresno	Laton
028453Y	2	09/96, 09/02	Gates	Fresno	Fresno
028454F	2	02/03, 02/03	Gates	Fresno	Fresno
028552W	2	08/97, 06/98	Gates	Fresno	Fresno
028554K	2	07/95, 06/96	Gates	Fresno	Fresno
028556Y	2	01/97, 04/03	Flashing Lights	Fresno	Fresno
028570U	2	03/95, 09/99	Flashing Lights	Fresno	Fresno

Fed ID	# Crashes	Crash Dates	Equipment	City	County
028578Y	2	10/96, 02/01	Gates	Fresno	Fresno
028585J	2	12/01, 09/03	Gates	Fresno	Fresno
028618U	2	11/96, 07/97	Gates	Madera	Madera
028627T	2	01/02, 01/04	Gates	Madera	Madera
028687C	2	03/98, 04/04	Gates	Merced	Merced
028704R	2	03/99, 12/00	Gates	Merced	Atwater
028705X	2	12/98, 02/03	Gates	Merced	Winton
028706E	2	10/00, 05/04	Gates	Merced	Winton
028714W	2	03/01, 09/01	Gates	Merced	Denair
028739S	2	03/95, 01/97	Gates	Stanislaus	Empire
028752F	2	11/02, 03/04	Gates	Stanislaus	Riverbank
028755B	2	05/95, 05/99	Gates	Stanislaus	Riverbank
028790P	2	05/98, 09/04	Gates	Stanislaus	Riverbank
029371V	2	02/01, 02/03	Other Active	Fresno	Fresno
029578C	2	07/98, 04/02	Gates	San Joaquin	Stockton
029654T	2	10/95, 11/04	Gates	Contra Costa	Antioch
029677A	2	10/96, 05/98	Gates	Contra Costa	Antioch
029854C	2	11/95, 03/01	Flashing Lights	Contra Costa	Richmond
411774J	2	03/01, 10/02	Flashing Lights	San Bernardino	Ontario
687892A	2	09/01, 10/01	Flashing Lights	Yolo	West Sacramento
745838S	2	10/02, 11/03	Gates	Ventura	El Rio
745839Y	2	10/00, 12/02	Gates	Ventura	El Rio
745989G	2	06/99, 03/01	Gates	Los Angeles	Los Angeles
745990B	2	01/00, 08/00	Gates	Los Angeles	Los Angeles
745998F	2	02/99, 08/03	Gates	Los Angeles	Van Nuys
746006D	2	06/95, 10/02	Gates	Los Angeles	Los Angeles
746016J	2	01/99, 07/99	Gates	Los Angeles	Santa Clarita
746047H	2	09/95, 08/03	Gates	Los Angeles	San Fernando
746054T	2	01/95, 10/02	Gates	Los Angeles	Los Angeles
746784S	2	02/97, 01/03	Gates	Los Angeles	Burbank
746796L	2	01/00, 01/03	Gates	Los Angeles	Glendale
746797T	2	08/96, 01/97	Gates	Los Angeles	Glendale
746859N	2	01/97, 03/97	Gates	Los Angeles	Los Angeles
746898E	2	03/95, 05/03	Gates	Los Angeles	El Monte
746964P	2	10/96, 01/01	Gates	San Bernardino	San Bernardino
746970T	2	04/98, 03/01	Flashing Lights	San Bernardino	Fontana
747267G	2	12/96, 03/01	Crossbucks	San Bernardino	Chino
747316B	2	07/95, 07/03	Gates	Los Angeles	Covina
747602G	2	06/98, 10/99	Flashing Lights	Los Angeles	Los Angeles
747615H	2	02/00, 04/01	Crossbucks	Los Angeles	Los Angeles
747622T	2	10/97, 11/99	Other Active	Los Angeles	Los Angeles
747629R	2	03/98, 12/98	Crossbucks	Los Angeles	Los Angeles
747656M	2	01/96, 09/97	Flashing Lights	Los Angeles	Los Angeles

