A comprehensive analysis of and direction for

MoDOT's Cable Median Barrier Program

Submitted to
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Introduction

Cable median barriers have been used with great frequency in the past decade. Many states have come to realize the system-wide benefit these barriers provide without the expense of a more traditional system. Cable barrier use has become so widespread so quickly, that few, if any, states fully understand the parameters of its use.

After installing hundreds of miles of cable median barrier throughout the state, MoDOT has realized and even documented the tremendous safety benefit the system has provided. However, given the fairly limited knowledge of the barrier as well as the state's inexperience with its use, the need for a comprehensive examination of the system has become apparent. To that end, the MoDOT Chief Engineer commissioned a report to identify and recommend solutions to the numerous variables within Missouri's cable median barrier program.

In response, a multidisciplinary team was formed drawing on resources from divisions, districts and the Federal Highway Administration (FHWA). During the six-month research phase, the team held weekly meetings, consulting with various resources from emergency personnel, to safety researchers, to roadside hardware vendors, to MoDOT senior management.

The goal of the Cable Median Barrier Team was to analyze MoDOT's experience and the state of the practice to develop guidelines for the future of the Department's cable installation program. These guidelines would then be used to generate a comprehensive report that would manage the unknowns inherent in the cable barrier implementation program in Missouri.

The following report is just that. It will examine five key areas of the program, troubleshooting problem areas and making recommendations for the future of the barrier program.

The five areas that have been examined, in-depth, and reported upon are:

- Systematic Application
- Cable Barrier Type Selection
- Optimization of Lateral Placement
- Routine Maintenance and Incident Repair
- Emergency Access Issues

Executive Summary

After examining and discussing the data from the research phase of this study, recommendations were made in each of the five key areas.

Systematic Application

- Prioritize cable median barrier installation locations based on traffic and safety data analysis, treating all divided highways equally.
- Install new median cable median barrier on a corridor-wide basis, between logical termini.
- Review traffic and safety data each year to validate current priorities and identify any emerging cross median safety concerns.
- Identify and prioritize all remaining cable median barrier needs statewide (see Appendix A).

Cable Barrier Type Selection

- High-tension, socketed systems should be employed on future large-scale installations.
- Low-tension cable barriers may be used only for small installations, replacement work in current installations and sealing the gaps between current low-tension installations.

Optimization of Lateral Placement

- In medians 30 ft. wide or wider, the cable barrier should be installed 4 ft. down-slope of the edge of shoulder.
- In medians narrower than 30 ft., the cable barrier should be installed at the vertex of either a V or flat-bottomed ditch.
- Post spacing should not exceed 15 ft.
- Discontinue the use of parallel installations (double runs) of cable median barrier, irrespective of median condition.
- Ensure vegetation control measures are not omitted from cable installations as practical design or value engineering measures.

Routine Maintenance and Incident Repair

- Lower the response time for non-priority cable repair to seven days.
- Educate MoDOT personnel as well as external partners on the importance of a well-maintained cable median barrier system
- Schedule regular visual inspections of the district's entire installation of cable barrier.
- Continue to outsource the maintenance of low-tension cable barrier.
- Maintain high-tension barrier with in-house maintenance forces as much as current workloads and efficiency allow.
- Consider cable barrier maintenance on a corridor basis instead of only maintaining by district.
- In addition to the cable barrier, ensure the surrounding median is restored to its pre-impact condition with each repair.

Emergency Access Issues

- Emergency crossovers for freeways should be spaced approximately 2-½ miles apart. Additional crossovers in the vicinity of sparsely spaced interchanges may be required to facilitate snow removal.
- Crossover spacing on expressways should mirror that of freeways. It is likely, however, that such a spacing is already present on these routes.
- The geometric design of the access should be in accordance with Standard Plan 606.41.
- Emergency crossovers should be intentionally unattractive in order to discourage use by the general public.
- MoDOT and the FHWA should enter into a programmatic Access Justification Report (AJR) in order to streamline future emergency crossover installations.

Systematic Application

When determining the original system-wide installations of cable median barrier, data analysis led decision makers to initially choose Interstates 70 and 44 due to crash history and traffic volume. Sections of these routes with median widths less than 60 feet are being treated. By the end of 2007, this first task will be complete.

With the success of these projects in saving lives and reducing serious injuries, it is important to continue the use of cable median barrier. It is also important to choose the most appropriate locations for additional installation. Different options were discussed regarding how this should be done.

Regardless of the method used to identify future installation needs, it is important to remember that a law of diminishing returns governs the cable median barrier program. According to this relationship, beyond some point, each additional unit of input to a system yields less and less additional output. Dramatic decreases in cross-median fatality accidents were realized by treating the medians of Interstates 70 and 44. However, given the high volumes and speeds, as well as the operational characteristics of these facilities, such decreases are almost expected. The probability of seeing such fatality reductions on roads of lower functional classification is unlikely.

Finish the Interstates? One option focused on completion of the Interstate system. While this has some value (being able to say, “Every Interstate in Missouri has a median barrier.”), discussion among the team and with Senior Management yielded little support. Additionally, a number of Missouri Interstates have neither the current traffic volume nor severe crash history to justify installation of cable.

Data Analysis. Analyses of cross median crash history and traffic volume provide valuable information to determine the likelihood of future severe crashes on these routes. In order to prevent future fatalities and disabling injuries, it is important to focus safety efforts on locations that will benefit the most from safety countermeasures.

- **Crash Data Analysis.** When analyzing cross median crashes, the designation of a route (Interstate, US Highway, Missouri Route) is not important. What is important is the number of cross median crashes on that route, especially when the crashes result in fatalities and disabling injuries. This approach treats all divided highways the same when analyzing crash data.

  The public response to cable median barrier follows this logic. Their concerns about cross median crashes relate directly to severe crashes that have occurred in their area, regardless of route type.

  It is important this analysis is robust, particularly on expressways. Due to at-grade intersection crashes on these routes (these types do not exist on freeways), a simple query of cross median crashes may include unwanted events and exclude necessary ones. Care must be taken to ensure accurate data.

- **Traffic Volume Analysis.** Recent research has connected traffic volume growth directly to cross median crash events. As volumes increase, the probability of a motorist crossing the median and hitting an oncoming vehicle also increases. Instead of relying solely on crash history, there is an opportunity to proactively address this crash type before the crashes occur by studying traffic volume patterns and installing a system of cable median barrier on routes whose volume is approaching a “tipping point” or threshold.

- **Median Width.** Recent national experience has shown that cross median crashes occur on highways with median widths above MoDOT’s initial 60 feet threshold. No route will be excluded from analysis and consideration solely on the basis of median width.

Recommendations

- Prioritize cable median barrier installation locations based on traffic and safety data analysis, treating all divided highways equally. It is important to address the crash severity and type (cross median fatalities and disabling injuries) regardless of a route's official designation, functional class, or median width.

- Install new cable median barrier on a corridor-wide basis. The system-wide approach currently used with cable median barrier has proven effective in reducing severe cross median crashes. A corridor should have similar geometry, traffic volume and/or crash history, and the placement of cable median barrier on this corridor should have logical termini. Spot location installation of new cable median barrier should be used only sparingly in unique situations.

