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ABSTRACT

Driver behavior at rail highway crossings has been the subject of numerous studies, most of which show that violations are relatively commonplace. The focus of this paper will be on those drivers who drive around fully descended gates. Drivers commonly misjudge the speed and distance of trains. They must make a decision about the time remaining before the train arrives based on sensory signals as well as non-sensory factors such as expectations and motivation. At a gated crossing, where drivers have been alerted to the imminent danger by lowered gates, there is more to be gained by preventing gate running, or at least making it very difficult, than by attempting to aid drivers in making a better informed decision as to whether or not there is sufficient time to clear the crossing before the train arrives. This is especially true given people's innate inability to judge the speed of a large object coming directly at them, both because the growth in size is not linear, and because human vision underestimates the speed of large objects. Given the costs involved in closing or making a crossing impenetrable, it is worthwhile looking at other approaches that can cost effectively reduce gate-running. These include long-arm gates, medians, photo enforcement, and four-quadrant gates.

BACKGROUND

In California, during the five years 2000-2004, 434 drivers ignored gates with flashing lights at highway-rail crossings and became involved in crashes with trains, including 84 who drove around or through gates into the side of a train. While society does not necessarily have an obligation to protect people from themselves, it is required to protect them from the actions of others. Because train operators, train passengers, and vehicle passengers can be put at risk due to the errant behavior of some drivers, steps must be taken to eliminate train-vehicle crashes.

Driver behavior at rail highway crossings has been the subject of numerous studies, most of which show that violations are relatively commonplace. Meeker and Barr (1), for example, found that of 57 drivers who approached a rural rail grade crossing in the presence of activated warning flashers, two thirds continued across the tracks. Carlson and Fitzpatrick (2) found that 60 percent of drivers at 19 sites in Texas equipped with lights and gates crossed the track between the time the lights activate and two seconds after gate arms begin to descend. In addition, violations occurring after the arms had been in motion more than two seconds and before the arms were horizontal, occurred during one-third of the gate-activations.

Clearly, activated warnings are *not* commonly perceived by drivers as a signal that the risk is too great for them to cross. "Rather, the results are consistent with the view of Leibowitz (3), who suggested that 'active' warning systems merely cue drivers as to the need to make a decision whether or not to cross" (1).

Not all violations are equally dangerous. The majority of the violations reported in highway-rail crossing studies are of the "flashing light" or "passing under a descending gate arm" variety. The Federal Highways Administration's "Manual on Uniform Traffic Control Devices for Streets and Highways, Part 8: Traffic Controls for Highway-Rail Grade Crossings" (MUTCD) states that "The gate arm... shall reach its horizontal position at least 5 seconds before the arrival of the train, and shall remain in the down position as long as the train occupies the highway-rail grade crossing." Thus for most vehicles, there is nothing *intrinsically* dangerous about these actions since even a vehicle passing under a descending arm would have ample time to clear the tracks before the arrival of the train. Moreover, Meeker and Barr (1) note that "it is not entirely satisfactory to conclude that [the drivers who crossed in the presence of activated warning flashers] 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."

The focus here, then, will be those who engage in dangerous behavior by driving around or through gates that are fully descended, a much smaller group of drivers. Cooper and Ragland (4), for example, in a study of a crossing in College Station Texas, found that of 48 violations, only three involved going around a lowered gate.

Since it can reasonably be assumed that the vast majority of drivers who drive around gates are not suicidal, those involved in crashes mistakenly decided that there was sufficient time to clear the crossing before the train arrived. With the exception of those cases where poor sightlines hid the train, the error most likely involves a misjudgment of the speed and/or distance of the train. Velocity estimation can be influenced by a number of factors - driving experience, visual cues available, darkness, the presence of visual information in the background, whether the other vehicle (train) is coming straight on or crossing in front, adaptation to previously observed train speeds, and actual train speed, since high speeds tend to be underestimated and low speeds overestimated (5).

