SAFER ROADS SAVE LIVES

SAFETY BENEFITS OF MEDIAN BARRIER AND ROADSIDE GUARDRAIL

PREPARED UNDER CONTRACT BY AUBURN UNIVERSITY

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Overview

Roadway departure (RwD) crashes account for more than 50 percent of all motor vehicle traffic fatalities. There are a number of reasons a driver may leave the travel lane (e.g., an avoidance maneuver, inattention or fatigue, or traveling too fast for weather or geometric conditions). Over the past few decades, different engineering countermeasures have been proposed, implemented, and tested by various state and local agencies to mitigate RwD crashes. Improving median or roadside barrier design is one of the most effective countermeasures available to reduce RwD fatal crashes.

This publication focuses on highlighting the safety benefits of roadside and median barriers. These devices suffered damage to their reputation as life savers because of some isolated unfortunate incidents, however the safety benefits beyond any doubt have been proven by numerous research studies. At this juncture, the life-saving qualities of roadside guardrails and median barriers need to be underscored. This publication attempts to do that by telling just a few of many stories of individuals who were saved from harrowing crashes by either a guardrail or a cable barrier at the crash location. A total of eight case studies are included in this booklet. Of the eight, four case studies are based on incidents where a cable median barrier saved lives, the other four cases tell the stories of individuals saved by roadside guardrails. All the case studies presented in this report are based on real-life incidents.

In addition to the case studies, the publication also discusses the importance of having trained personnel to install, inspect, and maintain the roadside safety devices. Trained installers ensure that safety devices are installed in compliance with the product and design specifications. The role of a trained inspector is to regularly check the safety devices within their jurisdiction for any damage and decide to repair or replace the damaged devices. This is vital to highway safety, since a damaged device could fail to perform as tested. Finally, trained maintenance personnel are necessary for making repairs or executing proper maintenance procedures on guardrails or median barriers. Sometimes, a safety device may need maintenance due to wear and tear caused by environmental factors. A trained maintenance crew can spot minor defects in safety devices and repair them before they evolve into irreparable damage.

Finally, this publication discusses the 2016 edition of the Manual for Assessing Safety Hardware (MASH). This document is the most recent in the series of guidelines for assessing and evaluating safety hardware such as guardrails and cable barriers. MASH replaces its immediate predecessor, the National Cooperative Highway Research Program (NCHRP) Report 350. MASH includes a gamut of tests to be performed on safety devices before deeming them crashworthy for deployment. Between the NCHRP 350 and the MASH 2016 test criteria, several changes are made regarding the test vehicles and specifications for guardrails and cable barriers. This report briefly discusses the said changes and potential impact on improving the safety of roadside and median barriers. ■

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List of Acronyms

AASHTO	Association of State Highway and Transportation Officials
ATSSA	American Traffic Safety Services Association
AU	Auburn University
CMF	Crash modification factor
DOT	Department of transportation
FHWA	Federal Highway Administration
HTCB	High-tension cable barrier
MASH	Manual for Assessing Safety Hardware
NCHRP	National Cooperative Highway Research Program
NGO	Non-governmental organization
NHTSA	National Highway Traffic Safety Administration
ROR	Run-off-road
TCD	Traffic control device
WSDOT	Washington State Department of Transportation

1. INTRODUCTION

Many state and local governments, private industry, and non-governmental organizations (NGOs) have adopted policies that set a goal of eliminating fatalities on America's roadways (e.g., Toward Zero Deaths or Vision Zero). To achieve that goal, we must recognize that the safety of America's roads is a shared responsibility. Figure 1 shows a road safety ecosystem that indicates the responsibility by six different parties. For example, road safety devices are designed by device manufacturers, installed by contractors, approved for eligibility for Federal-Aid Highway Program reimbursement by the Federal Highway Administration (FHWA), and maintained by state departments of transportation (DOTs).

Longitudinal barriers are commonly used road safety devices that can prevent errant vehicles from colliding with fixed objects such as trees or poles, entering a dangerous area such as a drop-off or ravine, or crossing the roadway into oncoming traffic. Longitudinal barriers can be placed either on the roadside or along the median, depending on the site conditions and need. This publication focuses on the safety benefits of two types of longitudinal barriers: median barriers and roadside barriers. Roadside barriers are intended to prevent run-off-road (ROR) crashes and stop vehicles from colliding with obstacles present on the roadside. On the other hand, median barriers prevent swerving vehicles from entering opposing traffic. Roadside barriers and median barriers are important traffic safety devices that can significantly reduce the severity of ROR crashes.

Their efficacy in mitigating crash severity is assessed by a crash modification factor (CMF), an estimate of the change in crashes expected after implementing a given countermeasure at a specific site. A CMF reflects the safety effect of a countermeasure, whether it is a decrease in crashes (CMF less than 1.0), increase in crashes (CMF more than 1.0), or no change in crashes (CMF of 1.0) *(1)*. For example, in Table 1, CMF of median barrier for preventing cross-median fatal injury crashes is 0.34. This means, the expected number of fatal crashes after installation of median barrier will be reduced by approximately 66 percent.

