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## ABSTRACT

The only way to absolutely prevent all drivers from going around lowered gates at level rail-highway crossings is to make it physically impossible, or at least very difficult, for them to do so. While there are various options to accomplish this (constructing a separation of grade, closing the crossing, or deploying an impenetrable concrete barrier), most have high monetary or social costs. Alternative approaches—such as channelization devices and long-arm gates—while not 100 percent effective, can be used to prevent deaths and injuries while remaining economically feasible. Research has shown that the addition of channelization devices can dramatically reduce the number of violations at level rail-highway crossings. While long-arm gates appear to be effective, additional study is needed to determine their suitability for individual locations. Unfortunately, even when overall rail crash totals for the country or for a given state are high, crashes at specific crossings are relatively rare events, making it extremely difficult to show that the addition of a safety treatment at a particular site prevented a crash. However, based on the efficacy of channelization devices—75 percent—in addition to the experiences of various transportation agencies, these devices appear to be a viable, low cost safety upgrade for at-grade crossings.

## BACKGROUND

A significant challenge to evaluating highway-railway grade crossings for collision potential and to estimate the safety effect of potential countermeasures is the extreme rarity of such collisions. They tend to be spread over a vast number of sites, with few—if any—occurring at any specific site in any given year. To improve safety at all 6,443 grade crossings in California would be prohibitively expensive and impractical. However, given that grade crossings are an inevitable part of the railway and highway network, decision makers must find ways of making crossings safer with the available resources by providing cost-effective countermeasures that maintain grade crossing safety within a tolerable level.

There exists a subset of drivers who will go around lowered gates if they think it is “safe” to do so. The only way to absolutely prevent these violations is to make it physically impossible for them to occur. This can be accomplished by constructing a separation of grade, closing the crossing, or by deploying an impenetrable barrier, all of which carry a high monetary or social cost (e.g., loss of convenience, slower response times for emergency vehicles, or loss of potential customers driving by a business).

There are other approaches that, while not being 100 percent effective, can be used to find a middle ground that can prevent deaths and injuries while remaining economically feasible. Two of these, channelization devices and long-arm gates, will be described along with their associated costs, potential ability to reduce crashes when added to a two-quad gate system, durability, and observations from transportation representatives in areas where they have been deployed. Because efficacy and installation costs are relatively unambiguous and uniform, emphasis will be on durability and recommendations.

## CHANNELIZATION DEVICES

For our purposes, channelization devices are defined as mountable centerline medians with upright reflectors that can be applied directly to the existing roadway, as shown in

Figure 1, or be part of a more complex structure consisting of an island with the device mounted on the top, as shown in Figure 2. 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 discourage drivers from circumventing the traffic control devices at the crossing while allowing emergency vehicles to cross over into opposing lanes to go back in the opposite direction (*1*). Usually, such a system can be placed on existing roads without the need to widen them.

**Efficacy and Cost**

Channelization devices are currently being used in a large number of locations across the country, from Massachusetts and North Carolina in the east to Washington State in the west. Their efficacy has been well documented. Research reports on installations in Florida (*2*), Washington State (*3*), Nebraska (*4,5*) and Canada (*6*) indicate that, when added to two-quad gate crossings, violations are cut by 75 to 80 percent.

A 2006 email from the manufacturer of the most widely used rail-crossing channelization devices stated that "a typical crossing involves about $10,500 of material...We do not install [the system] ourselves, but have noted that installation costs vary quite a bit from state to state. Perhaps $1,500 give or take $500 is a reasonable estimate." Recent experience at North Carolina DOT leads them to estimate a cost of around $10,000 for materials and $3,000 for labor for a new installation in NC consisting of 200 linear feet total median length for two roadway approaches to a crossing.