Fed ID	# Crashes	Crash Dates	Equipment	City	County
747669N	2	10/96, 02/97	Flashing Lights	Los Angeles	Lynwood
747701E	2	06/01, 01/03	Flashing Lights	Los Angeles	Los Angeles
747711K	2	11/98, 11/98	Gates	Los Angeles	Los Angeles
747735Y	2	10/01, 09/04	Crossbucks	Los Angeles	Los Angeles
747833P	2	01/97, 06/01	Flashing Lights	Los Angeles	Los Angeles
747834W	2	04/95, 11/96	Other Active	Los Angeles	Los Angeles
747876H	2	04/98, 07/00	Crossbucks	Los Angeles	Compton
747899P	2	11/96, 04/98	Other Active	Los Angeles	Carson
748865Y	2	05/96, 12/02	Gates	Siskiyou	Mount Shasta
749584T	2	12/95, 09/01	Flashing Lights	Alameda	Oakland
749585A	2	10/00, 11/03	Flashing Lights	Alameda	Oakland
749712Y	2	11/96, 02/99	Gates	Alameda	Oakland
749907L	2	11/97, 07/98	Gates	Alameda	Hayward
749965G	2	03/99, 06/03	Flashing Lights	Santa Clara	Santa Clara
750102M	2	04/96, 01/00	Flashing Lights	Santa Clara	San Jose
750504U	2	10/97, 08/99	Gates	Shasta	Redding
750506H	2	11/95, 05/99	Gates	Shasta	Redding
750642H	2	01/95, 11/03	Gates	Los Angeles	Lancaster
750954R	2	09/01, 01/04	Crossbucks	Kern	Bakersfield
751224V	2	03/97, 08/00	Gates	Yolo	Davis
751291P	2	06/01, 05/02	Gates	Solano	Fairfield
751294K	2	11/99, 11/01	Gates	Solano	Fairfield
751527E	2	01/95, 04/95	Gates	Solano	Benicia
751693W	2	05/95, 10/03	Gates	Contra Costa	Richmond
751754K	2	01/97, 10/03	Flashing Lights	Contra Costa	Martinez
752445B	2	01/02, 01/02	Gates	San Joaquin	Manteca
752446H	2	07/03, 02/04	Gates	San Joaquin	Manteca
752775G	2	01/96, 01/04	Gates	San Joaquin	Stockton
752887F	2	07/99, 12/99	Gates	Sacramento	Sacramento
752929P	2	10/95, 11/96	Crossbucks	San Joaquin	Stockton
753140G	2	10/98, 11/99	Gates	Placer	Bowman
753188J	2	01/99, 07/04	Gates	Nevada	Truckee
753238K	2	08/95, 04/96	Gates	Placer	Lincoln
753250S	2	02/99, 08/00	Gates	Placer	Sheridan
753289V	2	10/97, 10/99	Flashing Lights	Sutter	Yuba City
754904B	2	08/95, 12/98	Gates	San Mateo	San Mateo
755011Y	2	05/01, 01/04	Gates	Santa Clara	Palo Alto
755013M	2	03/99, 04/04	Gates	Santa Clara	Mountain View
755148T	2	12/95, 06/98	Gates	Santa Clara	San Jose
756766W	2	07/97, 12/02	Crossbucks	Tulare	Dinuba
756867H	2	04/00, 08/01	Gates	Fresno	Fowler
756949P	2	11/99, 08/02	Gates	Kern	Bakersfield
757413M	2	02/98, 04/02	Gates	Kern	Edison

Fed ID	# Crashes	Crash Dates	Equipment	City	County
760558C	2	09/96, 10/04	Crossbucks	Los Angeles	Los Angeles
760678T	2	08/96, 01/97	Gates	Riverside	Calimesa
760685D	2	05/01, 11/02	Flashing Lights	Riverside	Beaumont
760690A	2	12/98, 09/04	Gates	Riverside	Banning
760714L	2	04/03, 03/04	Gates	Riverside	Indio
760717G	2	05/98, 09/02	Gates	Riverside	Indio
760848K	2	05/99, 12/99	Crossbucks	Imperial	Imperial
760982W	2	02/95, 07/02	Gates	Madera	Madera
761132K	2	07/95, 08/96	Gates	Madera	Madera
761167L	2	12/95, 02/98	Flashing Lights	Orange	Anaheim
761525T	2	01/96, 07/02	Flashing Lights	Los Angeles	Los Angeles
761526A	2	01/96, 12/96	Flashing Lights	Los Angeles	Los Angeles
761541C	2	03/00, 10/00	Crossbucks	Los Angeles	Long Beach
762301Y	2	08/02, 05/04	Gates	Tehama	Red Bluff
765942R	2	03/99, 09/99	Gates	Merced	Chowchilla
765943X	2	03/97, 08/99	Gates	Merced	Chowchilla
766040P	2	02/95, 11/98	Flashing Lights	Tulare	Tulare
810868L	2	01/95, 06/98	Crossbucks	Los Angeles	Industry
810885C	2	12/99, 03/02	Gates	Los Angeles	City Of Industry
810899K	2	12/98, 11/02	Gates	Los Angeles	Pomona
810907A	2	12/98, 07/04	Gates	San Bernardino	Ontario
810910H	2	01/98, 11/99	Gates	San Bernardino	Ontario
810936K	2	12/98, 04/04	Crossbucks	Los Angeles	Vernon
811065H	2	10/95, 05/97	Crossbucks	Los Angeles	Vernon
811069K	2	07/96, 07/99	Flashing Lights	Los Angeles	Industry
811479J	2	08/03, 12/04	Gates	Los Angeles	Los Angeles
833642P	2	11/03, 05/04	Flashing Lights	Lassen	Westwood
833704K	2	08/02, 08/02	Crossbucks	Plumas	Quincy
833901Y	2	12/02, 08/04	Crossbucks	Santa Clara	Milpitas
833930J	2	10/00, 09/04	Gates	San Joaquin	Stockton
834942G	2	05/04, 11/04	Gates	Yuba	Marysville
835052A	2	09/98, 09/98	Gates	Butte	Marysville
853843K	2	11/96, 12/99	Flashing Lights	Stanislaus	Modesto
865215N	2	09/95, 02/96	Crossbucks	Stanislaus	Modesto
865223F	2	11/95, 01/98	Flashing Lights	Stanislaus	Modesto
865231X	2	05/96, 09/96	Flashing Lights	Stanislaus	Modesto
865283P	2	05/96, 08/96	Crossbucks	Stanislaus	Modesto
865288Y	2	11/97, 02/99	Crossbucks	Stanislaus	Ceres
865360M	2	01/96, 06/99	Flashing Lights	San Joaquin	Escalon

10.6. APPENDIX F:
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10.7. APPENDIX G:
LEIBOWITZ HYPOTHESIS

A TEST OF THE LEIBOWITZ HYPOTHESIS by Joseph E. Barton, Theodore E. Cohn and Robert V. Kenyon, 2006

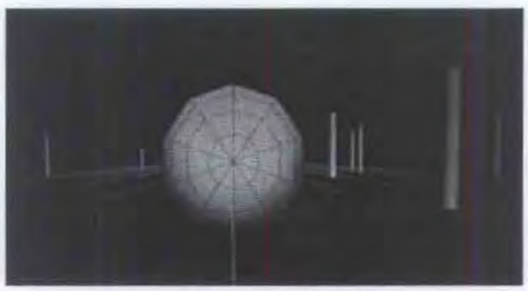
Do large objects appear to approach more slowly than smaller objects traveling at the same speed? If so then this might help explain the inordinately high accident rates involving large vehicles such as buses and trains. To test this we constructed an experiment using a 3D visual simulator in which different sized textured spheres approached at different speeds. We found that observers consistently judged the smaller sphere to be the faster, even in cases where the larger sphere was traveling at up to twice the speed of the smaller. Analysis of these results suggests that the brain relies upon the perceived rate of change of an object's visual angle, dθ/dt, to determine how quickly an object is approaching.