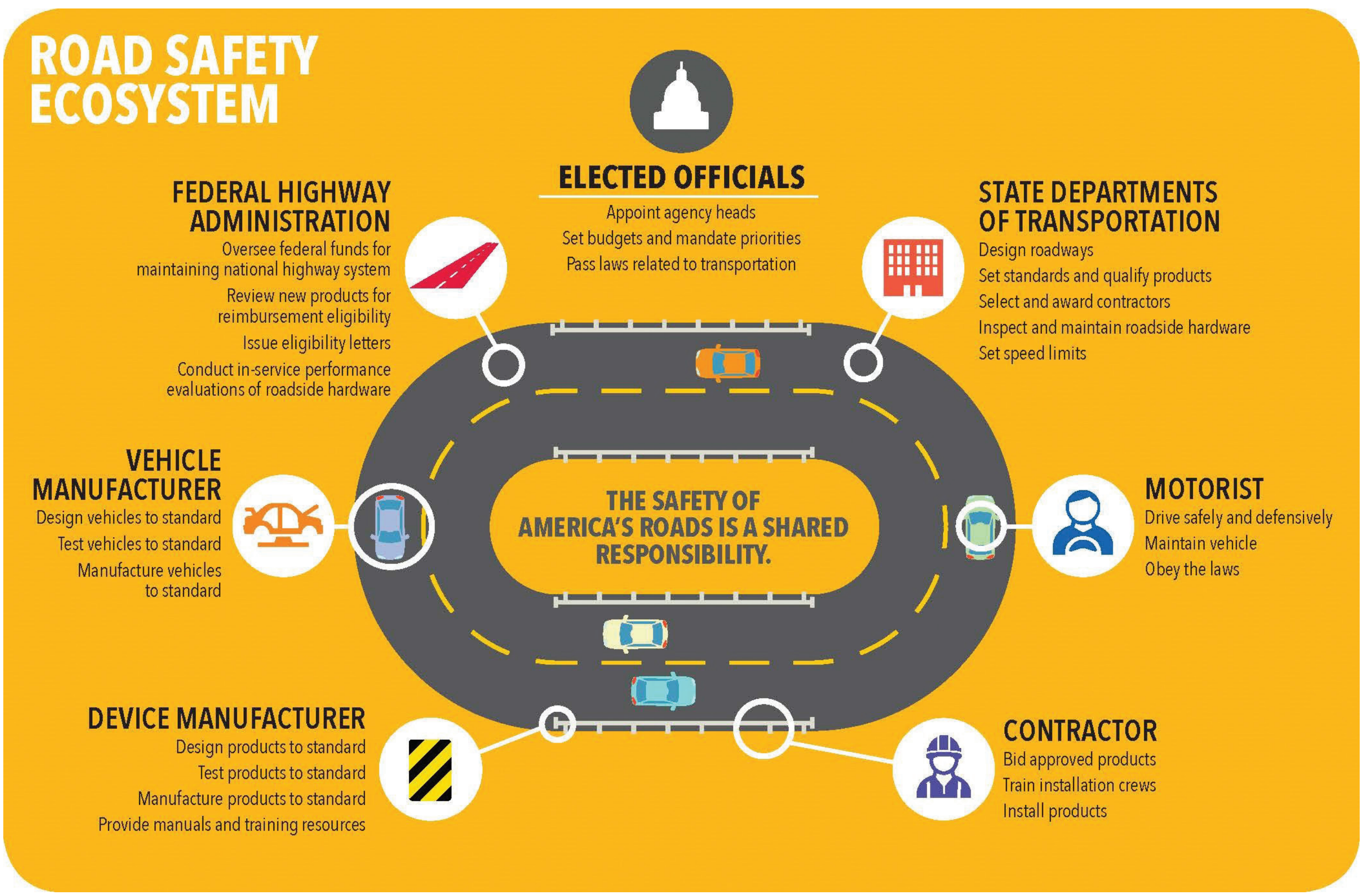

Figure 1.
Road Safety Ecosystem

Table 1.
CMFs of Barrier and Guardrail Treatments *(1)*

Countermeasure	Crash Type	Crash Severity	CMF
Median Barrier	All	Serious injury	0.39
	All	Fatal	0.48
	Cross-median	Serious injury	0.19
	Cross-median	Fatal	0.34
	Other	Seriour injury	0.31
	Other	Fatal	0.45
Roadside Guardrail	All	Fatal and serious injury	0.84
	ROR	Fatal and serious injury	0.74
	ROR (dry weather)	Fatal and serious injury	0.79
	ROR (wet road)	Fatal and serious injury	0.75
	ROR (nighttime)	Fatal and serious injury	0.53

Figure 2.
Types of Median Barriers: a. Flexible; b. Semirigid; c. Rigid

Table 1 lists several CMFs pertinent to median barriers and roadside guardrails in the CMF Clearinghouse database. They are applicable to principal arterials as well as other freeways and expressways where roadside guardrails and median barriers are deployed. All the CMFs in Table 1 are less than one, which indicates a ***decrease*** in fatal and serious-injury crashes by the installation of guardrails and median barriers. Guardrails are effective in reducing fatal and serious-injury crashes, ranging from 16 to 47 percent in reducing such crashes. Median barriers are very effective in reducing cross-median crashes (expected 52 percent reduction in all fatal crashes and 61 percent reduction in all serious-injury crashes). All the CMFs for guardrail and median barriers in Table 1 have a Star Quality Rating of three or more, which means the results of the study producing the CMF are in good quality (five stars is the highest rating) *(1)*.