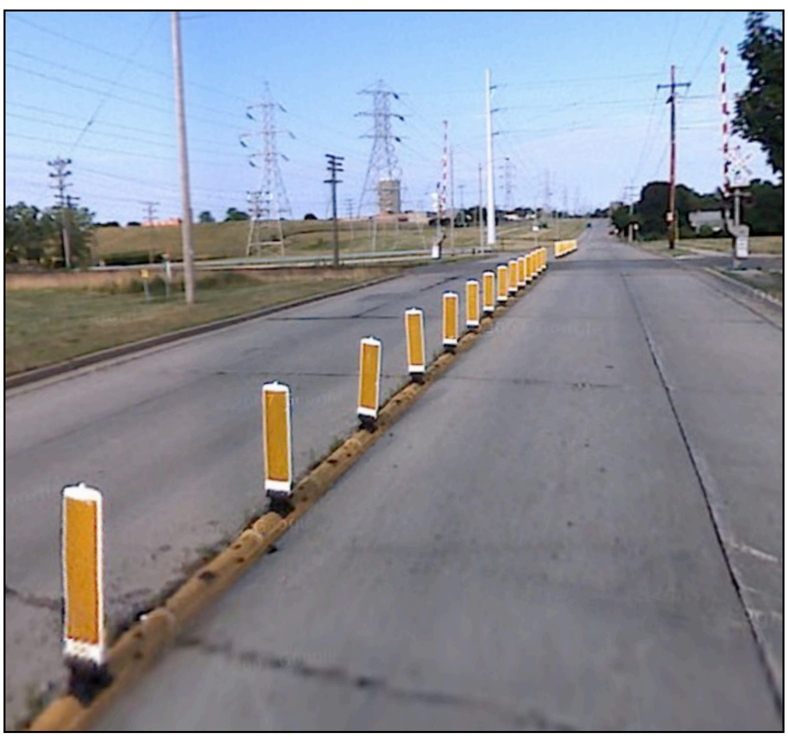

**FIGURE 1 Street Mounted Channelization**

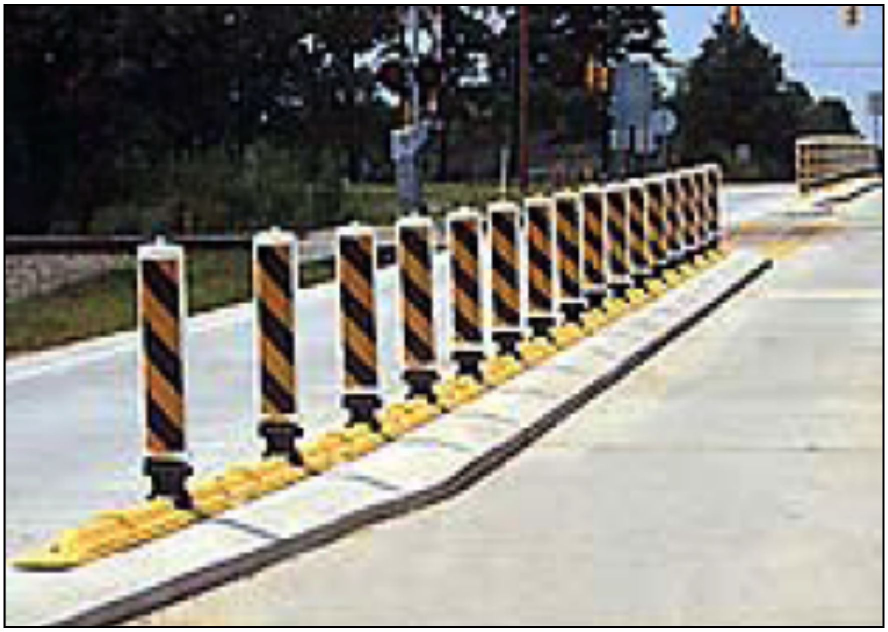

**FIGURE 2 Island Mounted Channelization**

Various types of channelization devices are available from different manufacturers, as described in correspondence from the North Carolina Rail Division, Engineering & Safety Branch:

"[One particular brand of channelization device] [Figure 3, left and center] was first available and was therefore first deployed by NCDOT. [This product] is somewhat higher in cost than its competitors; delineators are proprietary, as is delineator mounting system, driving higher costs (without significantly better durability) than more generic tubular markers that one of the competing products can accommodate. Options in types of delineators are wider than most competitors offer. [The manufacturer] has not been receptive to NCDOT's suggested modifications in its products to lower costs. [This channelization device] is a high-density recycled rubber product, and is paintable. This product meets NCHRP 350 requirements.

"[Another product from a different manufacturer was] the second product offered and the second used. [This manufacturer] agreed to accommodate in its extrusion process low-cost tubular markers by other manufacturers in its design for delineators [and was] also was willing to build an extrusion mold and set up a production sequence to manufacture a curb section to NCDOT specs if we could commit to a specified minimum linear footage—we could not, as we were already deep into installation of standard sections of this product and others, so we did not pursue this option. NCDOT experienced lower costs for materials and equivalent costs for installation labor. [This channelization device] is also a high-density recycled rubber product, and is paintable.

"We installed [a third channelization] product [Figure 3, right], at one crossing outside the Sealed Corridor, as it came to market later than the other two and our Sealed Corridor construction was complete with regard to modular medians. [This product] is a more rigid plastic than the recycled rubber products. It is a molded product (as opposed to extruded) with internal radial rib construction (as opposed to solid), making it lighter in weight than the other two products. While I cannot provide evidence of such, we have concerns that this product may fracture more easily, given its rigidity. This product meets NCHRP 350 requirements."

