# Continuous Pavement Friction Measurements: A Technology that Can Save Lives and Work Towards Zero Deaths

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## Abstract

The friction provided by a roadway surface affects how vehicles interact with the roadway. Measuring, monitoring, and maintaining pavement friction can prevent many roadway departures and intersection related crashes, which account for approximately 75 percent of traffic fatalities across the United States. Both wet-pavement and dry-pavement crashes can be mitigated by improving pavement friction and texture, resulting in fewer serious injuries and fatalities.

The Federal Highway Administration (FHWA) advocates reducing deaths on our nation's highway system to zero. A safe system is how we will get there. While no crashes are desirable, the Safe System Approach (SSA) prioritizes fatal and serious injury crashes and aims to eliminate them for all road users. A strategy on preventing crashes on the nation's roadway network must reach beyond educating road users on how best to navigate the road sections, but rather focus on creating safer roads, which is an SSA element. Continuous Pavement Friction Measurement (CPFM) falls into the safer roads element of the SSA.

CPFM is an established and proven approach that has been used for several decades in Europe and New Zealand and could revolutionize the role of pavement friction in framing our understanding and management of the safety performance of the roadway system in the United States.

Pavement friction is not currently a parameter widely used in crash-based safety modeling in the same way as other roadway characteristics, such as number and width of travel lanes; presence, width, and type of shoulder; degree of curvature; etc. By investing in CPFM for a Pavement Friction Management Program that collects pavement friction data on a jurisdiction's roadway network, combined with existing geometric data and other risk factors, agencies will be better prepared to design roadway environments that make for safer roads and safer road users.

This paper will provide background on CPFM, present case studies from the United Kingdom and other countries and demonstrate why CPFM is needed to reduce crashes across the country. Further, this paper will include the technology and the methodology of pavement friction data collection using CPFM and support the argument for it with case studies. Resources for implementing CPFM will also be provided.

# Safety at FHWA

The National Highway Traffic Safety Administration (NHTSA) has released its latest projections for traffic fatalities in 2022, estimating that 42,795 people died in motor vehicle traffic crashes[1]. This represents a small decrease of about 0.3 percent compared to 42,939 fatalities reported for 2021. The estimated fatality rate decreased to 1.35 fatalities per 100 million vehicle miles traveled (VMT) in 2022, down from 1.37 fatalities per 100 million VMT in 2021. An increase in VMT by 1 percent from 2021 to 2022 indicates Americans are driving slightly more than they did during the height of the COVID-19 pandemic.

NHTSA also projected fatalities declined in the fourth quarter of 2022. This would be the third straight quarterly decline in fatalities after seven consecutive quarters of increases that started in the third quarter of 2020.

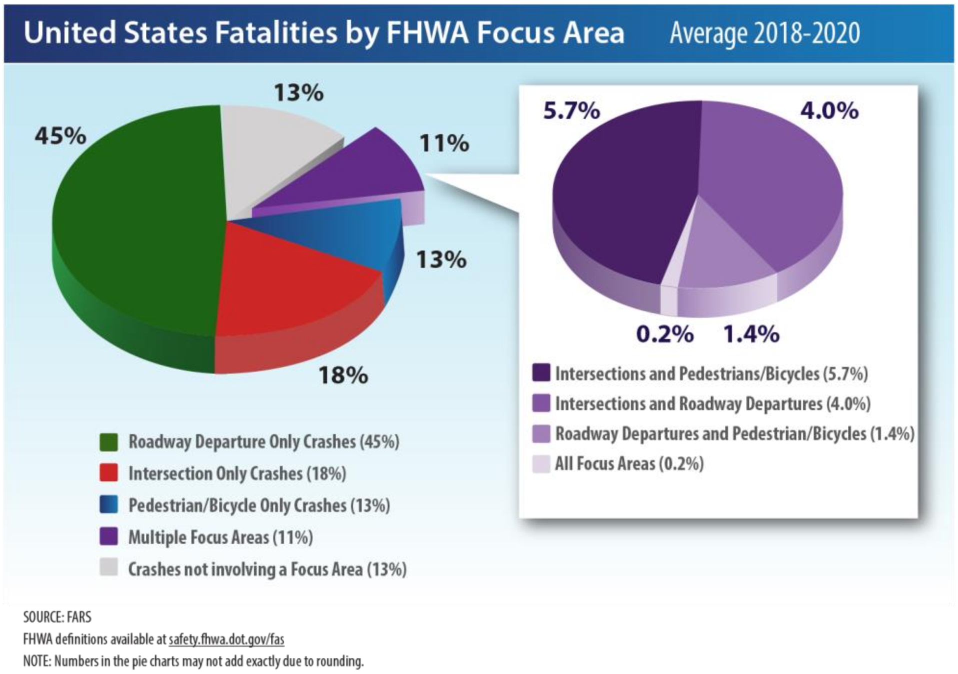
These recent improvements can likely be contributed to proactive safety policies and programs, such as the Federal Highway Administration (FHWA) Highway Safety Improvement Program (HSIP) instituted in 2005, as well as improved guidance on highway safety, such as the 2010 American Association of State Highway and Transportation Officials (AASHTO) *Highway Safety Manual*. Various safety goals have been established to further the progress, the latest being the National Strategy on Highway Safety Toward Zero Deaths (TZD) effort and its vision for a highway system free of fatalities.