Rear-end collisions with buses and collisions with trains at railroad crossings occur at significantly higher rates than the corresponding cases involving only automobiles. This has long puzzled accident investigators, since one would expect the movements of larger objects to be more easily noticed and interpreted by motorists. In a 1985 article, Leibowitz observed that large aircraft at airports appeared to move more slowly than smaller aircraft, even though the former were traveling much faster. He went on to hypothesize that this misperception must in turn be caused by the way in which the brain processed and interpreted the visual information provided in this scenario. To our knowledge, Leibowitz' hypothesis has never been tested, and we set out to do this using a 3D visual simulator.

We constructed a two alternative forced choice (2AFC) experiment consisting of two sequential time epochs. In one of the epochs, chosen at random, a five foot diameter sphere approached the observer at eye level, traveling at 35 mph. In the other epoch, a ten foot diameter sphere approached at one of the speeds given in Figure 1a. The observer's task was to indicate by pressing a button which epoch contained the faster approaching sphere. An experiment consisted of 270 such trials. The number of times that the ten foot diameter sphere assumed each approach speed (also selected randomly) is also indicated in Figure G1a.

Speed (mph)	# Trials (Out of 270)
25	40
35	40
45	40
55	50
65	50
75	50

a) Ten Foot Diameter Approach Speed



b) Approaching Sphere

Figure G-1

A faceted white sphere was constructed using OpenGL (10 longitudinal slices, 10 lateral slices, with a black wire-frame coinciding with the edges formed by the slices). It was presented against a black ground plane and horizon. The ground plane was delineated with yellow longitudinal lines 5 ft apart. Twenty white, six ft high, .25 ft diameter cylinders were randomly placed throughout the ground plane (but not in the path of the approaching sphere) to give the observer a sense of perspective and proportion. The scene was presented on a projection-based virtual reality (VR) system. The viewer, seated in front of the projection screen, wears stereo shutter glasses and a six-degrees-of-freedom head-tracking device. As the viewer moves his or her head, the correct stereoscopic perspective projections are calculated for each eye and presented. The scene was presented with a frame rate in excess of 60 Hz (resulting in a greater than 30 Hz frame rate for each eye.) A frame from one such presentation is shown in Figure 1b. Each time epoch started with the sphere 6.5 seconds away from the observer, and ended with the sphere 0.25 seconds away, so that it remained in view for 6.25 sec. Since tests of this type are fatiguing, the experiment was divided into four segments of approximately 67 trials each to give test subjects a chance to rest in between. Subjects could also stop and rest within a segment if they needed to.

Four visual cues are thus available to the observer in judging the faster of the two approaching spheres: monocular image expansion, binocular cues deriving from stereopsis, texture dilation, and reference to the static cylindrical posts and ground plane lines. Even though we have included binocular effects in these experiments, we do not expect them to play much, if any, role in this task. Since such effects are not noticeable at distances greater than approximately 30 ft, this information will not be available to observers until the final 0.33 sec of a (6.25 sec) 35 mph approach, and only the final 0.02 sec of a 75 mph approach. It seems highly unlikely that the brain would be able to utilize such a small quantity of information, occurring at the very end of the presentation. Here we allow the sphere to come within .25 sec of the observer before occluding it. In practical applications where decisions would have to be made 2-4 sec before collision, binocular cues would be entirely unavailable.

We tested the ability of five males (labeled S1 to S5, ranging in age from the early 20's to the mid 50's, with corrected normal eyesight) to identify the faster of two, different sized approaching spheres. The results of these tests are summarized in Figure G2, which plots the

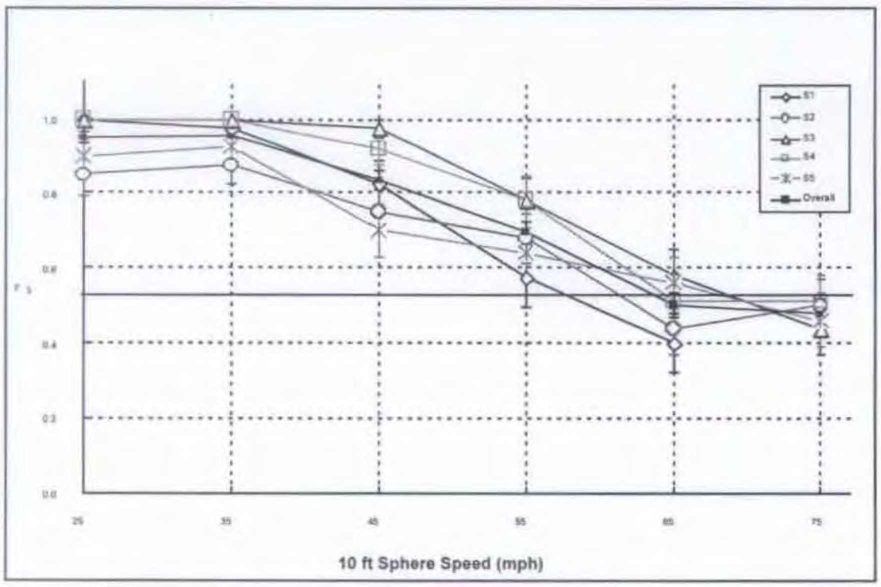


Figure G-2: Experimental Results

proportion of times the 5 ft diameter sphere was judged to be faster (P_5) as a function of 10 ft sphere speed (V_{10}). This shows a strong tendency to judge the smaller sphere as the faster, even when the actual approach speed of the larger sphere is 20 mph greater ($V_{10} = 55$ mph). Only when V_{10} reaches speeds of 65-75 mph (twice that of the smaller sphere) does the observer become unsure as to which is approaching faster ($P_5 \approx 0.5$).