- Review data each year to validate priorities and identify any emerging cross median safety concerns. A regular review of divided highway traffic volume and crashes will provide information regarding the "tipping point" issue and provide information to proactively address severe cross median crashes.

Cable Barrier Type Selection

There are two types of cable median barrier systems in use today, low tension and high tension.

Low-tension. MoDOT has installed low-tension cable median barrier on portions of I-44, I-70, I-55 and other routes. This system basically consists of driven posts and a series of suspended cables with only enough tension to hold the cable off the ground and minimize sag between posts. The low tension, provided by large springs at the end anchors, limits the runs to 2000 to 2500 ft. It is generally installed in the center of the median as shown in Figure 1.

Advantages of low-tension cable median barrier include:

- Lower installation cost.
- Placement in center of median reduces "shy"

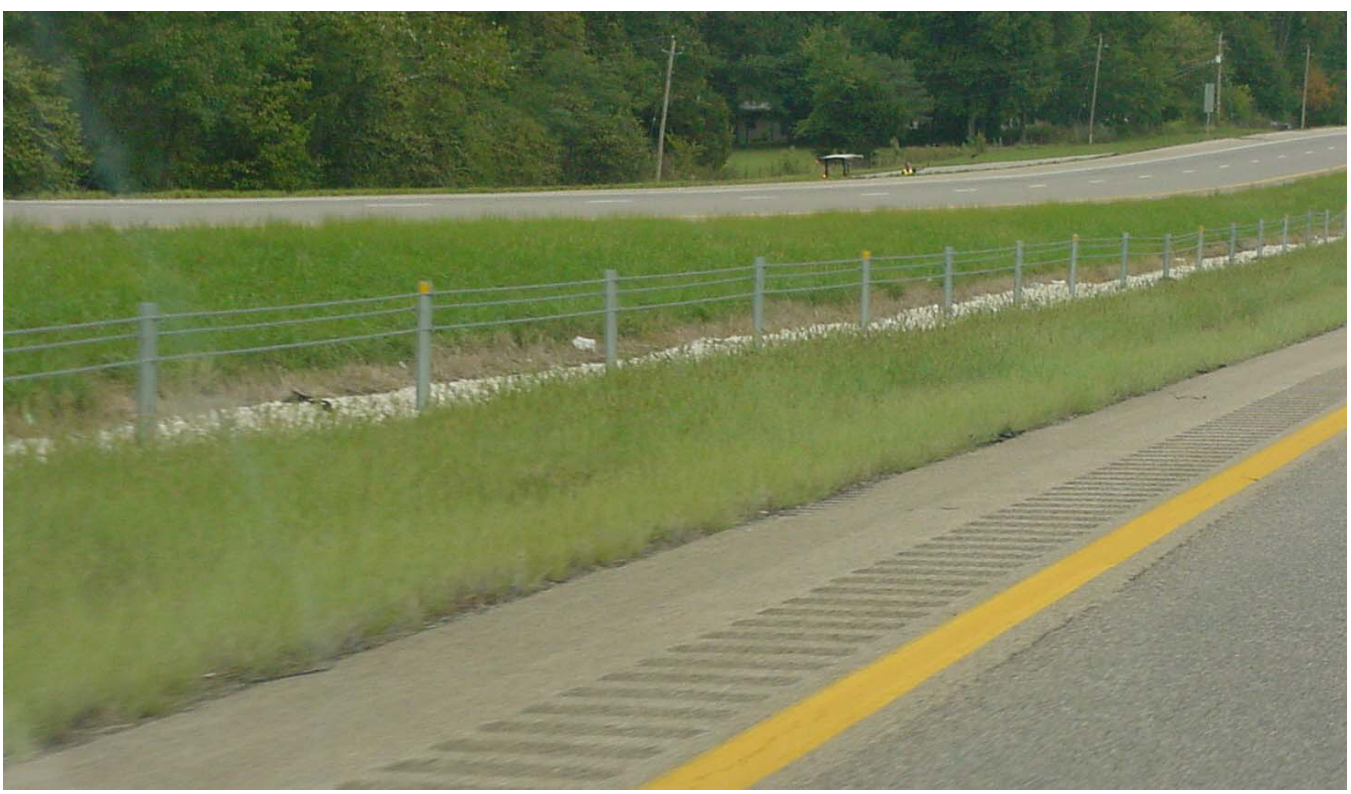

FIGURE 1 Low-tension cable median barrier

issues with the adjacent lane.

- MoDOT and contractors are familiar with its use.
- It is a non-proprietary design and in the standard plans.

Disadvantages to low-tension cable median barrier include:

- Specialized equipment, including post driver, is required for repairs.
- Traffic control during repair often requires a lane drop.
- On-call repair contracts have cost as much as $10,000 per mile per year.
- In many locations, the median drainage must be extensively modified or the quantity of cable must be doubled to provide a parallel installation. In such installations, the barrier is located on both inside edges of shoulder.
- In many cases, hit cable lays on the ground until a repair can be made. Since this requires mobilizing an on-call contract, a repair can take one to two weeks or longer.

High-tension. MoDOT has installed high-tension cable median barrier on portions of I-44 in Districts 7 and 8. This system consists of three or four pre-stressed cables supported by weak posts. Currently, all high-tension systems are proprietary, that is, marketed under exclusive right of a specific manufacturer. There are five systems currently being marketed in the United States. One such system is shown in Figure 2.

During installation, the cables are placed on the posts, and then tightened to a specific tension according to temperature. The tensions values range between approximately 2,000 and 9,000 pounds. Due to this tightening, the cable installations can be of indefinite length, in fact, the runs are usually only limited by the presence of obstacles such as median openings or bridge columns.

Benefits of high-tension cable median barrier include:

- Lower repair costs, approximately $2,800 per

FIGURE 2 High-tension cable median barrier

mile per year.

- System can be placed on one side of the divided highway and is crashworthy from both directions of traffic.
- Some systems that have been tested as crashworthy on a 1V:4H slope.
- Requires only 'shoulder work' signing and no lane drop for most repair because the work can be accomplished from behind the barrier.
- Median drainage modifications are not required if approved 1V:4H systems are used and installed as indicated.
- Anecdotal evidence exists which suggests a residual safety value of the system for secondary impacts. This phenomenon is due to the tension in the cables that tends to keep them above the ground after most impacts.
- Repairs are usually quick and easy. After a typical hit by a passenger car or light truck, repairs can be made in approximately one hour by two maintenance employees, equipped with simple hand tools and a half-ton pickup. The repairs consist of placing new posts in the sockets and reattaching the cable.
- Dynamic deflections are significantly lower, especially through horizontal curves, compared to low-tension systems.

Disadvantages to high-tension cable median barrier include:

- Higher installation costs.
- All existing systems are proprietary so the establishment of a standard specification and comparison of bids is somewhat difficult. A non-proprietary system is currently being developed at the Midwest Roadside Safety Facility at the University of Nebraska.