FHWA is collaboratively advancing the implementation of the National Roadway Safety Strategy (NRSS) —the United States Department of Transportation's (USDOT) comprehensive plan to significantly reduce serious injuries and fatalities on America's roads. This strategy embraces the SSA, which builds multiple layers of protection around road users and is based on the reality that although people make mistakes, those mistakes do not have to be fatal. The approach increases awareness of critical severe crash types and leads to key safety infrastructure improvements. This results in fatality reductions in the three FHWA critical focus areas: roadway departures, intersection crashes, and pedestrian and bicycle crashes.  These three areas encompass almost 90 percent of the traffic fatalities in the U.S.

As shown in Figure 1, it is in these three focus areas that most traffic fatalities occur.

[1] National Highway Traffic Safety Administration (NHTSA). FARS Encyclopedia [online]. Updated: n.d. [Viewed 15 April 2024. https://www-fars.nhtsa.dot.gov/Main/index.aspx

*Figure 1. United States Fatalities by FHWA Focus Area, Average 2018-2020*




*Source: FARS*

Safety is the top priority of the USDOT. For FHWA, this means road systems should be designed to protect their users through life-saving programs and infrastructure safety solutions. FHWA's goal is eliminate all transportation-related fatalities and serious injuries across the transportation system.

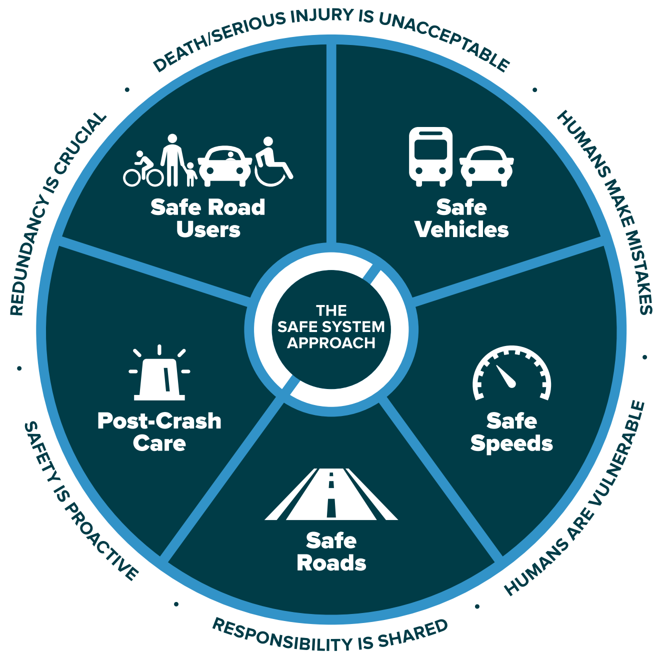
## Safe System Approach

The SSA accommodates human mistakes by designing and managing road infrastructure to reduce incidence and severity. It does so through a holistic view of the road system that (1) anticipates human mistakes and (2) keeps impact energy on the human body at tolerable levels. In a safe system, neither a human mistake nor force on the human body should lead to death, which means the infrastructure should be designed to manage the potential risk to any road users. The principles of the SSA are:

1. Deaths and injuries are unacceptable
2. Humans make mistakes
3. Humans are vulnerable
4. Responsibility is shared
5. Safety is proactive
6. Redundancy is crucial

These six principles define the approach used in each of the five SSA Elements (Safe Roads, Safe Road Users, Safe Vehicles, Post-Crash Care, and Safe Speeds), which together create the required layers of protection for road users. Another key to the SSA is the safety culture that an agency has that places safety first and foremost in their decision-making process.

*Figure 2. Safe System Approach Principles and Elements*




**For more information about the FHWA SSA, visit:** https://safety.fhwa.dot.gov/zerodeaths/zero_deaths_vision.cfm

*Source: Federal Highway Administration (FHWA)*

# Pavement Friction and Safety

Implementing various FHWA's Proven Safety Countermeasures initiative (PSCi) in the national road network will reduce fatalities and serious injuries on our Nation's highways. Widespread implementation of PSCs can accelerate the achievement of local, State, and National safety goals. Continuous Pavement Friction Measurements (CPFM), a key element in achieving the desire Pavement Friction, one of the PSC, addresses several safety focus areas including speed management, intersections, roadway departures, and pedestrians/bicyclists. Additionally, the integration of pavement friction management and safety management practices to achieve safety performance goals is consistent with the Safe System approach.