Let z(t) be the distance from the observer to the sphere at any time t ($0 \le t \le 6.5$ sec). Then

$$z(t) = V(6.5-t)$$

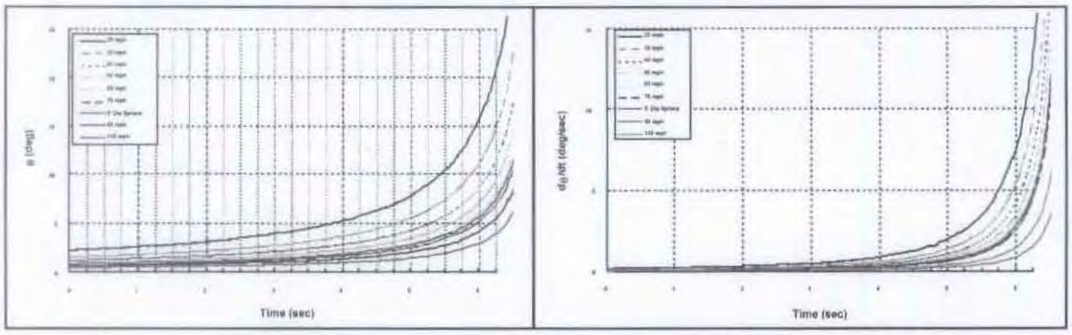
Where $V = dz/dt$ is the approach velocity of the sphere. If r is the sphere's radius, then the visual angle θ_r that it subtends is

$$\theta_r(t) = 2\tan^{-1}\left(\frac{r}{z(t)}\right) = 2\tan^{-1}\left(\frac{r}{V(6.5-t)}\right)$$

while

$$\frac{d\theta_r}{dt} = \frac{r}{z^2 + r^2}V$$

These are plotted as functions of time in Figure 3. From these we see that for $V_{10} < 70 = 2\ V_5$,



θ vs time **dθ/dt vs time**

Figure G3

$\theta_{10} > \theta_5$ and $d\theta_{10}/dt > d\theta_5/dt$ for all t. For $V_{10} > 2\ V_5$ the opposite holds, and for $V_{10} = 2\ V_5$ the two sets of profiles coincide with one another. This final observation demonstrates the obvious fact that the monocular view of the smaller sphere's approach is exactly matched by that of a sphere twice as large, approaching twice as fast, from twice as far away. This, along with our experimental results, suggests that observers rely heavily on the monocular cues when making judgments about the speeds of approaching objects. In this case they could be relying exclusively on θ (i.e., comparing θ for various t), exclusively on dθ/dt, or they could be using both in some combination.

If it is true that observers place heavy emphasis on monocular cues in performing this task, then it is easy to see why judgments about approaching objects are so unreliable. interesting note that for $V_{10} < 2\ V_5$ the brain judges the larger sphere to be approaching more slowly, even though its associated subtended angle and expansion rate are both *greater* than those associated with the smaller sphere.

We note too that compared with the final 2-3 seconds of the approach, the information provided in the first 3-4 seconds appears barely distinguishable in going from one speed to the next.

- They could be observing and comparing θ for various t in order to infer approach speed;
- They could be observing dθ/dt directly.

10.8. APPENDIX H:
CALIFORNIA VEHICLE CODE:
AUTOMATED ENFORCEMENT: PHOTOGRAPHIC RECORDS

2006 California Vehicle Code

Division 11: Rules of the Road
Chapter 2 Traffic Signs, Signals, and Markings
Article 3: § § 21450-21468 - Offenses Relating to Traffic Devices

21455.5 Traffic Signal Automated Enforcement

21455.5. (a) The limit line, the intersection, or a place designated in Section 21455, where a driver is required to stop, may be equipped with an automated enforcement system if the governmental agency utilizing the system meets all of the following requirements:

(1) Identifies the system by signs that clearly indicate the system's presence and are visible to traffic approaching from all directions, or posts signs at all major entrances to the city, including, at a minimum, freeways, bridges, and state highway routes

(2) If it locates the system at an intersection, and ensures that the system meets the criteria specified in Section 21455.7.

(b) Prior to issuing citations under this section, a local jurisdiction utilizing an automated traffic enforcement system shall commence a program to issue only warning notices for 30 days. The local jurisdiction shall also make a public announcement of the automated traffic enforcement system at least 30 days prior to the commencement of the enforcement program.

(c) Only a governmental agency, in cooperation with a law enforcement agency, may operate an automated enforcement system. As used in this subdivision, "operate" includes all of the following activities:

(1) Developing uniform guidelines for screening and issuing violations and for the processing and storage of confidential information, and establishing procedures to ensure compliance with those guidelines.

(2) Performing administrative functions and day-to-day functions, including, but not limited to, all of the following:

(A) Establishing guidelines for selection of location.

(B) Ensuring that the equipment is regularly inspected.