Some of these disadvantages are simply perceived and will be discussed, in depth, in the following section of this report.

Cost Analysis. Each system was analyzed using a present value calculation, including a combination of installation costs and estimated yearly maintenance

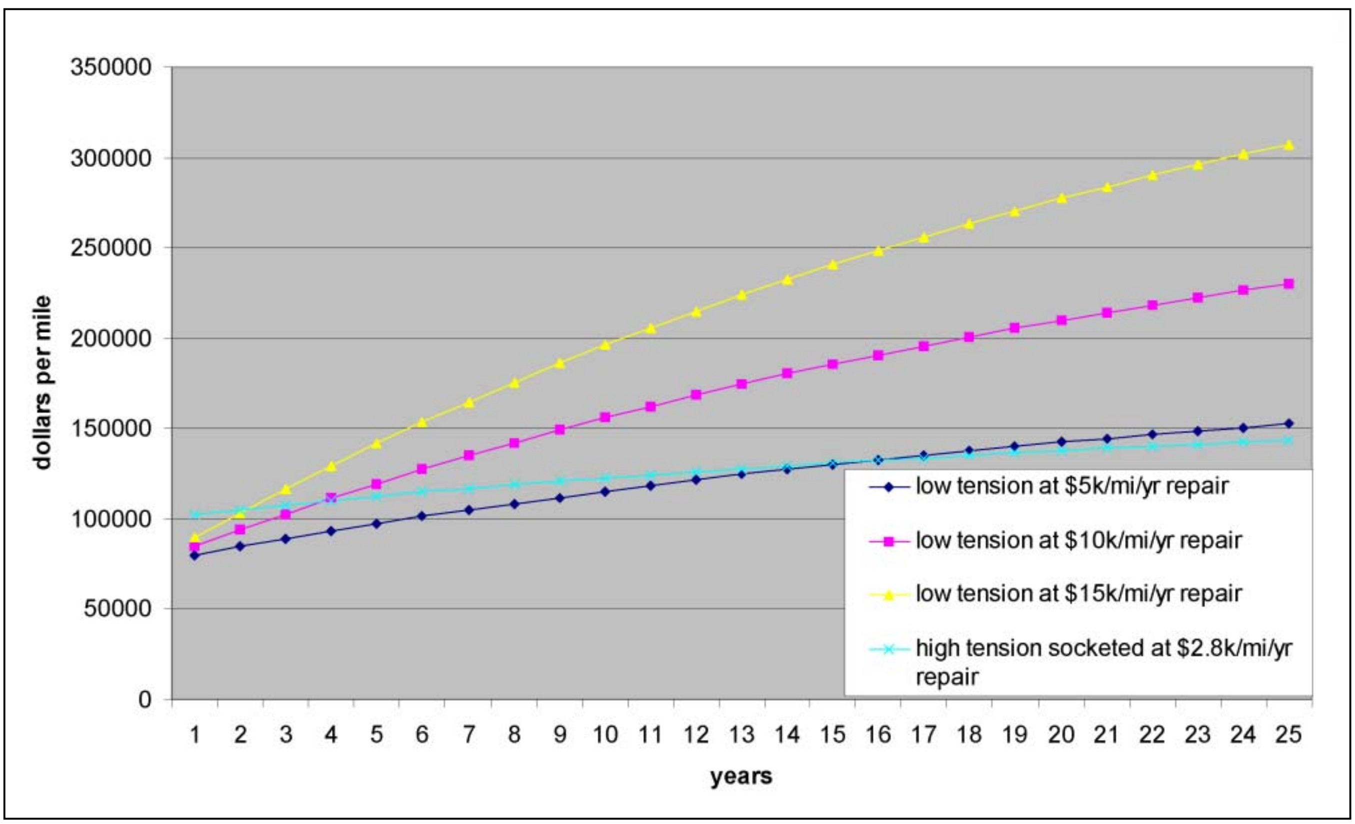

FIGURE 3 Life cycle cost

and repair costs. Rates of 4% and 10% were used for interest calculations.

Assuming a minimum service life of four years at 4%, the 3-strand high-tension socketed system is equal in present value to the low-tension system with heavy grading. This assumption is overly conservative since the life expectancy of the system is much greater than four years. Even with such conservative figures, however, the 3-strand high-tension socketed system has a lower life cycle cost than the low-tension system.

Assuming investment in a system to be maintained in perpetuity, the capitalized cost of the high-tension system is 48% less.

Recommendation. A socketed, high-tension system is recommended for all future large-scale installations. While the higher cost of material and system installation is a factor that must be considered during scoping, the issues related to slope correction and median drainage modifications that are avoided with this design may ultimately reduce the cost differential beyond the comparative values used in this analysis.

FIGURE 4 Asphalt vegetation control apron

A high-tension system incorporating socketed posts and three strands of cable has been in service for six months in District 8. During that time, improvements in repair costs, time to return to service after repair, and cross median accident reduction have been documented. This system is easily repaired and maintained with the resources currently available to the district maintenance personnel.

Vegetation control in the area between the cable and the passing lane is an issue that must be addressed as part of the implementation. Besides spraying, possible options include the previously implemented geotextile-aggregate strip, or asphalt apron (Figure 4).

Removal of the positive vegetation control measure cannot be allowed as a practical design or value engineering measure. Given conventional equipment and methods, a 4 ft. wide strip of grass between the barrier and the inside shoulder (Figure 2) will present maintenance personnel with a rather difficult mowing operation.

Low-tension systems have been in service for some time and have proven their value at reducing cross median accidents. However, the issues related to down time and the necessity to utilize on-call contracting cause a perpetual drain on department resources. For these reasons, the use of low-tension cable systems should be limited to small-scale installations. An example would be filling in a gap in a corridor that already includes low-tension cable.

Optimization of Lateral Placement

When Missouri began to use cable barrier with regularity in the mid 1990's, it seemed intuitive to place the barrier directly in the center of the median. That placement has met with a success rate of 95% according to an ongoing in-service performance evaluation.[1] However, other states have witnessed what they believed to be an inordinately high incidence of failures with the center of ditch placement. Some of these states have studied the issue and it has become so widely discussed as to have attracted national attention.

Over the past two years, the Federal Highway Administration (FHWA) and the National Highway

Traffic Safety Administration (NHTSA), through the efforts of the National Crash Analysis Center (NCAC), have studied the issue of lateral placement of cable barrier within the median. The NCAC is a collaboration of the FHWA, NHTSA, and George Washington University and primarily supports the U.S. Department of Transportation's (USDOT) strategic goal to reduce fatalities and injuries on the Nation's roadways.

The research and recommendations of the NCAC in this area represent the most comprehensive investigation performed on the issue to date. As such, the recommendations of this report will be drawn as logical conclusions from the NCAC Data.

Dynamics of Cross Median Crashes. When a vehicle leaves the roadway and enters the median, certain predictable dynamics occur. Vehicles may enter the median at a variety of speeds and angles, but for the purposes of roadside safety research and testing, a 60 mph departure at a 20° or 25° angle is generally used.[2] Those departure parameters will be used throughout the lateral placement discussion in this report.