**FIGURE 3 Channelization Examples from Different Manufacturers**

**Durability**

For the most part, users of traffic channelization devices have been satisfied with their durability although the need for upright replacement has varied widely from location to location. Along the North Carolina Sealed Corridor, the devices were found to be "durable, but not indestructible." Snow removal operations damaged curb sections, some beyond repair, and resurfacing operations did not often take time or effort to properly remove or replace curb. Delineators were subject to damage by wide vehicles (mobile homes, farm equipment, wide-load lowboys) and drivers with intent to damage or destroy the materials, and therefore required relatively frequent repair and/or replacement. As a result, NCDOT retained a contractor for maintaining the curbs and delineators (plus special signage) at a cost approaching $100,000 per year. About 60 percent of the cost is for quarterly inspections at the 17 locations currently equipped with modular median products, while the other 40 percent is for removal/replacement for maintenance activities and replacement of materials damaged by highway traffic or highway maintenance operations.

There was significant damage to a channelization installation at the US 98 site in Frostproof, Florida. Nine consecutive markers were completely removed from the traffic separator, apparently by the impact of a large motor vehicle such as a semi-trailer. Factors that may have contributed to the collision include narrow lane width: 9.2 feet, and the number of lanes: 2. With additional lanes, motorists have the ability to compensate for the presence of the traffic separator and may be able to avoid collision with the markers (*7*). Nearby, on State Route 17, there was also substantial damage to another channelization device (Figure 4).

**FIGURE 4 Damage to Channelization Devices in Frostproof, Florida**

One study compared two sites in Nebraska that had channelization devices installed at rail crossings (*5*):

"While the barriers installed at the two study locations were similar in construction material and installation, the observed maintenance needs were different due to differences in roadway traffic, geometry, and traffic composition. The barrier at Waverly received more abuse due to higher roadway traffic and higher percentage of truck volume compared with the Fremont site. Also, the Waverly site involved a 90-degree turn, which exacerbated the situation with trucks frequently overrunning the end of the barrier (Figure 5). Hence, maintenance needs were higher at the Waverly location. Since relatively little truck traffic volume and no significant turning traffic were involved at the Fremont site, the barrier was much less abused at that location. Nonetheless, the barrier at Fremont was overrun by roadway traffic and damaged as evident from tire tread and scuff marks (Figure 6), which required some maintenance."

**FIGURE 5 Flattened Curbing Caused by Trucks**

**FIGURE 6 Scuff and Tread Marks**

In Houston, Texas, trucks have also been a problem. The city, which has a quiet-zone program, found that while delineators constructed from rubber are initially cheaper than concrete medians, they may require frequent maintenance in areas with heavy truck traffic. For example, at San Felipe Road, five or six panels on average are replaced three times per year. The problem arises when drivers of 18-wheelers on high volume streets choose not wait in queue while the arm is down and instead execute U-turns over the median.

Replacement demand at other sites in Houston is much lower as suggested by the fact that the city continues to use the rubber channelization devices for new installations. However, this may be due in part to the approval process for such devices being substantially easier than for concrete medians, perhaps because the non-concrete installations are not considered a change to the roadway. Another benefit is that channelization devices are easily removed and replaced for street maintenance.

The Oakland County, Michigan road commission removed the traffic separators at the Andersonville Road crossing due to the high maintenance cost. The commission stated that their roads were experiencing premature edge cracking from vehicles driving on the edge due to the narrow lane width and motorists shying away from the separators.

They also indicated that damage to the markers, markers being ripped from the curb, and fracturing of the curb continued to occur (*2*).

Other installations throughout the country have fared much better:

Wyoming—"We have been very pleased with the low maintenance needed. These have taken a beating. You can see on the painted surfaces where the bumper height is on the vehicles that have been harassing them."

Illinois—"We have one installation for a quiet zone and are satisfied with [the channelization devices which were] installed due to cost of concrete median. The biggest problem is with snowplows. We've had no vandalism to speak of. Ideally it would be good to have a concrete raised median, but for what it is doing it has worked out well. We've had to replace 3 or 4 uprights in last couple of years."

Puyallup, Washington—Seven sites, with average AADTs of 9,800, have required replacement of three to four upright tubes per site per year.

North Carolina—While the DOT's first choice is concrete, given money or other constraints, they would not hesitate to install channelization. "You can get 200' of channelization for $12,000 and concrete is 2-2.5 times that. We developed a median standard of 4' width with a 2' width option. A 4' median almost always requires some changes to the roadway and a 2' median usually does. Maintenance department does not want to maintain narrower medians. They have a tendency to break easily when hit by large trucks or snow removal equipment."