At the present time there are 7,719 public at-grade crossings in California of which 43% are passive (i.e., no flashing lights, bells, or gates) and 57% are active. Most of the active crossings (71%) are equipped with gates and flashing lights. A look at the equipment at the public crossings where 593 train-vehicle crashes occurred from 2000 through 2004 reveals that 434 of them (73%) took place at crossings equipped with gates. Standard two-quadrant gates are obviously not enough to deter some drivers.

The crash records in the FRA database often lack detail, making interpretation of the data difficult. While each record contains a narrative entry that should clarify the circumstances of the crash, this section appears to be written after the fact, from checked boxes or short statements recorded elsewhere in the record. As an example of the difficulty of interpreting the data, in California, between the years 2000 and 2004, there were 40 crashes involving a vehicle that failed to stop, was not shown as going around or through crossing gates, and was hit as it moved over the crossing. Given that these were 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.

DRIVER DECISIONS

What failures in perception or judgment would cause 434 drivers (2000-2004) to ignore gates and flashing lights and become involved in crashes with trains? The following section will provide some insight into the interplay of perception, expectation, and human information processing theories which have been used in the development of strategies for grade crossing crash prevention.

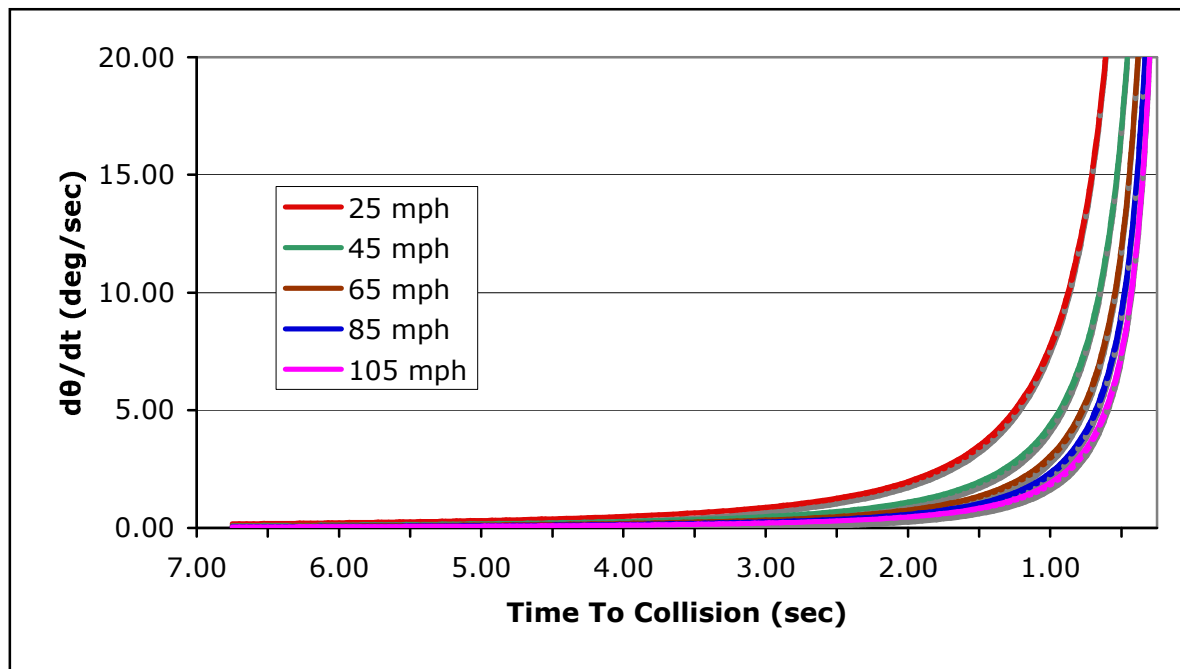
Signal detection theory (SDT) has been employed by a number of researchers as a means of analyzing, predicting, and preventing railroad crashes (e.g., Raslear (6), Rapoza and Fleming (7)). The motorist at a highway-railroad grade crossing must make a decision about the time remaining before the train arrives by differentiating between sensory signals and noise (e.g., train size and loudness, car radio, and sun glare) as well as non-sensory factors such as expectations (e.g., the usual number of trains at this crossing, previous signal malfunctions) and motivation, such as being late for an appointment (6).