(C) Certifying that the equipment is properly installed and calibrated, and is operating properly.

(D) Regularly inspecting and maintaining warning signs placed under paragraph (1) of subdivision (a).

(E) Overseeing the establishment or change of signal phases and the timing thereof.

(F) Maintaining controls necessary to assure that only those citations that have been reviewed and approved by law enforcement are delivered to violators.

(d) The activities listed in subdivision (c) that relate to the operation of the system may be contracted out by the governmental agency, if it maintains overall control and supervision of the system. However, the activities listed in paragraph (1) of, and subparagraphs (A), (D), (E), and (F) of paragraph (2) of, subdivision (c) may not be contracted out to the manufacturer or supplier of the automated enforcement system.

(e) (1) Notwithstanding Section 6253 of the Government Code, or any other provision of law, photographic records made by an automated enforcement system shall be confidential, and shall be made available only to governmental agencies and law enforcement agencies and only for the purposes of this article.

(2) Confidential information obtained from the Department of Motor Vehicles for the administration or enforcement of this article shall be held confidential, and may not be used for any other purpose.

(3) Except for court records described in Section 68152 of the Government Code, the confidential records and information described in paragraphs (1) and (2) may be retained for up to six months from the date the information was first obtained, or until final disposition of the citation, whichever date is later, after which time the information shall be destroyed in a manner that will preserve the confidentiality of any person included in the record or information.

(f) Notwithstanding subdivision (d), the registered owner or any individual identified by the registered owner as the driver of the vehicle at the time of the alleged violation shall be permitted to review the photographic evidence of the alleged violation.

(g) (1) A contract between a governmental agency and a manufacturer or supplier of automated enforcement equipment may not include provision for the payment or compensation to the manufacturer or supplier based on the number of citations generated, or as a percentage of the revenue generated, as a result of the use of the equipment authorized under this section.

(2) Paragraph (1) does not apply to a contract that was entered into by a governmental agency and a manufacturer or supplier of automated enforcement equipment before January 1, 2004, unless that contract is renewed, extended, or amended on or after January 1, 2004.

Added and Repealed Sec. 4, Ch. 922, Stats. 1995. Effective January 1, 1996. Repeal operative January 1, 1999.
Amended Sec. 3, Ch. 54, Stats. 1998. Effective January 1, 1999.
Amended Sec. 1, Ch. 496, Stats. 2001. Effective January 1, 2002.
Amended Sec. 1, Ch. 511, Stats. 2003. Effective January 1, 2004

Automated Enforcement Systems: Hearing: Prohibited Use

21455.6. (a) A city council or county board of supervisors shall conduct a public hearing on the proposed use of an automated enforcement system authorized under Section 21455.5 prior to authorizing the city or county to enter into a contract for the use of the system.

(b) (1) The activities listed in subdivision (c) of Section 21455.5 that relate to the operation of an automated enforcement system may be contracted out by the city or county, except that the activities listed in paragraph (1) of, and subparagraphs (A), (D), (E), or (F) of paragraph (2) of, subdivision (c) of Section 21455.5 may not be contracted out to the manufacturer or supplier of the automated enforcement system.

(2) Paragraph (1) does not apply to a contract that was entered into by a city or county and a manufacturer or supplier of automated enforcement equipment before January 1, 2004, unless that contract is renewed, extended, or amended on or after January 1, 2004.

(c) The authorization in Section 21455.5 to use automated enforcement systems does not authorize the use of photo radar for speed enforcement purposes by any jurisdiction.
Added Sec. 17, Ch. 828, Stats. 1998. Effective January 1, 1999.
Amended Sec. 8, Ch. 860, Stats. 2000. Effective January 1, 2001.
Amended Sec. 2, Ch. 511, Stats. 2003. Effective January 1, 2004.

10.9. APPENDIX I:
CROSSING OBSERVATIONS

Observation of drivers at rail crossings provides an invaluable tool for understanding their behavior under different combinations of grade crossing equipment and train frequencies and speeds. Three different methods were examined: a crossing camera at College Station, Texas, a crossing camera at Berkeley, California, and a train engine based camera in Napa California.

College Station, Texas

College Station, population 70,000 and located 90 miles northwest of Houston, has a rail monitoring system, The College Station ITS Integration Project (CSIP), set up along the Wellborn Road Corridor, a major north-south arterial in College Station. The project is a joint venture between the Texas Transportation Institute (TTI), the City of College Station Traffic Signal Office, and the City of College Station Fire Department and was set up to provide the City's Fire Station #4 with grade crossing status and travel time prediction information for trains traveling in both directions in the project corridor to aid station personnel in making route decisions when servicing an emergency call.

Adjacent to Wellborn Road lies the Union Pacific Railroad's Fort Worth Subdivision mainline which carries approximately 20 to 25 trains per day, varying from 1/2 mile to 1 1/2 miles in length. Train speed through the corridor can be as low as 15 to 20 mph as trains pull out of a siding just to the north of the project corridor to as high as 50 mph at the southern end of the corridor as the train enters a more rural area. Trains in the corridor do not travel on a fixed time schedule, but arrive randomly throughout the day, depending on train traffic on the line (TTI 2005).

The camera used for our observations is located on a pole on the southwest corner of the intersection of Holleman Drive and Wellborn Road where the tracks cross Holleman. Since we did not control the camera, our view was limited to the west side of the tracks as Holleman approaches Wellborn. The camera view is shown in Figure 1.This is not an ideal location for driver behavior research in that there is room for only one car per lane between the tracks and Wellborn (Figure 2). This space is quite often full, thus taking away the possibility of driving under or around the rail line crossing gates. Also, the position of the camera did not allow us to observe the flashing lights.