Upon departure, a vehicle will initially continue along its vertical trajectory. As the inslope falls away along the 25° vehicle path, the vehicle, in effect, becomes briefly airborne. When the vehicle's inertia can no longer overcome the force of gravity, it lands, at which point, its suspension deeply compresses. As the vehicle continues to travel through the median, the suspension rebounds and the bumper of the vehicle stays at a relatively constant height throughout the remainder of the errant travel.

FIGURE 5 Underride potential of single-cable engagement

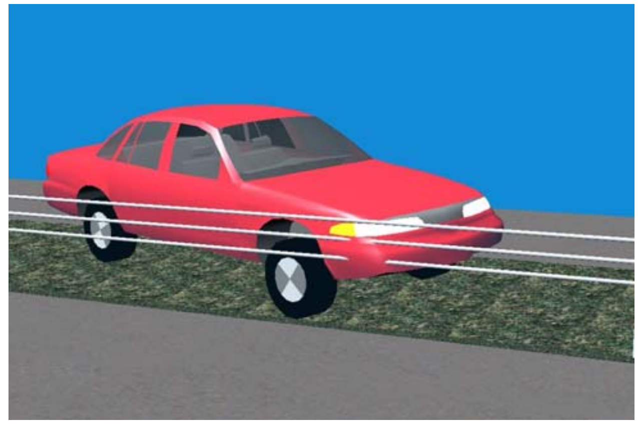

FIGURE 6 Capture potential of two-cable engagement

Every cable barrier crash is slightly different, being impacted by a host of site-specific factors. In general, however, the front of the vehicle must engage at least two of the three or four cables present in order to be contained by the system (Figures 5 & 6). Given the vertical path of the front of the vehicle as described above, the importance of lateral placement of the cable barrier becomes clear. From a perspective of pure functionality, then, the lateral placement of the cable median barrier becomes a rather simple issue when based on the research of the NCAC. For the purposes of this report, the NCAC research can be summarized into two main categories: medians wider than 30 ft., and medians narrower than 30 ft.

Recommendations

Medians 30 ft. or Wider. In medians 30 ft. or wider, the cable barrier should be installed 4 ft. down-slope of the edge of shoulder. In most cases, this location would place the barrier 8 ft. from the edge of traveled way. There are several advantages to this location but chief among them is the performance of the system in a crash. At the 4 ft. down-slope location, the errant vehicle, while airborne, is not at a great enough altitude to override the cable during a front side encounter. From the backside, the suspension of the errant vehicle will have recovered

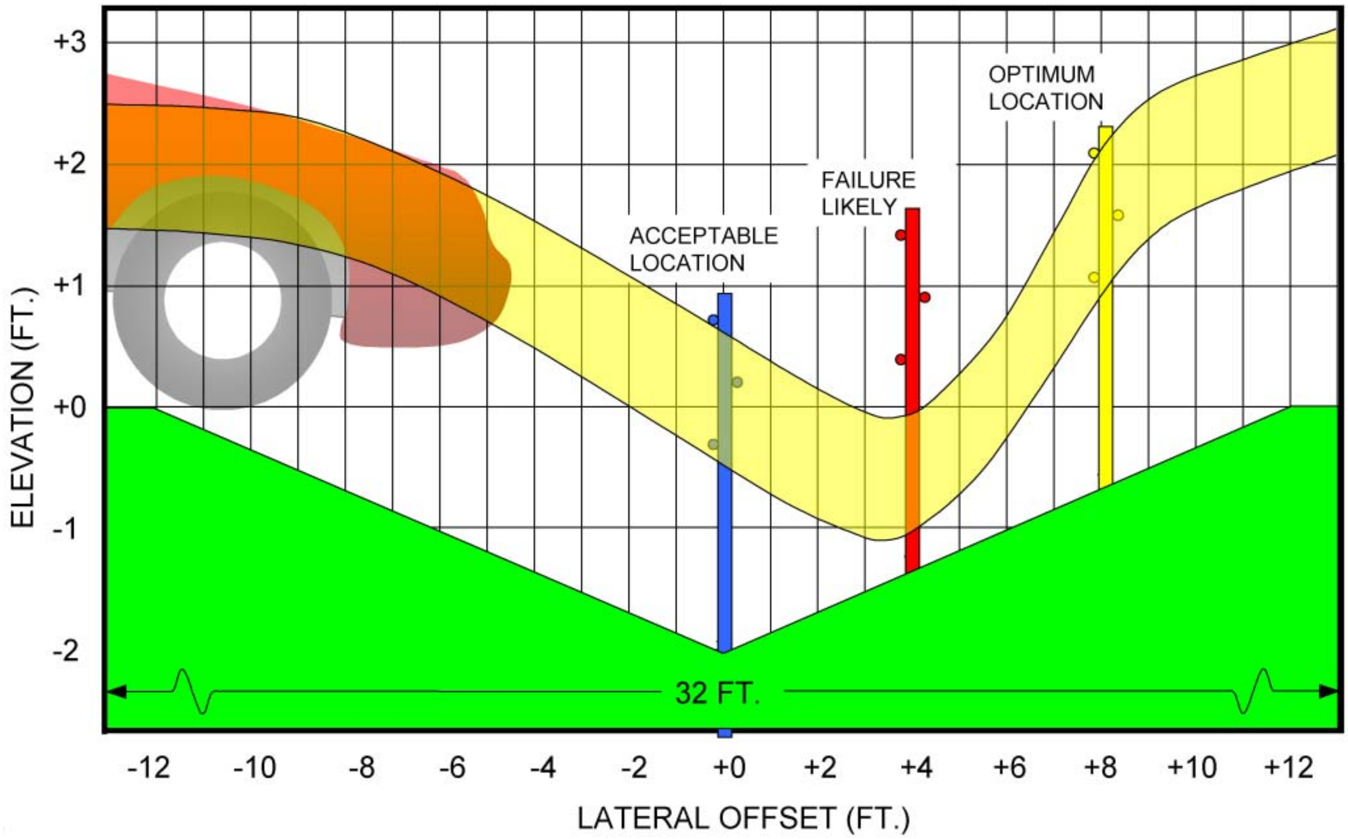

FIGURE 7 Vehicle trajectory trace in median wider than 30 ft.

enough to allow an impact to occur under relatively normal impact conditions (Figure 7).

There are other advantages to locating the barrier outside the ditch bottom.

- The system is out of the wettest, and therefore, softest part of the cross-section. The drier soil should lend greater stability to the post bases, which have, of late, been loosening or even pulling out of the ground.

- High-tension cable systems approved for installation on 1V:4H slopes are constrained to placement in the 4 ft. down-slope location.[4,5] Requiring all high-tension systems to be placed in this same corridor would produce a cleaner standard with less chance for placement error.

- System maintenance and repair can occur from the back side of the barrier. This location is particularly advantageous in medians of width approaching 30 ft. In these medians, a lane drop might previously have been required to accommodate the personnel and equipment near the edge of the roadway.