1.1 Median Barriers

1.1.1 Description

There are three different types of median barriers: flexible, semirigid, and rigid (Figure 2). Each type of barrier is best suited to a specific type of road environment.

- Flexible barriers consist of low-tension and high-tension cable barrier (HTCB) systems. HTCBs have replaced the low-tension cable barriers in most states due to improved performance and maintenance benefits. Cable barriers are best suited for deployment at locations with wide median areas and allow drivers to make a safe stop without re-entering the traffic or entering the travel lane of oncoming traffic (i.e., wrong-way driving). Their larger deflections allow for softer impacts, resulting in fewer injuries, and the open design allows for wind, sand, and snow to pass through the system.

Figure 3.
An Example of HTCB Median Barrier

Figure 4.
An Example of HTCB Roadside Barrier

- W-beam guardrails, box-beam and thrie-beam fall into the semirigid barrier category. This guardrail-type median barrier can flex more than 3 feet and allows a driver some control after impact. Guardrail-type barrier is most effective for protecting drivers from drop-offs or colliding with fixed objects on the median or roadside.
- Rigid barriers are made of concrete. Concrete barriers are rigid and are effective for redirecting straying motorists back into their lane. This type of barrier is most effective along roads where traffic in opposing directions is flowing in close proximity due to lack of space.

1.1.2 Median Barrier Safety Benefits

The primary purpose of a median barrier system is to reduce the collision severity when the vehicle leaves the roadway and encounters other vehicles in the opposing direction or hazards (fixed objects or terrain features) that are less forgiving than striking the barrier system.

Median barriers reduce the number of crossover crashes and severe-injury or fatal crashes. One major consideration about median barriers is the width of the median and knowing where and what type of barrier should be installed. The common median width for installing cable barriers is 40 feet to 75 feet. A few other factors to consider include the median slope, the amount of traffic, the crash history, and the cost. HTCBs are in wide use across the country and are seen as more effective than low-tension cable barriers. Figure 3 shows an installation of HTCB as a median barrier. HTCB can be placed on slopes as steep as 4:1 or flatter. It should be noticed that the HTCB can also be used as a roadside barrier. Figure 4 shows a roadside barrier using HTCB in Idaho. For more details on HTCB median warrants, readers are encouraged to refer to a technical memorandum published by the Minnesota Department of Transportation in 2015 *(2)*.

Figure 5.
A Roadside Guardrail

1.2 Roadside Barriers

1.2.1 Description

Roadside barriers are placed along the edge of a highway at dangerous sites. Guardrails are the most commonly used roadside barriers. Guardrails function as a system, which includes the guardrail itself, the posts, the soil that the posts are driven into, the connection of the guardrail to the posts, the end terminal, and the anchoring system at the end terminal. All these elements have a bearing in how the guardrail will function upon impact. Guardrails consist of two key functional components: the end terminal and the guardrail face (Figure 5). The guardrail face is the length of the guardrail extending from the end terminal alongside the road. Its function is to redirect the vehicle back onto the roadway. The end terminal is the starting point of the guardrail, also referred to as the end treatment. The exposed end of the guardrail needs to be treated to avoid a significant crash. One common treatment is an energy-absorbing end treatment that is designed to absorb the energy of an impact by having the impact head slide down the length of the guardrail. These end terminals function in two ways:

1. When hit head-on, the impact head slides down the guardrail, flattening, or extruding, the guardrail and redirecting the guardrail away from the vehicle until the vehicle's impact energy is dissipated and the vehicle has decelerated to a stop. An example of a head-on collision can be see in the video shown here (courtesy of Ohio Department of Transportation) - https://www.youtube.com/watch?v=4WnIpNkNFDk
2. When hit at an angle, the impact head may partially extrude the guardrail and then "gate" out of the way allowing the vehicle to pass behind the guardrail. This means the terminal and guardrail is pushed through, as if opening a gate.

1.2.2 Roadside Barrier Safety Benefits

A roadside barrier can prevent a vehicle from running off the road at dangerous sites. The best-case scenario, if a car is straying off the road, would be for that car to come to rest unhindered. In some cases, that is not possible. The roadway may be abutted by steep embankments or side slopes, or it may be lined with trees, bridge piers, retaining walls, or utility poles. In those cases — when the consequences of striking a roadside barrier would be less severe than striking the other objects next to the roadway — barriers should be installed. They can make roads safer and lessen the severity of crashes.

The most commonly used roadside barrier, W-beam guardrail, can operate to deflect a vehicle back to the roadway, slow the vehicle down to a complete stop, or in certain circumstances, slow the vehicle down and then let it proceed downstream past the guardrail. This is not to say that guardrails can completely protect against the countless situations drivers may find themselves in. The size and speed of the vehicle, the vehicle's orientation, and the condition of the guardrail system can affect guardrail performance. This fact highlights the need for standard testing procedures and employing qualified personnel to install and maintain guardrails.