**Observations**

In their 2007 study, Khattak et al. noted that the amount of damage was a function of traffic volume, percentage of trucks, and whether sharp turns were involved (*5*). Ko et al., 2007, also warned of truck traffic and added that channelization devices could pose a maintenance problem if the lane width is less than 3.4 m [11 ft.] (*2*). Additionally, the length of the traffic separator system should be based on the maximum queue lengths on the approach to discourage vehicles stopped at the back of the queue from entering the crossing from the wrong side of the road.

At the North Carolina, DOT, a concrete median was the first choice, and is substantially more expensive up front. However, while a concrete median is unlikely to require any maintenance for ten to twenty years, the rubber channelization devices require inspection at least several times a year and are subject to vandalism.

In Fort Worth, Texas, there was an instance of a neighborhood whose residents wanted a quiet zone, and where there was federal money for the project. A concrete median with extension of flexible delineators was planned but residents objected to the way it looked. A similar project was planned for a second location, but was also rejected based on its appearance. In both locations standard raised concrete medians were to be installed instead.

In Florida, it was shown that channelization devices hold up much better in urban rather than rural settings, with vandalism cited as the main reason.

**LONG-ARM GATES**

The best source of information for long-arm gates (or longer-arm gates) is the North Carolina Department of Transportation which is responsible for the NC Sealed Corridor (173 miles and 216 at-grade crossings) portion of the Southeast High Speed Rail Corridor that runs through the state. Forty-nine of those crossing have been equipped with these gates.

As reported in the North Carolina Sealed Corridor Phase I, II, and III Assessment study, the longer-arm gate systems must cover at least three quarters of the roadway. Tests at the Orr Road Crossing in Charlotte were conducted by the state's DOT to evaluate the effectiveness of longer-arm gates to reduce drivers' ability to drive around the gates (Figure 7).

**Efficacy and Cost**

A total of three tests were conducted with the first gathering driver violation data before the gate was installed, the second test gathering post-treatment violation data which showed a 67 percent reduction in crossing violations, and a third test which gathered "after" data on long gate arms a year after the first test to determine whether long-arm gates retain their effectiveness. The results from the third test showed an even higher reduction in crossing violations of 84 percent compared with pretreatment "before" numbers. Longer gate arms are used in conjunction with traffic channelization devices in some locations, but not where they would block a street or driveway intersection close to the crossing. The gates provide considerable discouragement to drivers who start to drive around and then realize how great the distance is.

As of 2001, the cost per crossing was $5,000 (approximately $6,500 in 2012 dollars, based on consumer price index [CPI]). Since installations may require stronger lifting mechanisms than those currently in place for normal arm length gate systems, additional costs for motor replacement may be required (*8*).

**FIGURE 7 Longer-Arm Gates at Orr Road, North Carolina**

As with channelization devices, maintenance on the long-arm gates is problematic where there is a lot of heavy vehicle traffic (large trucks, buses, etc.). The problem with these vehicles, particularly tractor-trailers, is that they could conceivably enter the crossing legally and, if running slowly, the gate on the exit side could get snagged on the trailer and break off, leaving the crossing unguarded. NCDOT has become very conscientious about not installing long-arm gates on routes with significant—more then 1 or 2 percent—truck traffic.

It was also determined that long-arm gates are only valid for two-lane roads. In their engineering assessment, DOT planners look for a shoulder that is wide enough to allow a perceived escape route so that vehicles can get around it on the exit side of the crossing.

In general, NCDOT's first choice is be channelization. The long-arm gates are effective but more extensive engineering study is required to determine their suitability at a specific location. The NCDOT now require a classification traffic count to determine the number of heavy vehicles, the combination of vehicles and their proportions, and whether the proportion of heavy vehicles is significant.

## DISCUSSION

The best solution to rail crossing collisions 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. Two low-technology, low-cost, low-maintenance methods—channelization devices and long-arm gates—have been deployed in many locations and, while not 100 effective, have been shown to prevent deaths and injuries while remaining economically feasible.

Research has shown that the addition of channelization devices can dramatically reduce the number of violations at level rail-highway crossings. While long-arm gates appear to be effective, additional study is needed to determine their suitability for individual locations. Unfortunately, even when overall rail crash totals for the country or for a given state are high, crashes at specific crossings are relatively rare events, making it extremely difficult to show that the addition of a safety treatment at a particular site prevented a crash. However, based on the efficacy of channelization devices—75 percent—in addition to the experiences of various transportation agencies, these devices appear to be a viable, low cost safety upgrade for at-grade crossings.

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