There are a few perceived disadvantages to the proposed location; however, rebuttals to each of them have been made.

- *There could be a greater incidence of non-critical or "nuisance" crashes given the close proximity to front side traffic, i.e. the traffic closest to the barrier.* While the closer location certainly does increase the likelihood of nuisance hits, this concern is offset by the increased distance the cable sits from the opposite direction.

- *The 4 ft. down-slope location results in insufficient width for mowing operations on the*

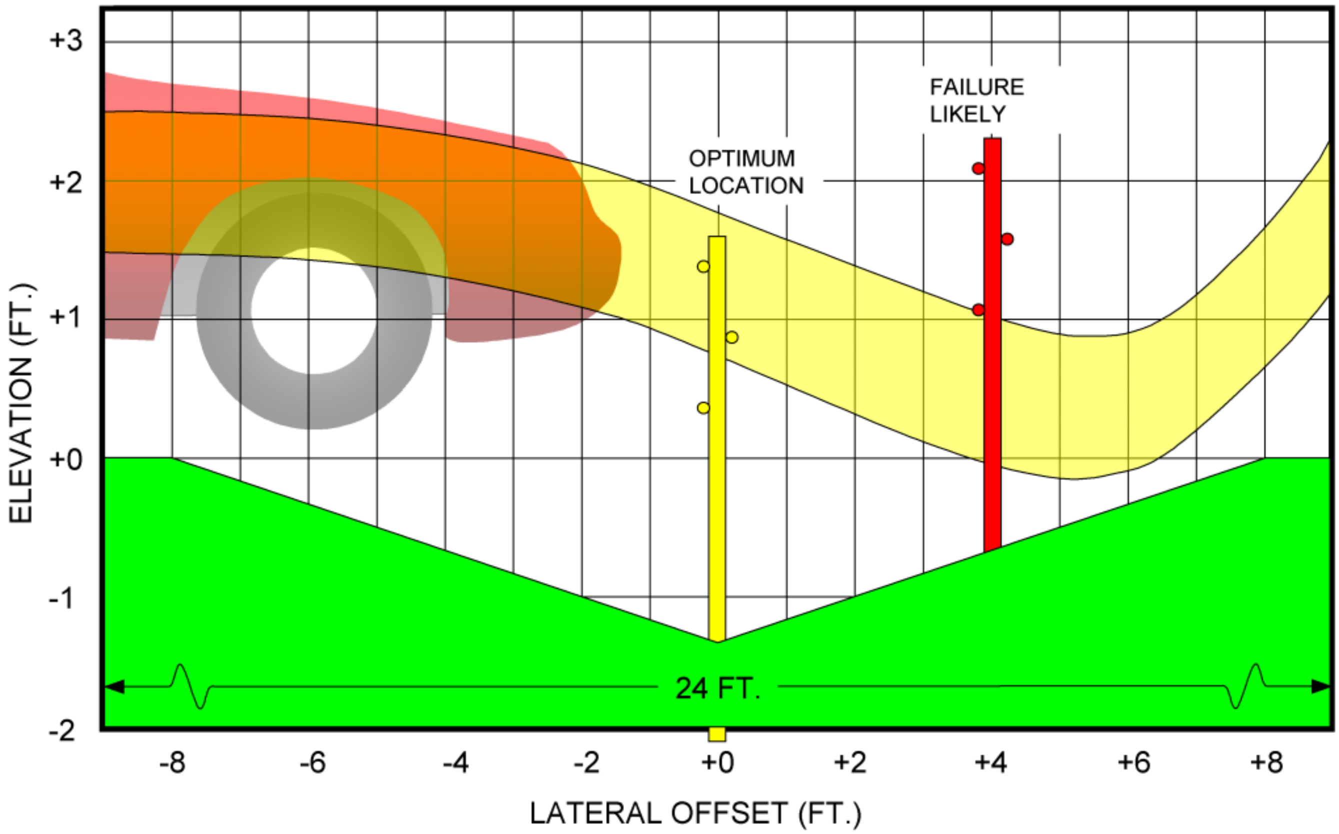

FIGURE 8 Vehicle trajectory trace in median narrower than 30 ft.

front side of the barrier, necessitating a lane drop. The life cycle cost analysis contained in this report accounts for vegetation control measures being placed during the initial installation of the system. These measures may vary, but will likely consist of a geotextile-aggregate combination or and additional 4 ft. of commercial mix pavement. By providing an initial vegetative barrier, the growth can largely be controlled through annual herbicide application.

- *The close proximity of the barrier to the roadway could be perceived as an obstacle, causing drivers in the passing lane to slow down or change lanes abruptly.* The lateral distance at which a driver no longer perceives a barrier as an obstacle is known as the shy line offset. The shy line offset value for 70 mph traffic is 9.2 ft., which does place the barrier within the shy distance. However, the AASHTO Roadside Design Guide says of lateral offset,

  "For long, continuous runs of railing, this offset distance is not so critical…As long as the barrier is located beyond the perceived shoulder of a roadway, it will have minimum impact on driver speed or lane position" [6]

  While it's unlikely that the 4 ft. down-slope location will present a shy line issue to motorists, the designer may choose to alternate the sides of the median on which the barrier is placed. The change would occur at natural breaks in the barrier such as emergency crossovers or median bridge columns. There is no defined benefit from this placement but neither does there seem to be a detriment.

- *The close proximity of the barrier to the roadway might leave insufficient space for a disabled vehicle.* The inside shoulder is not intended to be a refuge. The AASHTO Policy on Geometric Design of Highways and Streets affirms the following.