1.3 Implementation of Crash Testing Standards

Roadside safety hardware and traffic control devices (TCDs) are tested to meet standards developed by the public sector. The first such standards were developed in 1962, Highway Circular 482. Subsequently, these were updated through the NCHRP in 1974 (NCHRP Report 153), in 1980 (NCHRP Report 230), and again in 1993 (NCHRP Report 350). A new standard, called the Manual for Assessing Safety Hardware, or MASH, which takes into account significant changes in the vehicle fleet, was developed by the Association of State Highway and Transportation Officials (AASHTO) in 2009 with updates in 2016. The goal of the MASH standard is to assess various impact conditions with the objective of reducing the severity of crashes and reducing fatalities. As of the date of publication of this report, state DOTs are transitioning from NCHRP-350 standards to the new MASH standards. MASH, published by AASHTO in 2009 and updated in 2016 *(3)*, presents uniform guidelines for crash testing permanent and temporary highway safety features and recommends evaluation criteria to assess test results. This manual is recommended to be used by highway design engineers, bridge engineers, safety engineers, maintenance engineers, researchers, hardware developers, and others concerned with safety features used in the highway environment.

MASH is an update to and supersedes NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, for the purposes of evaluating new safety hardware devices. MASH does not provide any guidelines for the application of roadside safety hardware, which are contained within the AASHTO Roadside Design Guide *(4)*. An implementation plan for MASH that was adopted jointly by AASHTO and FHWA states that all highway safety hardware accepted prior to the adoption of MASH — using criteria contained in NCHRP Report 350 — may remain in place but may not be installed in new locations. In addition, FHWA will not accept the new installation of any devices tested to NCHRP Report 350 for eligibility for Federal-Aid Highway Program reimbursement beginning from Dec. 31, 2016. From that date, only those devices which are successfully crash tested to the MASH 2016 standards will be eligible for reimbursement.

Once a device has been tested at an independent testing facility and met the relevant standard, it is submitted to FHWA to obtain a letter of eligibility for federal-aid reimbursement to the roadway owners who use federal-aid highway funds. Subsequently, the manufacturer must apply individually to each of the 50 state DOTs to have the device placed on its approved product list, or qualified product list (APL or QPL).

Guardrails and cable barriers are defined as longitudinal barriers in MASH 2016. In both NCHRP 350 and MASH 2016, the same six test levels are listed for evaluating longitudinal barriers. Each test level corresponds to a certain impact speed using vehicles of a certain weight. However, MASH 2016 made some important changes to test vehicle types and impact angles. A test vehicle refers to the type of vehicle that must be used to evaluate the longitudinal barrier. The impact angle refers to the angle at which the test vehicle is expected to strike the barrier during testing. In MASH 2016, the size and weight of test vehicles were increased to reflect the increase in vehicle fleet size.

More specifically, vehicle types of 1100C (passenger car) and 2270P (pickup truck) replaced the 820C and 2000P test vehicles defined in NCHRP 350, respectively. An impact angle of 20 degrees is replaced by an angle of 25 degrees for 1100C (small car).

Testing criteria specific to cable barriers was introduced for the first time in the MASH 2009 edition. These criteria include minimum fence lengths, minimum tension for testing, and placement of hardware in the vehicle impact zone. In MASH 2016, six new tests (Tests 13 through 18) are added to test the effectiveness of cable barriers at 6:1 and 4:1 slopes for different performance conditions, including:

- Ability of a cable barrier to contain and redirect light trucks and SUVs as well as prevent barrier override.
- Ability of a cable barrier to safely contain and redirect small passenger vehicles without resulting in excessive vehicular instabilities and/or rollover.
- Ability of a cable barrier to safely contain and redirect small passenger vehicles as well as prevent barrier underride, component penetration into the occupant compartment, and excessive deformations of the A-pillar, roof, or windshield.
- Ability of a cable barrier to safely contain and redirect small passenger vehicles after traveling across the center of a ditch and up the back slope.
- Ability of a cable barrier to contain and redirect mid-size passenger sedans by preventing vehicle penetration through vertically adjacent cables.
- Ability of a cable barrier to safely contain and redirect light trucks and SUVs after traveling across the center of a ditch and up the back slope.

Each of these six new tests were recommended for testing cable barriers to be installed in median ditches of varying slopes. Test matrices for the selected cable barrier-ditch combinations are summarized in Tables 2-2B through 2-2E of MASH 2016.

The objective of MASH and NCHRP 350 is to provide specific standards for evaluation of safety devices. When conducting the test, the test vehicle range should represent about 85 percent of the passenger vehicle fleet. However, the weight of a small test vehicle outlined in NCHRP 350 is 1,800 pounds. Such vehicles have become difficult to find on roads since 2009. Therefore, MASH includes a new set of test vehicles, which are more representative of the current vehicle fleet on U.S. roads. In addition, the testing requirements for MASH are more stringent than NCHRP 350 *(5)*. So, the safety benefits offered by longitudinal barriers are expected to be elevated to a higher level by the new MASH standards.

1.4 Installation, Inspection, and Maintenance of Longitudinal Barriers

For successful performance of any safety devices, it should be properly installed, inspected, and maintained on a regular basis. Several state DOTs have developed guidelines for installation and maintenance of roadside safety devices within their jurisdictions. For example, the Washington State Department of Transportation (WSDOT) provides a design manual that covers roadside safety elements to give the design and installation information of the guardrail and median barrier *(6)*.