Figure I-1: College Station, Texas, Camera View

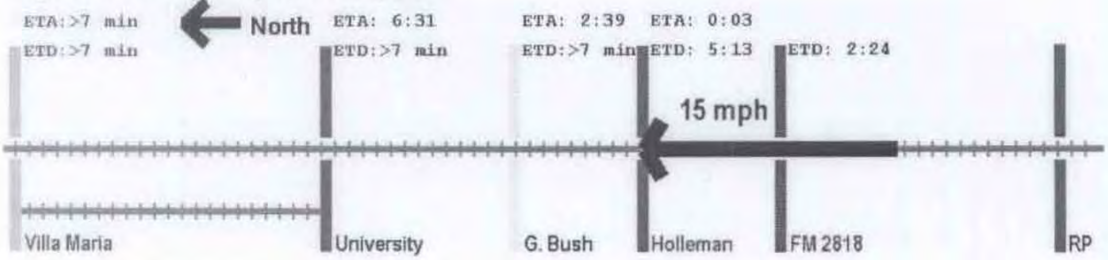
Figure I-2: Holleman and Wellborn Intersection

Procedure

Approximately 300 hours of live video feed from the College Station Holleman Avenue camera was downloaded from the internet and stored, using the MPEG4 format, for a total of 24 weekdays between June 22, 2005 and September 2, 2005. The number of hours of video we recorded in a day varied considerably due to the fact that if the signal was lost, even momentarily, the recording stopped. Since we did not have someone constantly monitoring the recording, it could be several hours before the recording was started up again. There were also days when the camera was not directed at the crossing.

At the same time we were collecting video data, a graphic depicting train speeds along the corridor (Figure 12) was downloaded at 20 second intervals, and stored. The direction of the train is illustrated with an arrow whose length is representative of the real length of the train.

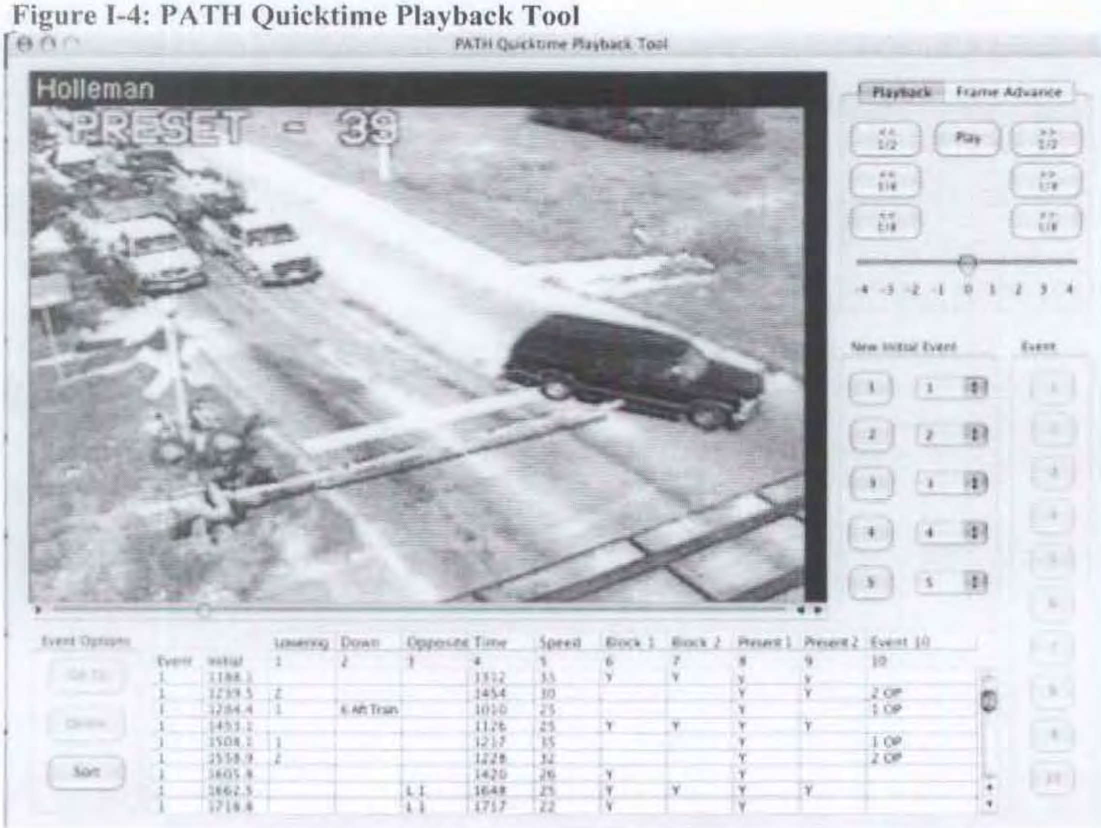
Figure I-3: Train Speed Graphic



After collection, the editing process began. The video was viewed using Quicktime Player and each gate operation during which cars were present was copied into a new file with the rest of that day's operations. This process took approximately one half hour for every 12 hours of raw video. Next the speed, date and time of each train were spliced into the video. This was a slow process, requiring about 10 minutes per train. The final editing step was to splice each day's video into one complete video.

The final data collection step utilized the PATH Quicktime Playback Tool shown in Figure 13. This tool allowed us to view the video at various speed, including frame by frame, time stamp events, and record the various kinds of infractions and behaviors. The resulting text file can then be opened and analyzed in Microsoft Excel.