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 approaching. Might every effort made 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?

The literature (8, 9) shows that, once the gates are down, there is little purpose in increasing the SDT signal/noise ratio for the driver because humans have an innate inability to judge the speed of a large object coming directly at them. The problem is twofold. First, detecting speed or time to collision from changes in an object's size has been shown to be relatively difficult (3). 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. This is illustrated in Figure 1 which plots the rate of change of the visual angle taken up by a 10' sphere moving directly at the observer at five different speeds from a starting position 6.75 seconds away.

The result of this hyperbolic growth pattern is that drivers tend to be effective at estimating the speed of the train when it is close because the change in visual angle is rapid. But when the train is at a greater distance, 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 (8).



Source: Adapted from Barton et al. (9)

FIGURE 1 Rate of change in viewing angle vs. time to collision

This phenomenon, as it relates to an approaching train, can be seen in Figure 2, which consists of four panels 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.

The second problem is a phenomenon noted by Leibowitz (3) who suggested that drivers underestimate the speed of trains because, in general, human vision underestimates the speed of large objects. However, the author presented only anecdotal evidence to support this claim, e.g., a large 747 jet seems to land more slowly than a small Piper Cub, even though the opposite is true.

Barton et al. (9), tested this hypothesis using a 3D visual simulator that showed either a 5' diameter sphere approaching the observer at 35 mph or a 10' sphere approaching at speeds ranging from 25 to 75 mph. The observer's task was to indicate by pressing a button which run, of each pair presented, contained the faster approaching sphere.