The installation of guardrails and median barriers needs to be done in a methodical manner so that these safety devices can deliver successful performance. Furthermore, the concerned transportation agency must ensure that these safety devices are inspected on a regular basis so that damaged or deficient barriers can be repaired or replaced according to the need. Periodic maintenance of longitudinal barriers is essential to improve the longevity of the device and helps in reducing long-term costs of repairs and restorations.

1.4.1 Installation

To begin with, detailed project plans and specifications are required to ensure that the barriers are installed as designed and tested. Information on the barrier type, post spacing, and any other relevant details must be outlined in the project plan *(7)*. Prior to installation, the site must be prepared by compacting and grading. The actual barrier installation cannot be completed unless the site is prepared. After site preparation, barriers can be installed, beginning with post driving. Later, based on the type of barrier, cables or guardrails are mounted onto the posts. Terminals to the barrier will be installed depending on design requirements. Finally, the alignment of the installed barrier should be checked and corrected if necessary. Steps of an installation process are shown in Figure 6.

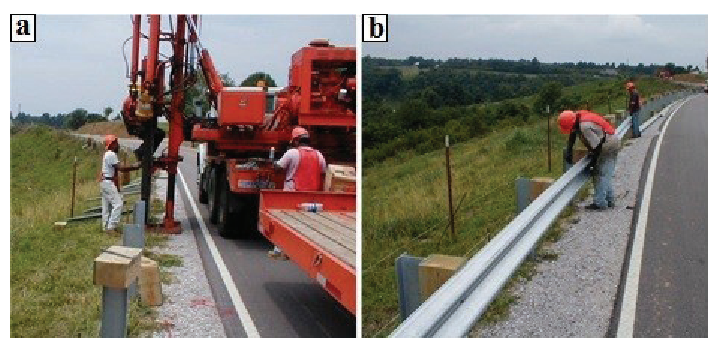

Figure 6.
Steps in Installation: a. Post driving; b. Guardrail Mounting *(7)*

Clearly, the installation of longitudinal barriers is a complex process that involves a significant amount of time, effort, and expertise. To perform the installation properly, utilizing personnel trained specifically for this process is necessary. Any errors in installation will create a faulty barrier system and might have a negative impact on the performance of the devices.

1.4.2 Inspection

Periodic inspection of installed barrier systems is essential for enhancement of roadway safety. Inspecting a barrier system involves a variety of tasks, ranging from site drive-through to on-site data collection. The inspection process begins well before the site visit. Information on traffic conditions, roadside features, work history, utility location, and pavement data of the barrier site are all gathered prior to the site visit *(8)*. Then, a brief site drive-through is necessary to gain an overall perspective of site conditions.

Various aspects of the installed barrier should be checked as a part of the inspection. First, it should be confirmed that the height of the barrier is compliant with the original plan. Second, the distance from the barrier to the edge of the roadway should be measured to check if it is according to the specifications. Finally, if any terminal installations or transition sections are present, they must be inspected for proper alignment, height, tension in cables, and any other relevant criteria *(7)*.

Similarly, the area around the barrier must also be inspected. The recovery area should be inspected to see if it is traversable so that errant vehicles have a chance to recover and correct its course. Additionally, it should be ensured that the approach area is level and debris-free *(7)*.

Performance of an on-site inspection requires trained personnel. They must be trained in collecting data, taking measurements, evaluating the barrier's crash worthiness, and in several other aspects of the inspection process. Lack of trained personnel results in faulty inspection and faster deterioration of safety benefits.

1.4.3 Maintenance

Despite spending large amounts of time and money toward repairing damaged longitudinal barrier systems, it can be difficult to maintain them in an ideal as-built condition *(8)*. Financial constraints prevent transportation agencies from maintaining all field-installed systems on a regular basis. Often, agencies prioritize repairs to barriers that are damaged to such an extent that their safety benefits are compromised. Consequently, identification of barrier systems to be repaired is vital for maintaining safety on roadways, and trained personnel are needed for making such identification. The NCHRP Report 656 *(8)* presents criteria for restoration of longitudinal barriers. According to this guide, there are three priority levels for maintenance of a barrier as summarized in Table 2.

NCHRP Report 656 *(8)* goes into more details on what constitutes a high-, medium- or low-priority repair level. The decision of assigning a priority level to a damaged barrier ultimately falls on maintenance personnel. Therefore, it is important to train the maintenance crew to accurately recognize the extent of damage done to a barrier and assign the appropriate priority level. It should be noted that any upgrades or replacements of damaged barriers should be MASH-compliant. ■

Table 2.
Repair Priority Scheme *(8)*

Priority Level	Description
High	A second impact results in an unacceptable safety performance, including barrier penetration and/or vehicle rollover.
Medium	A second impact results in a degraded but not unacceptable safety performance.
Low	A second impact results in no discernable difference in performance from an undamaged barrier.

2. MEDIAN BARRIER SUCCESS STORIES

To better illustrate the safety benefits of median barriers, four case studies concerning motorists who were saved by successful performance of these safety devices are presented in this section. Each story portrayed here tells us about the life-saving quality of median barriers.