Figure I-4: PATH Quicktime Playback Tool



Results
During the observation period, we were able to record 116 gate cycles during which cars were present. During 45 of those, cars were present in the storage space beyond the tracks, preventing approaching traffic on Holleman from crossing the tracks. In the remaining 71 cycles, 48 cars had the opportunity (defined as arriving at the crossing before the road was blocked by the gate) to go under the descending gate and 28 cars (58%) did so. One of the 28 cars went around stopped traffic and one car was hit by the gate.

Also during the 71 unblocked cycles, nine cars went around a lowered gate. Six of these took place after the train had passed and the gate did not go up. Two of the remaining three occurred in front of a train traveling at seven miles-per-hour and the last one in front of a train traveling at 26 miles-per-hour. In the case of the slow train, 35 seconds passed from the time the second car cleared the tracks until the train arrived. In the third case, the train arrived at the crossing nine seconds after the car had cleared.

Equipment
The primary objective of the College Station project was to provide the City of College Station Fire Station #4 with grade crossing status and travel time prediction information for trains traveling in both directions in the project corridor so that they could use the information in making route decisions when servicing an emergency call. While useful for monitoring behavior at rail crossings it cannot be used as a model for such observations given its complexity, need for long distance transmission of video signals, and long term durability requirements, which would make it prohibitively expensive.

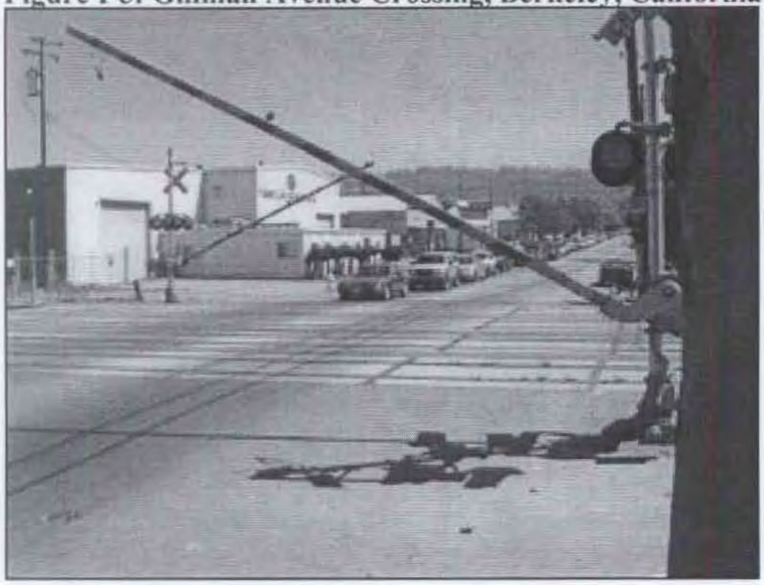
Berkeley, California

The Gilman street crossing in Berkeley, California, has two lanes of traffic crossing three sets of tracks, of which only two are used. The crossing is equipped with two quadrant gates, bells and flashing lights. There are up to 70 trains per day including 24 operated by Amtrak's Capitol Corridor, consisting of an engine and four passenger cars traveling at speeds up to 60 MPH.

Procedure
Two different setups were used during our observations at this location. The first, shown in Figure 15, utilized two cameras, each located in the back of a van parked along Gilman Avenue. Each camera was set up so as to shoot traffic coming directly at it from across the tracks and on the same side of the street. This setup turned out to have two major disadvantages. First, since vehicular traffic was coming directly at the camera, speeds and distances were very difficult to judge. Additionally, the first car in the queue blocked the view of any other cars. This was compounded by the second problem, which was that the cameras, located inside the vans, were too low to get a good view of the crossing.

These problems were solved by going to the setup shown in Figure 16. Here the vans were moved directly across the street from their original position so that they could view traffic diagonally across the tracks. Also, the cameras were mounted on poles which offered a much better view.

Figure I-5: Gillman Avenue Crossing, Berkeley, California



FigureI-6: Gilman Ave. First Setup

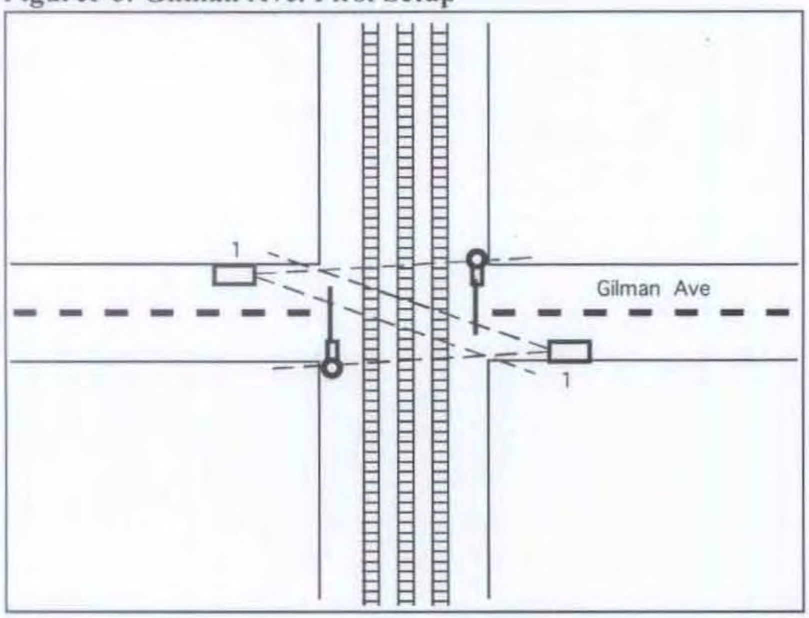
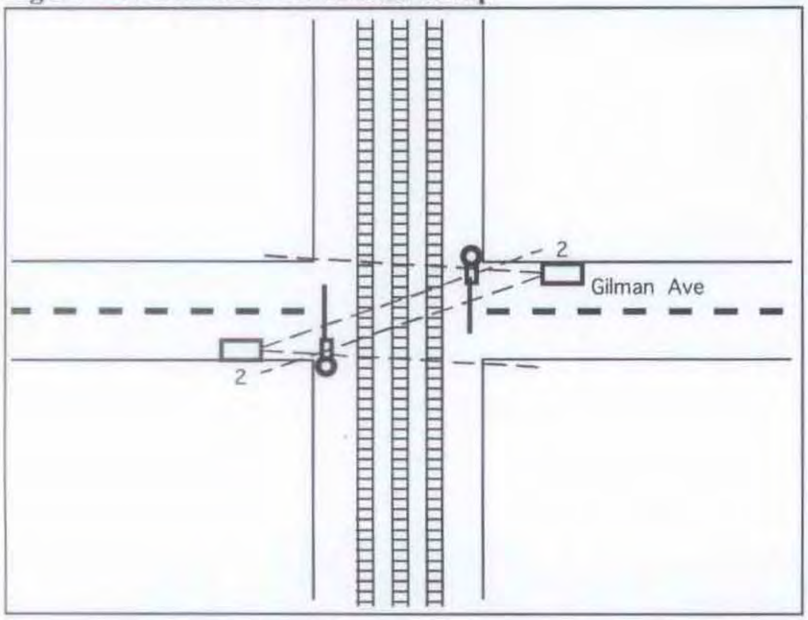