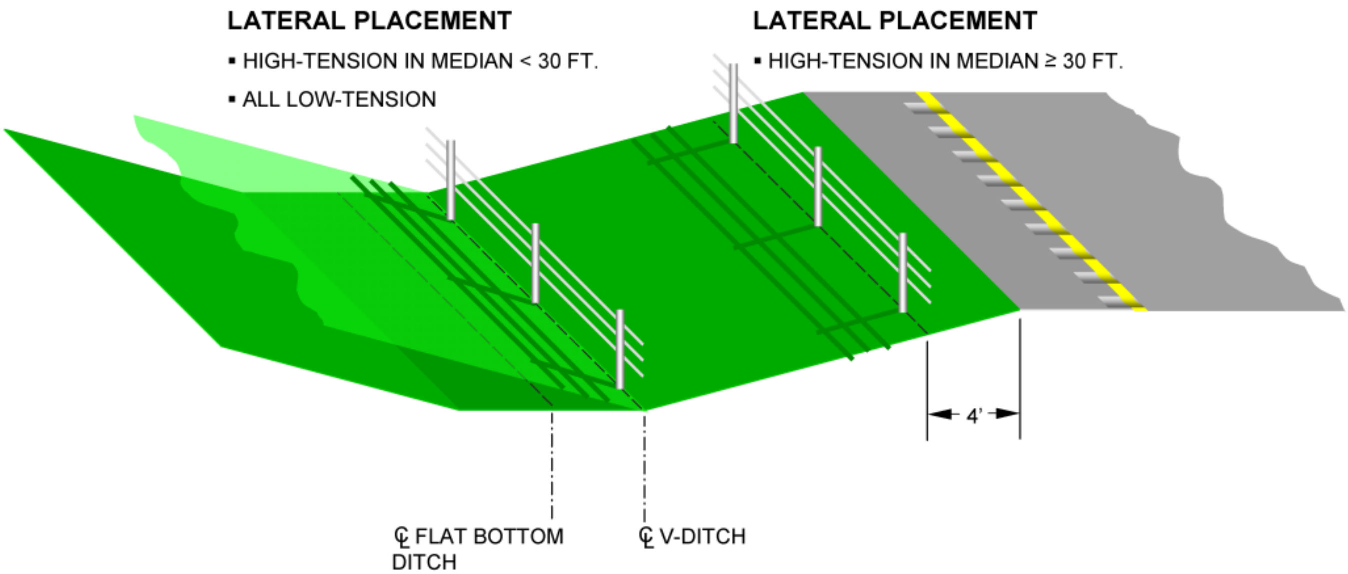

FIGURE 9 Optimized lateral placement

> "Shoulder space on the left side of the individual roadways of a four-lane divided arterial (i.e., within the median) is not intended to serve the same purpose as the right shoulder. The shoulder on the right, through customary use on undivided arterials, is accepted by all drivers as a suitable refuge space for stops. Where the median is flush with the roadway or has sloping curbs, vehicles may encroach or drive on it momentarily when forced to do so to avoid a crash. Only on rare occasions should drivers need to use the median for deliberate stops. On divided arterials with two lanes in each direction, a paved shoulder strip 4 ft. wide should satisfy the needs for a shoulder within the median." [7]

Common vehicle widths range from approximately 5 ft.-6 in. for a subcompact car to 6 ft.-9 in. for a wide sport utility vehicle. A minivan is usually about 6 ft. wide.[8] On the rare occasion a vehicle would take refuge against the cable median barrier, the average driver and passenger should have ample room to exit the vehicle on the left side, minimizing occupant risk.

Medians Narrower than 30 ft. In medians narrower than 30 ft., the cable barrier should be installed at the vertex of either a V or flat-bottomed ditch. As previously discussed, this location is the most advantageous from a performance standpoint. As shown in the Figure 8, the 4 ft. down-slope location starts to fail in narrower medians as the suspension of the vehicle impacting from the back side is most tightly compressed around that location. Again, fully compressed suspension has proven to be the principal reason for vehicles under riding the system.

From the standpoint of clarity and efficiency, separate standards for medians wider and narrower than 30 ft. is a less than desirable condition. However, the relative rarity of untreated medians narrower than 30 ft. should keep ambiguity to a minimum.

Post Spacing. While cable barrier systems have been tested and approved with post spacing ranging from 6.5 to 32.5 ft., it is widely believed that the wider post spacing lead to greater deflections and an increased likelihood of vehicle penetration due to underride or traveling between the cables. For this reason, post spacing should not exceed the conventional limit of 15 ft.[9]

Parallel Installations. Current MoDOT cable median barrier guidance cites the preferred method of treating slopes between 1V:4H and 1V:6H as high tension systems approved for those slopes. This remains the best-known solution. The guidance further states that, in certain situations where these systems may not function well, a parallel installation of cable median barrier should be specified.
Contrary to this guidance, in-service experience with parallel installations has shown a less than desirable result. The close proximity of each installation to traffic has caused an inordinately high incidence of nuisance hits resulting in rather high long-term maintenance costs.

This report recommends discontinuing the use of parallel installations of cable median barrier, relying instead upon a barrier system other than cable in undesirable median areas.

Routine Maintenance and Incident Repair

Irrespective of routes treated, proper placement, or system used, cable median barrier is only as functional as its ongoing maintenance and repair. With MoDOT potentially installing hundreds of additional miles of barrier, this aspect becomes even more critical. Proper maintenance and incident repair will ensure that the system is always in a state of functionality that will provide motorists a greater level of safety on Missouri highways.

Maintenance. Outside of vegetation control, there is very little routine maintenance required for a cable median barrier system. If pre-stressed cables are used for high-tension systems, and compensators are properly compressed for low-tension systems, the tension in the cable should properly acclimate to any weather condition. There is a period in which the tension requires occasional monitoring, but that stage occurs during and shortly after construction.

Improperly tensioned cables are sometimes the result of loose post bases. However, if post bases and sockets are properly engineered, they should perform well for years.

This report has demonstrated the importance of cable height in properly capturing and redirecting errant vehicles. Although cable height is relatively static in all systems, erosion under the barrier can sometimes cause a localized increase in height, resulting in possible underride.

Maintenance personnel should be educated on the necessity of proper cable height and encouraged to identify and repair locations where erosion or the accumulation of silt have altered the relative cable height.

Most other maintenance issues are rendered insignificant, given the frequency with which the system is impacted and subsequently repaired or replaced. For that reason, this report will focus on incident repair as the controlling issue in the ongoing maintenance of the system.

A secondary issue, closely related to incident repair, is the post-entry condition of the median. In addition to the repair of the roadside hardware, the median condition with respect to rutting, loss of vegetation, and accident debris should be remedied following each incident. These incidental concerns could cause instability in the trajectory of future errant vehicles and could, at worst, result in a failure of the system.

By making these repairs as the result of an accident, the costs may be reimbursable through the property damage subrogation program. Under this program, the DOT attempts to collect the costs of property damage from the errant driver’s insurance company.

On-Call Repair Contracts. Until very recently, all of the cable median barrier installed in Missouri was low-tension. As previously discussed, the maintenance of this system is vastly more complicated than that of a high-tension system. In fact, the complexity of the system coupled with the frequency of crash incidents, have traditionally resulted in the system’s maintenance being outsourced through on-call contracts. Although MoDOT maintenance personnel are entirely capable

of maintaining the low-tension system, additional staff, equipment, and resource commitments would be required.
Although there are slight variances between districts, current contracts require normal priority repairs to be made within 10 calendar days. High priority repairs require a 48-hour response time. In most cases, a two-day lag time before the notice to proceed is built into the contract in order for the contractor to request the identification of underground utilities.

The costs of the contracts vary widely from $5,000 per mile per year to $10,000 per mile per year.

The notification of the need for repair may come from a variety of sources including MoDOT Maintenance personnel, concerned citizens (by way of district customer service), and by the Missouri State Highway Patrol. Upon notification, a MoDOT inspector writes up the contract repairs into a work order.

On-call repair has generally worked well with the notable exception being a lack of adequate response to repairs in some rural areas. This is thought to be due to difficulty in mobilizing specialty contractors to complete the work.

In-House Repair. Since most of MoDOT's cable median barrier consists of the low-tension system, in-house maintenance has rarely been considered. With the advent and increasing use of high-tension barrier, however, the prospect of incident repair being accomplished through MoDOT forces is being examined. In fact, a few districts have begun conducting their own high-tension repairs.

In general, these districts have realized lower costs as well as quicker response times. The costs have been as low as $2,800 per mile per year. The equipment and hardware needs are minimal, and repairs to socketed systems can generally be accomplished in under an hour with two workers, some hand tools, and a pickup truck.