Figure 7.
Mr. Krull's Tractor-Trailer Captured by a Cable Median Barrier on Hwy 41 in Wisconsin

2.1 Major Highway Disaster Averted by Median Cable

Collisions involving trucks are often disastrous. Fortunately, in this case, presence of a cable median barrier averted one such major disaster. The incident described here occurred near Fond Du Lac, Wis., on Oct. 6, 2007. On that fateful day, Leo Krull, a 63-year-old truck driver was traveling southbound on Highway 41. Little did he know that it would be his final day at work. Mr. Krull suffered a severe cardiac arrest while still behind the wheel of his semitrailer.

Witnesses later recalled that the semitrailer being driven by Mr. Krull dramatically slowed down and began to run adrift on the highway. Soon, the truck's path got deflected and the vehicle started moving toward the northbound section of Highway 41. The truck was then on a collision course with traffic flowing in the opposite direction. Up to that time, everything that could go wrong, went wrong: an incapacitated driver in an out-of-control semitrailer, about to crash head-on with multiple vehicles. But, a prudent decision to install a median barrier changed the outcome.

The semitrailer wandered off its lane and was headed through the median toward oncoming traffic. But just before disaster was about to strike, the truck was redirected and tipped over. The newly installed cable median barrier caught the truck and slowed it down before bringing the heavy vehicle to a complete stop. Thus, a major calamity was prevented by the cable barrier.

Officer Jeffery Belsma from the Fond Du Lac County Sheriff's Office had this to say regarding the tragic incident, *"This accident had the potential of being horrific. Thanks to the guardrail that was installed in the median, the semitruck was unable to drift to the other side of the highway. Other drivers could have died that day if that safety feature had not been installed. Since we implemented more cable barriers, the median crossovers on this highway have dropped from 10 to zero. They are a necessity to ensuring the safety of our drivers."*

Figure 8.
Ms. Bernskoetter's Vehicle Snagged by a Cable Median Barrier on I-70 in Missouri

2.2 Motorist Loses Control on Icy Road, Saved by Cable Median Barrier

To most of us, Christmas is a joyous time. It brings memories of merry choirs and lovely gifts. In Missouri, Christmas also comes with snow and ice on roads, and this is not as pleasant and peaceful as the rest of the festive season. Ice on roads is one of the major culprits in several traffic collisions during the winter season. Ice makes road surfaces slippery and renders braking ineffective. Coupled with low visibility brought about by fog, icy roads are responsible for several fatal head-on collisions every year. Even defensive drivers run into problems while trying to negotiate icy roads and end up in violent crashes. Ms. Kristina Bernskoetter of Columbia, Mo., had the misfortune of being involved in one such collision.

On Christmas day in 2005, Ms. Bernskoetter was traveling on Interstate 70 near Columbia, Mo. Aware of the icy road she was traveling on, Ms. Bernskoetter made sure that her speed was well below the posted speed limit. Nonetheless, her car hit a particularly nasty patch of ice. Even before she realized, Ms. Bernskoetter's vehicle rapidly slid out of control and violently hurtled toward oncoming traffic. Ms. Bernskoetter had no time to react; all she could do was close her eyes and pray.

As a result of a safety initiative, there was a median cable barrier exactly where Ms. Bernskoetter lost control of her vehicle. The median steel cable barrier snagged Ms. Bernskoetter's vehicle and cushioned the blow. The car was brought to a complete stop by the cable barrier and was prevented from entering the traffic stream coming from the opposite direction. Ms. Bernskoetter left the scene of the accident without any injuries. Since no other vehicles were involved, other potential injuries were averted as well.

Ms. Bernskoetter, after escaping physically unscathed from this incident shared her thoughts, *"I remember thinking, 'I'm going to cross into the other lanes,' because I didn't even notice the guard cables. I said a quick prayer, closed my eyes and hit — but I was safe."*

2.3 Cable Median Barrier Saves Mother of Three

Merging and weaving maneuvers are performed millions of times every day across the country, but this hides the fact that they are such delicate exercises and demand constant coordination between all drivers involved. It is very easy to get these maneuvers wrong, which can result in terrible collisions on the road. This is especially true at locations where lane drop occurs and vehicles traveling in multiple lanes try to merge into the condensed space while traveling at high speeds. Here is the story of a driver who was involved in one such collision.

In mid-April 2007, Mrs. Melissa Klohn, mother of three, was traveling on Interstate 94 in Sherburn County, Minn., near Elk River and Rogers Exit. She was traveling in the left-most lane on a three-lane segment of I-94. She approached a stretch of highway where one of the three travel lanes drops. At this very location, vehicles from an on-ramp are entering the highway. Just as Mrs. Klohn entered the two-lane stretch, she noticed a coach bus merging into the left lane, dangerously close to her. The bus driver failed to notice Mrs. Klohn's vehicle, which was in the blind-spot region. Mrs. Klohn sensed danger but was helpless to do anything as she had nowhere to go.