Figure I-7: Gilman Ave. Second Setup



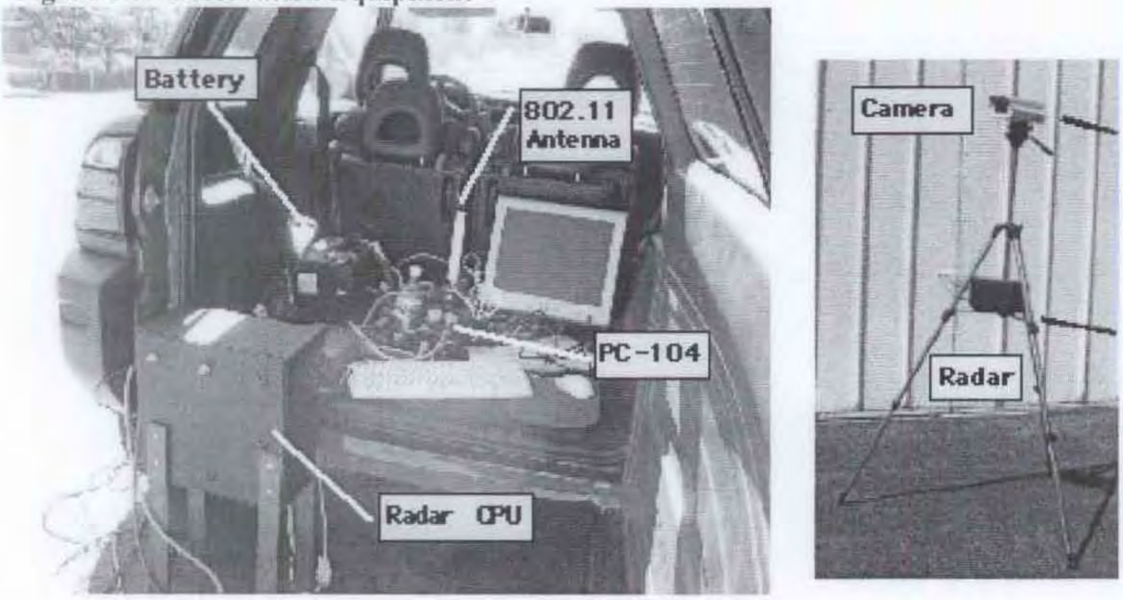
Results

Over a period of four days, there were a total 114 gate cycles with vehicles present (eastern and western gate cycles counted separately). There were 86 opportunities for a vehicle to go under a descending gate - 17 vehicles (19.8%) did so. No cars went around fully descended gates.

Gilman Avenue Observation Equipment

°Traffic Monitoring Video Cameras
  High resolution and weather proof
°PC-104 Digital Video Recorder
  Automated data collection
  Converts video to MPEG format
°Eaton-VORAD Radar Sensors
  Train and motor vehicle speed

Figure I-8: Observation Equipment



Napa Valley Wine Train

The Napa Valley Wine Train provides a 3-hour round-trip covering the 36- miles between the town of Napa through the village of St. Helena and back. The train consists of nine rail cars and a double-sided Alco Diesel Engine. The data collected from this train comes from a camera mounted in the engine and operated by the engineers. The resulting tapes were obtained from the Napa Valley Railroad Police Department. While the data are anecdotal in nature they provide valuable insight into the public's general lack of knowledge of both the law regarding rail crossings and the basic laws of physics. One person, for example, a passenger in a car that had stalled on the tracks, got out of her car and stood between the car and the oncoming train, waving for the engineer to stop. Fortunately, a woman in another car got out and dragged the first woman to safety just before the train hit her car.

Traffic Safety Center
Setting New Directions in Traffic Safety

CALIFORNIA PATH

FINAL REPORT

DRIVER BEHAVIOR AT RAIL CROSSINGS

COST-EFFECTIVE IMPROVEMENTS TO INCREASE DRIVER SAFETY AT PUBLIC AT-GRADE RAIL-HIGHWAY CROSSINGS IN CALIFORNIA

PREPARED FOR

Caltrans

COOPERATIVE AGREEMENT
T.O. 5208

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