Recommendations

Response Time. A reduction in response time from ten to seven days should be enforced, irrespective of the entity that performs the work. This time could be further decreased for high-tension socketed systems since, in general, there would no longer be a need to locate subsurface utilities.

The possibility of assigned repair priority one to cable barrier, essentially equating its importance with that of an out of service STOP sign, was considered. This idea was discouraged, however, due to the random nature of cross-median crashes as well as the fact that damaged cable does not necessarily reflect an imminent danger.

Emergency and MoDOT Maintenance personnel should be alerted to the importance of functional cable median barrier and strongly encouraged to report damage immediately so remedial action can commence. Consideration may even be given to an incentive program under which employees can be rewarded, in some manner, for reporting damage to the barrier. A similar program has been implemented by the city of Springfield, Missouri. The details of that program are attached to this report as Appendix C.

In addition to this campaign, MoDOT personnel should schedule regular inspections in which the entire cable barrier corridor is driven and any critical damage is reported. Inspections of this nature would be especially pertinent after a heavily traveled holiday weekend.

Low-Tension Repair Responsibilities. The repair of low-tension barrier systems should continue to be outsourced. However, the administration of those contracts should be examined in order to better enforce contract repair times. The assessment of liquidated damages may be a reasonable method by which this can be accomplished.

High-Tension Repair Responsibilities. The repair of high-tension barrier systems should be handled by MoDOT maintenance staff but only if their other responsibilities, primarily pavement maintenance, can be efficiently accomplished with existing employees. Most cable barrier repairs can be conducted with two workers bearing minimal equipment. Local maintenance sheds will also have to stock the necessary repair hardware.

There may be an occasional need for assistance with traffic control, but, for the most part, most of the work can be accomplished well away from the roadway.

Repair Responsibilities Across District Lines. There could be some benefit in maintaining cable median barrier by corridor rather than by district. Some rural districts have only small amounts of the cable system in place and the locations usually border on more urban districts with many more divided arterials.

By performing maintenance across their borders, districts needn't spend the money and resources necessary to maintain a limited system. The possibility of system maintenance by corridor should be explored.

Emergency Access Issues

The cable median barrier program in Missouri has, by any estimation, been a remarkable success. This success is a leading reason why MoDOT's program has expanded so rapidly and why further expansion is planned. Closing medians has greatly enhanced their safety, but one key safety factor, emergency access, warrants further study.

In the past, Emergency services have had unlimited access to reverse their direction by crossing the median. With the installation of cable median barrier, this access has been greatly curtailed.

In order to ensure the greatest possible efficiency on the part of emergency services, the cable median barrier team solicited a meeting with most of the major services. The Missouri State Highway Patrol and the Missouri State Fire Marshall's Office attended a meeting, discussed the issues, and, together with the multidisciplinary team, arrived at the recommendations contained herein.

MoDOT's maintenance Division also has a great interest in cross-median access. Ample access ensures safe and efficient work on the part of maintenance crews. However, for the sake of clarity, this section will use the term "emergency access" to refer to both traditional emergency services and MoDOT maintenance.

Federal Highway Administration Guidelines. Currently, the FHWA has a set of guidelines that define their policy on emergency crossovers for freeways. Those guidelines can be summarized as follows:

- A minimum sight distance of 1500 ft. must be available.
- Crossovers must be spaced a minimum of 1500 ft. from the divergence or convergence of a ramp.
- Crossovers should be spaced three to four miles apart.
- The number of crossovers should be kept to an absolute minimum in order to limit potentially hazardous misuse by the general public.

In a conventional, open median, these guidelines are reasonable. However, closing the median with cable barrier costs emergency services their ability to change direction wherever needed. Since the barrier will force their access to occur at a limited number of fixed points, those points should occur where they are most effective.

Recommendations

Freeway. In general, cross median access, whether grade-separated or at-grade, should be provided every 2-½ miles. If the access is at-grade, it must meet the sight distance and ramp clearance guidelines of the FHWA.

By this recommendation, two interchanges spaced less than 2-½ miles apart would not have any at-grade access available between them. Two interchanges three to five miles apart would have emergency at-grade access approximately midway between them.

Interchanges spaced five miles apart could warrant at-grade access at either minimum ramp clearance in addition those spaced at 2-½ miles. These additional crossovers would better facilitate snowplowing operations in the vicinity of the interchange. Even when this interchange spacing is present, however, the core team should work closely with district Maintenance staff to determine if the need for the additional access truly exists. In some cases, two evenly spaced at-grade crossings between the interchanges could adequately accommodate both emergency and maintenance operations.

For interchange spacing of six miles or greater, at-grade access at either minimum ramp clearance should be provided, in addition those spaced at 2-½ miles. Snow removal operations should also be taken into account in the vicinity of weigh station ramps as well as rest area ramps. In these situations, the 1500 ft. minimum separation required of interchanges would still apply.

These recommendations, while thorough, are not all encompassing; local variables may require a different course of action. When constructing or relocating emergency crossovers, district personnel should meet with local emergency responders and review MoDOT's incident management policy to ensure the recommendations given in this report are truly feasible.

Expressway. The frequency of emergency median access for expressway should follow the same general principals as that of freeway. It is likely, however, that adequate access already exists in these medians by virtue of current, non-emergency, median openings.

Geometric Design. The design for cable barrier termination as well as the grading for the crossover, should be in accordance with *Missouri Standard Plan for Highway Construction* 606.41, Sheet 6 of 6. The width of the crossover should not exceed 20 ft. If feasible, the crossover should be located immediately downstream of an existing median drop inlet in order to eliminate a pipe culvert.

An unauthorized U-turn into high-speed traffic, on the part of the general public, represents a hazardous situation. In order to discourage non-emergency use of the crossover by motorists at large, the crossings should be kept narrow with small transition radii. Neither should they have hard surfaces or deceleration tapers.

An aggregate surface of predominately 6" material should provide an adequate, all-weather surface that still appears unattractive to the non-emergency motorist.

Access Justification. The FHWA requires justification of access for each new freeway access designed. Their approval is granted in response to an Access Justification Report (AJR), which details the purpose and need for the access and analyzes its impact upon traffic flow. As the AJR is typically a rather lengthy and time consuming document to produce, the FHWA should enter into a programmatic AJR with MoDOT.

The parameters of emergency median crossovers as well as their impact upon traffic are both predictable and static. As such, a single AJR could efficiently address the design and construction of every future emergency access.

Appendix A

Identification and Prioritization of Remaining
Cable Median Barrier Needs Statewide

Identification and Prioritization of Remaining Cable Median Barrier Needs Statewide

The Purpose of Median Guard Cable. When identifying and prioritizing routes for treatment, it is critical to remember that the primary purpose of the statewide median cable barrier program is saving lives. For that reason, the data used in this analysis is based largely on the occurrence of fatal crashes.

Data Analysis. Routes were analyzed both as segments (separated at logical points) and long corridors. They were then ranked in a number of ways, including total fatal crashes, equivalent property damage only (EPDO) number per mile, and severity number per mile.