A lot happened in the following few seconds. The coach bus continued to encroach into Mrs. Klohn's space, and she ended up hitting the bus. She quickly lost control of her car and was projected into the highway median. Luckily, Mrs. Klohn's car was caught by the median barrier on impact. Due to the high speed of impact, the car spun around and scraped along the length of barrier for some distance but quickly lost its speed due to the cushioning effect. Eventually, the car came to a complete stop and the median cable held the vehicle safely in place. Without the median barrier, Mrs. Klohn's vehicle would have been thrown directly into the oncoming traffic, with catastrophic consequences. A median barrier saved a mother of three that day.

After leaving the crash scene without sustaining any injuries, Mrs. Melissa Klohn had this to say, *"I thought it was all over. I thought I would die. Without the median cable barrier, I would have crossed the freeway. There was not a lot of room in the median. I was surprised I didn't bounce back into the lanes. The cable kept me right in the median."*

Figure 9.
Mrs. Melissa Klohn Saved by Cable Median Barrier

Figure 10.
Mrs. Terecia Wilson Saved by Cable Median Barrier

2.4 Cable Median Barrier Saves Family From Deadly Head-On Collision

Nighttime traffic collisions are often deadlier than their daytime counterparts. The instances of driving under influences, speeding, and driving without a safety belt all significantly increase during the night hours, and each contributes directly to increased fatality rates. One speeding vehicle or one careless driver is sufficient to wreak havoc on roads. A South Carolinian family almost fell victim to the carelessness of a speeding driver but were saved by the median barrier. Here is their story.

In early November 2008, Mrs. Terecia Wilson and her family were returning home after enjoying a movie in Columbia, S.C., on a Saturday evening. Mrs. Wilson was behind the wheel, and they were traveling westbound on Interstate 26 in the left lane. On that particular evening, there was unusually heavy traffic on that westbound stretch of I-26. All of a sudden, an SUV moving at dangerously high speed came at them from the eastbound direction. Even though Mrs. Wilson noticed the errant vehicle, she could not do anything, since her vehicle was surrounded by other vehicles in all directions. Her whole family was traveling in her vehicle. The speeding SUV seemed like devastation on wheels. Should it hit her vehicle, it would surely lead to a multivehicle collision, causing irreparable damage to several lives. Helpless, Mrs. Wilson kept on driving in a state of fear and disbelief.

Just as the SUV was about enter the westbound traffic, it was stopped by the cable barrier separating traffic in opposing directions. The SUV hit the median and safely bounced back to its lane on impact. The cable barrier stopped the SUV from crossing over the median and into the oncoming lanes of traffic, thus preventing a horrible accident. Mrs. Wilson and her family arrived home safely that night, thanks to the cable median barrier.

Here are Mrs. Terecia Wilson's thoughts on what transpired that night: *"Thank goodness for the cable guardrail. We don't know if the SUV driver had fallen asleep or was not paying attention. Had the cable guardrail not been there, the SUV would have hit our vehicle and caused a multivehicle collision, based on the traffic surrounding us. We were very thankful to reach our destination."* ■

3. Roadside Guardrail Success Stories

Guardrails have been in use for a long time as a part of almost every highway. Guardrails are a hazard of some magnitude and should be used only when necessary. In the past, some guardrails have been placed improperly and used in a manner that prevented them from performing as intended. Such incidents have created a slight prejudice against guardrails among the general public. As an attempt to remove any misconceptions, here are three of numerous stories that illustrate the life-saving qualities of guardrails.

Figure 11.
Mr. Ben Tandberg's Car After Colliding With a Guardrail Terminal in Montana

3.1 Swerving Vehicle Hits Guardrail, Driver Sustains Zero Injuries

A study conducted by the Sleep Education and Research Foundation revealed that driving in a tired condition is as dangerous as drunken driving *(9)*. Just like driving under the influence, drowsy driving makes the driver incapable of staying alert. Tired or fatigued drivers tend to nod off while driving at high speeds and cannot make evasive maneuvers if the need arises. Such drivers often get involved in ROR crashes. In July 2016, Mr. Ben Tanberg of Montana was involved in one such crash.

Mr. Tandberg is an electrical engineer who works for an airline company. A particularly hectic week at work prompted him to seek respite at a golf course during the weekend. After the golf trip, Mr. Tandberg was headed home on Interstate 90. By mid-afternoon, he was feeling tired and started to nod off a little bit. Mr. Tandberg realized he needed some stimulation to stay alert, so he decided to grab some coffee at Deer Lodge, Mont., the nearest town along his way home. Just as he approached the exit to Deer Lodge, Mr. Tandberg dozed off behind the wheel while travelling at 75 mph. The next few seconds were a blur.

Right after Mr. Tandberg dozed off, his sedan swerved to the right and collided violently with the guardrail terminal. The guardrail performed exactly as it was designed to. The energy-absorbing guardrail end terminal took in most of the momentum from impact and deflected the guardrail away from the vehicle. By doing this, the vehicle slowed down gradually and came to a complete stop on the roadside. Mr. Tandberg left the scene uninjured even though his car was totaled.