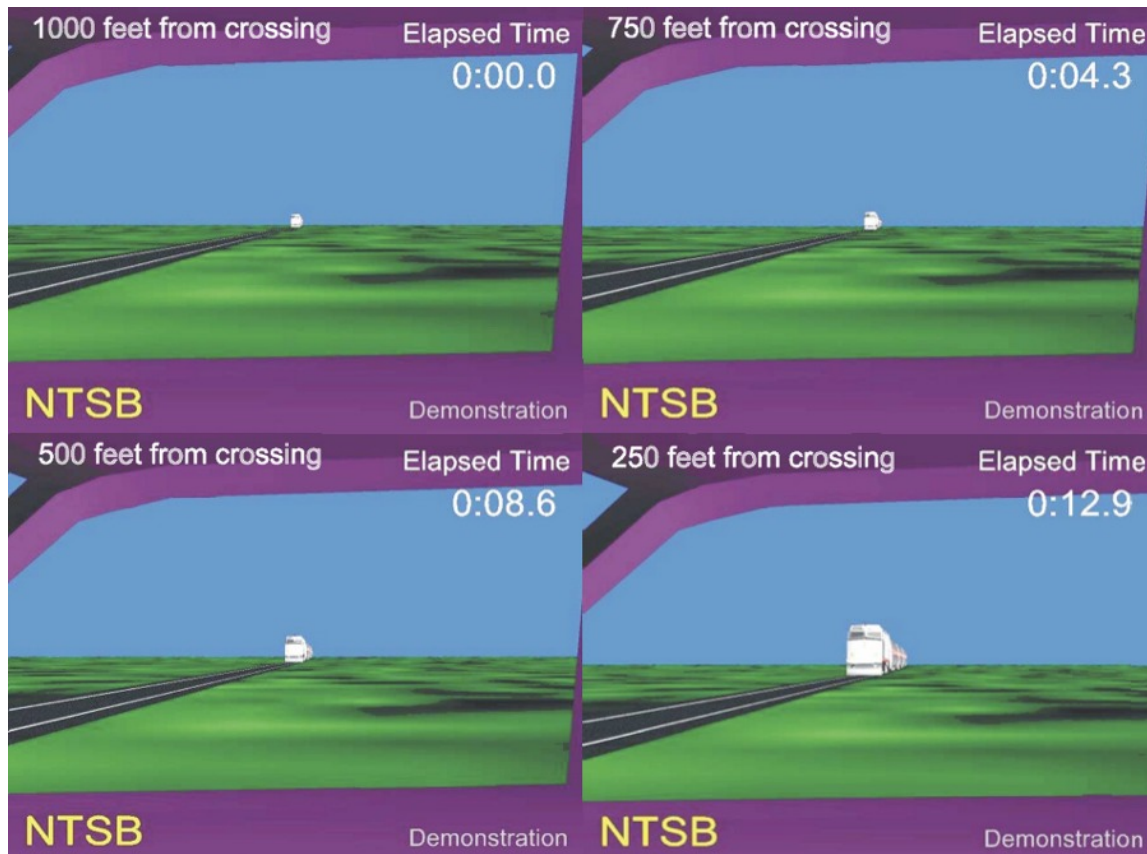


FIGURE 2 View of approaching train from vehicle stopped at crossing

The results of the experiment showed that the observers had a strong tendency to pick the smaller sphere as the faster, even when the approach speed of the larger sphere was as much as 20 mph greater. In fact, only when the speed of the larger sphere reached speeds twice that of the small sphere, did the observer become unsure as to which was approaching faster. Furthermore, the results suggested that experimenters would have to include trials in which the large sphere approaches at more than 2.7 times that of the small sphere before subjects would unambiguously pick the large sphere as the faster approaching.

From both signal detection theory and the tests of the Leibowitz hypothesis, it is apparent that, in general, humans are unable to accurately judge the speed and distance of an oncoming train. Since sight-line improvements, train conspicuity improvements, and warning system upgrades will not improve this situation, and since providing additional timing information (e.g., some sort of countdown timer) could actually encourage gate-running by increasing driver confidence, the solution to rail crossing crashes must be found by removing the need to make such a decision by making it impossible, or at least very difficult, for the driver to bypass the lowered gates.

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 deploying an impenetrable barrier, all of which carry a high monetary or social (e.g., 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 along with their associated costs and potential ability to reduce crashes when added to a 2-quad gate system.

POTENTIAL RAIL CROSSING UPGRADES

The estimated efficacy for the following upgrades is given when compared to a two-quad gate alone. For example, the 75% efficacy listed for median separators means that after their addition, crashes at that crossing could be expected to be reduced by 75%.

Long-Arm Gates

Regular gates usually cover one-half of the roadway. Long-arm gates, which cover at least three quarters of the roadway, have been shown to be an effective means of discouraging gate “drive-arounds” (10, 11). Their estimated efficacy is 75% (11) and cost approximately \$5,000 (11) per crossing.

Median Separators

Median separators are mountable centerline medians with channelization devices that can be applied directly to the existing roadway, often without requiring street widening, or can be added as part of a more complex structure consisting of an island with reflectors mounted on the top. Such systems present drivers with a visual impediment to crossing into the opposing traffic lane yet are designed to allow emergency vehicles to cross over to go back in the opposite direction. Their estimated efficacy is 75% (12) and cost approximately \$14,000 per crossing (12).

Photo Enforcement

In the event of a signal or gate violation, photo enforcement systems are designed to obtain a clear photograph of the violation, the vehicle’s license plate, and the driver of the vehicle. Capital costs for photo enforcement can vary a great deal depending on the requirements of the community to be served (12). However, one way to reduce costs is to move a single camera among several sites without drivers knowing which sites are active at any given time. The estimated efficacy is 72% (11) and cost approximately \$55,000 - \$100,000 per crossing (13).

Four-Quadrant Gate Systems

Four-quad gate systems consist of automatic flashing-light signals and gates where the gates extend across both the approach and departure side of roadway lanes, providing additional visual constraint and inhibit nearly all traffic movements over the crossing after the gates have been lowered. Adding to the complexity and cost of these systems is the need to incorporate a means of preventing vehicles from being trapped between the gates. Their estimated efficacy is 75% (11) and cost approximately \$350,000 per crossing (10).

CONCLUSIONS

There will always be people who are late for an appointment, in a hurry, distracted, or simply looking for a thrill, who will make bad decisions at rail-highway crossings. The key to reducing the number of resulting crashes can be found in removing the need to make such a decision by making it impossible, or at least very difficult, for the driver to bypass the lowered gates. There are a number of cost-effective, socially-acceptable approaches listed in this report that could be used for such a purpose.

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