The EPDO method is a way of considering all accidents at a location on an equal basis. It is accomplished by weighting the more severe crashes (fatal, disabling injury, and minor injury) accordingly, and adding them to the property damage only (PDO) crash totals.

The severity number is similar, however, it only takes into account the fatal and disabling injury crashes.

Identification and Prioritization. In keeping sight of MoDOT's emphasis on reducing fatalities, the first identifier for cable barrier treatment was a fatal crash count of two or more for the segment of roadway being considered. Upon compilation of that list, the candidate segments were prioritized by EPDO and severity number. The priority thresholds are as follow:

- **Tier One**
  Projects in which the greatest and most immediate benefit can be realized from cable barrier treatment
  EPDO per mile .... greater than 3.5
  Severity Number per mile........... greater than 2.5
  Fatal Crashes 2.0
- **Tier Two**
  Projects in which significant benefit can be realized from cable barrier treatment
  EPDO per mile ....3.5 to 2.5
  Severity Number per mile......................2.5 to 1.5
  Fatal Crashes 2.0

List of Prioritized Projects

Tier 1

Priority	**Route**	**Termini**
1	I-470	Various sections in Jackson County
2	65	I-44 to Rt. 60 in Greene County
3	71	63rd St. in Jackson County to Rt. 7 South in Cass County
4	67	I-55 in Jefferson County to Rt. E in Madison County
5	I-55	Rt. 61 to I-57 in Scott County
6	63	I-70 in Boone County to Rt. 54 in Callaway County

Tier 2

Priority	**Route**	**Termini**
7	169	Various sections in Clay County
8	I-55	Rt. 67 in Jefferson County to Rt. E in Cape Girardeau County
9	I-29	Rt. 159 in Holt County to Rt. 6 in Buchanan County
10	I-55	I-57 in Scott County to Arkansas border

Appendix B

Cost Analysis and Funding Sources

Cost Analysis and Funding Sources

Cost Analysis. The cost of high-tension median cable barrier installation is dependent on a number of factors; chief among them are functional classification and vegetation control.

The primary cost difference due to functional classification is the change in access between freeway and expressway. On average, cable anchors are expected to be placed every 2.5 miles apart; on expressway, about every mile. The difference in cost amounts to less than $4,000 per mile and is not a primary cost driver. As a worst case, the cost analysis provided in this report is based upon costs for expressway installations.

A vegetative barrier is critical to the realization of the full, long-term maintenance value of the recommended cable barrier system. The vegetation control can be as simple as a geotextile/aggregate system or as complex as an asphalt system. The cost analysis given in this report assumes the geotextile/aggregate option.

Detailed Cost Analysis

Item	Unit	Qty.	Unit Cost	Total
Cable	Lin. Ft.	5280	$13	$68,640
Anchors	Each	2	$3,663	$7,326
Linear Grading	Sta.	53	$170	$9,010
Aggregate Bedding	Cu. Yd.	391	$75	$29,325
Traffic Control	Lump	1	$3,000	$3,000
Seeding & Mulching	Acre	2	$4,500	$9,000
Erosion Control	Lump	1	$600	$600
Subtotal				$126,901
Mobilization	Lump	1	3%	$3,807
Total Cost per Mile				**$130,708**

Program Cost

Tier 1

Priority	Route	Length	Cost
1	I-470	9.4	$1.23 Million
2	65	8.5	$1.11 Million
3	71	24.9	$3.25 Million
4	67	55.1	$7.20 Million
5	I-55	27.6	$3.61 Million
6	63	28.1	$3.67 Million
Subtotal			$20.07 Million

Tier 2

Priority	Route	Length	Cost
7	169	18.0	$2.35 Million
8	I-55	63.4	$8.29 Million
9	I-29	31.3	$4.09 Million
10	I-55	66.2	$8.65 Million
Subtotal			$23.38 Million

Total	**$43.45 Million**

Funding Sources. Funding for the recommended projects can come from a number of sources.

- Open Container Transfer Funds (Section 154): 3% of Federal appropriations, earmarked for hazard elimination as a result of states not having open alcoholic container legislation in place by October 1, 2002.
- Highway Safety Improvement Plan (HSIP) Funding:
  A significant increase in the funding available for infrastructure-related highway safety improvement projects under SAFETEA-LU.
- STIP funds
- Operations funds
- Other sources

For these projects to be installed as quickly as possible, it will be important to utilize funding sources beyond the Open Container funds.

Appendix C

Sample Employee Involvement Campaign

City of Springfield, Missouri
24/7 Program

PUBLIC WORKS PILOT PROGRAM
TWENTY-FOUR / SEVEN

All Public Works employees are encouraged to report infrastructure defects that they notice on holidays, evenings and weekends (beyond normal work hours). The defects can vary from a malfunctioning traffic light to an overflowing sanitary sewer manhole. Defects to be reported under this program are those defects that can affect public health and safety and those that demand immediate attention. Employees would call 864-1955 which is the Nights and Weekends Public Works number and inform the person answering that this is a "24/7" report and give the person answering your name, the Division you work for and the type of defect and location of the defect you are reporting. If the defect is reported more than once only the first person reporting the defect will be recorded as reporting the defect. This program should provide the means to convey and receive important information needed by the Public Works Department to carry out the City's Mission and Council Priorities.

Defects to be reported under this program

- Malfunctioning traffic lights within the Springfield City Limits
- Missing or damaged stop signs within the Springfield City Limits
- Overflowing City of Springfield sanitary sewer manholes
- Missing or damaged manhole lids
- Broken or damaged storm water inlet
- Dangerous sidewalk defect
- Debris in the street
- Tree limbs blocking traffic signals or signs
- Other defects or problems which should receive prompt attention

Logistics

At the beginning of each month the names of employees who have called in defects in the previous month will be put into a container and one name will be pulled from the container. If an employee had called in more than once, their name will be placed in the container for each time a defect was reported. The person whose name is pulled will be given a $30 gift certificate for dinner at a downtown Springfield restaurant for the employee and their spouse.

Benefits to the City of Springfield

"24/7" has the potential to:

Increase
- Public safety
- Organizational effectiveness
- Customer satisfaction
- Employee engagement and Morale

Decrease
- Loss of life
- Accidents /property damage
- City liability
- Service requests

Why "24/7"?

- Public Works' areas of responsibility are expanding at a greater rate than its resources. "247" taps into the entire organization to help Public Works stay ahead of the curve with regard to public safety.
- "24/7" gives a name, procedure, and incentive for reporting. We currently have no widely understood or advertised system in the City organization.
- "24/7" can be easily disseminated throughout the organization and encourages participation. It engages and encourages organizational responsibility.
- The apparatus for "24/7" is already in place and the cost for implementation relative to its potential payback is minimal.

This has been approved by the City Manager as a pilot program. This program will begin June 1, 2007. The effectiveness of this program will be evaluated after December 31, 2007 to determine if the program should continue and perhaps be expanded to include all City employees.

Appendix D

Sources

Sources

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