Figure 12.
Tractor-Trailer Crash With a Guardrail on I-85 in Oconee County, S.C. *(11)*

Figure 13.
Mr. Webb's Car Stuck on a Guardrail in Missouri *(12)*

3.2 Drowsy Truck Driver Saved by Guardrail

Drowsy driving is a dangerous practice, often leading to unpleasant outcomes. Drowsy drivers were responsible for 846 fatal crashes in 2014 *(10)*. Drowsiness comes from being tired or lack of sleep. Controlling a vehicle in such a state may cause drivers to swerve off the road into opposing traffic or a roadside ditch, resulting in a crash. The presence of a properly installed and well-maintained guardrail will help in mitigating such crashes.

On Oct. 21, 2017, a tractor-trailer was traveling southbound on I-85 in Oconee County, S.C. The truck was carrying a fully loaded cargo of frozen goods. The truck driver had been driving for several hours without a break. He had a hard delivery deadline to meet. Uninterrupted driving made the driver feel fatigued. Just as the truck approached the bridge at Mile Marker 1 on I-85, the driver completely fell asleep.

The truck swerved to the right and headed on a collision course toward the bridge. However, the bridge was shielded by a guardrail. The resulting crash did not cause significant structural damage to the bridge, and the driver of the truck left the scene unscathed. The presence of a guardrail saved a life and protected the bridge.

3.3 Guardrail Stops Errant Vehicle From Falling Into a Ditch

Gore area is the space between an exit ramp and the adjacent freeway lane. Highway exit gore areas are often characterized by ditches. Therefore, should a vehicle swerve off the road near a gore area, the likely outcome is that it might end up in a ditch. It is necessary to protect vehicles from such hazards and W-beam guardrails can do just that. Installation of guardrails to shield vehicles from falling into a ditch has proved to be beneficial in many cases.

On Oct. 2, 2017, Mr. Rickey Webb of Eldon, Mo., was traveling westbound on Highway 54 near Osage Beach, Mo. Mr. Webb was driving a 2004 Chevrolet Avalanche, and there was a passenger, Ms. April Bungart, along with him in the car. Mr. Webb and his passenger were traveling to the city of Osage Beach. They approached the city on Highway 54 and proceeded to take the Case Road exit into the city. By that time, Mr. Webb was feeling drowsy and nodding off after driving for several hours without a break. After traveling a few hundred feet along the on-ramp, Mr. Webb completely fell asleep. The situation quickly deteriorated after that.

Mr. Webb lost control of his car and veered to the left. The vehicle ran into the guardrail, which was installed along the ramp to protect vehicles from falling into the ditch beside the ramp. The collision with the guardrail occurred in such a way that Mr. Webb's car ran up onto the guardrail and continued forward on it for a few yards. Finally, the vehicle came to a full stop with its two driver's-side wheels stuck on top of the guardrail and the other two wheels on the ground.

The presence of a guardrail ended up preventing a harrowing crash. Had the guardrail not been present, Mr. Webb's vehicle would have fallen into the ditch adjacent to the exit ramp, causing possible loss of life. Thanks to the guardrail, Mr. Webb and his passenger sustained only minor injuries despite their vehicle being damaged extensively.

 

Figures 14 and 15.
The Guardrail Replaced After the Accident and Bianca Harris at the Crash Site

3.4 Hydroplaning Causes Vehicle to Swerve, Guardrail Prevents Deadly Collision

The friction between tires of automobiles and the road surface is vital to traffic safety. Optimal tire friction is required for vehicles to travel in a controlled manner. The presence of water on pavement deteriorates the essential friction and prompts vehicles to slide on a road surface. This phenomenon is referred to as hydroplaning. According to the National Highway Traffic Safety Administration (NHTSA), approximately 19 percent of all automobile crashes in a year occur on wet pavements *(13)*. Often, when a vehicle swerves off due to hydroplaning, a guardrail might be the only line of defense that can prevent a deadly collision. Here is a story that stands as a testimonial to the life-saving qualities of guardrails even in adverse weather conditions.

Ms. Bianca Harris is a resident of Fredericksburg, Va. She works as a customer service representative for ATSSA. Around 8:30 p.m. on Aug. 5, 2017, Ms. Harris was traveling northbound on Interstate 95 toward her home along with her brother. It had been raining sporadically that day, making the pavement slick. Ms. Harris was aware that traveling at high speeds on a wet road surface would lead to hydroplaning. Therefore, she was driving only at a speed of 30 mph. As she approached the exit toward her home, Ms. Harris turned the steering wheel to get on the exit-ramp. At that instant, she unknowingly hit a patch of pavement particularly prone to hydroplaning. Before she even knew, Ms. Harris's car began to slide on the road and headed on a collision course toward a patch of trees on the roadside. Even in such panic-filled moments, Ms. Harris instinctively did the right thing. She took her foot of the gas pedal and tried to regain control over the car. She noticed a guardrail to her left and immediately turned the steering wheel toward the barrier. Her vehicle then hit the guardrail and safely came to a complete stop. If the guardrail had not been there, Ms. Harris's car would have hit a tree or possibly even crashed into the oncoming traffic. At the end of the day, two lives were saved, thanks to the guardrail.

In the aftermath of the collision, Ms. Harris shared her thoughts about how the guardrail saved her life. *"Once we hit the guardrail, the hood of my car flew up and I looked at my brother in such shock and disbelief. I couldn't believe in such a way our lives were saved from a simple guardrail. I also had never known the importance of a guardrail until my brother's life and my own were saved because of it."* ■

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