Roadway safety depends on multiple factors: human factors (such as driver and/or passenger behavior), vehicle factors (such as design and condition), and the roadway environment (including roadway geometry, roadside design, traffic control features, and pavement surface characteristics). Pavement friction is a critical characteristic that affects how vehicles interact with the roadway, which is directly related to crash frequency. Measuring, monitoring, maintaining, or enhancing pavement friction—especially at locations where vehicles are frequently turning, slowing, and stopping—can prevent many roadway departure, intersection, and pedestrian-related crashes.

Pavement surface characteristics include friction, texture, roughness, cross slope, and hydroplaning potential. These characteristics are defined by the pavement surface course and include both physical attributes, such as stand-alone pavement surface properties like texture and porosity and dynamic attributes such as friction and rolling resistance that result from vehicular movement over the pavement surface.

One of the key elements that can affect pavement friction is the pavement surface texture. The surface texture of a pavement surface impacts safety considerations such as driving control, turning, braking, and steering. When the pavement friction falls below a certain threshold, agencies must quickly restore the pavement friction to prevent potential crashes and improve roadway safety. One of the key safety countermeasures, High Friction Surface Treatments (HFST), has achieved significant crash reduction.

Highway engineers can take proactive actions to influence some of these roadway environment factors to reduce highway crashes and related fatalities where the lack of skid resistance—because of friction, texture, or roughness in the roadway surface—is a contributing factor. As noted above, areas that may experience lack of skid resistance include horizontal curves, intersection approaches, crosswalks and their approaches, and congested and merging/weaving areas of freeways.

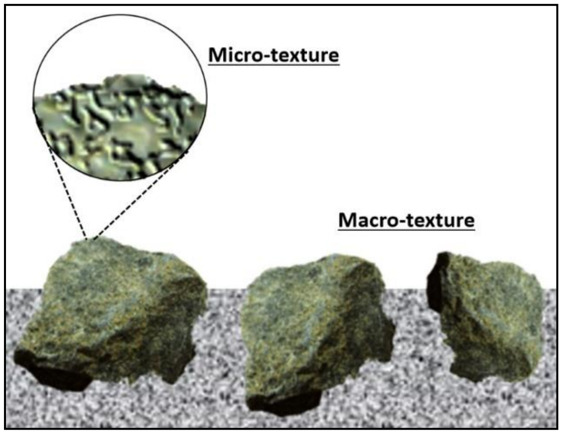
## Pavement Surface characteristics and pavement Friction

Pavement surface characteristics can directly influence the occurrence of highway crashes. This is partially because most drivers do not quickly adjust their driving habits during severe weather conditions, especially when driving in wet pavement conditions.

Pavement friction provides the counterforce that resists the relative motion between a vehicle tire and pavement surface. Having adequate pavement friction is key for roadway motorists to safely navigate curves because tires need friction to avoid sliding across the pavement surface, which can lead to roadway departure crashes.

Two key categories related to the texture of the pavement surface that are critical for influencing tire-pavement friction are microtexture and macrotexture (Hall, 2009). As shown in Figure 3, microtexture, a property associated with the aggregate, is a fine-scale texture below about 0.5 millimeters on the surface of the coarse aggregate in asphalt or the sand in cement concrete that interacts directly with tire rubber on a molecular scale characterizes the surface texture of each aggregate (Hall, 2009), which provides that needed hardness of a pavement surface. Macrotexture is typically formed by the shape and size of the aggregate particles in the surface or by grooves cut into some surfaces. Pavement macrotexture is important to produce friction and to channel water away from beneath the tire, helping to avoid hydroplaning, wherein the tire floats on a film of water above the roadway surface. Macrotexture serves as a key contributing factor on both wet and dry pavements in all speed conditions, but especially on wet pavements since skid resistance decreases with increase in speed.

*Figure 3. Pavement-surface Texture Characteristics that Influence Pavement Friction*




*Source: FHWA*

Pavement friction and texture can positively contribute to vehicle crash reduction by increasing the friction coefficient and increasing the skid resistance of a roadway to reduce crashes across the United States.

## Pavement Friction Management Programs

The main purpose of a pavement friction management program (PFMP) is to minimize friction-related vehicle crashes by:

- Ensuring new pavement surfaces are designed, constructed, and maintained to provide adequate and durable friction properties.
- Identifying and correcting sections of roadway that have elevated friction-related crash rates.
- Prioritizing the use of resources to reduce friction-related vehicle crashes in a cost-effective manner.
- Effectively collecting and analyzing pavement friction, crash, and traffic data to reduce friction-related crashes.

Current FHWA policies regarding pavement safety are as follows:

- The FHWA pavement policy indicates that States shall design pavement to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner.
- The FHWA policy related to the HSIP indicates that each State shall incorporate a process for analyzing available safety data that identifies highway safety improvement projects on the basis of crash experience, crash potential, or other data supported means.
- Pavement friction management includes providing surfaces with adequate and durable friction properties as well as collecting data and performing analysis to ensure the effectiveness of the program.
- The Pavement Friction Management Technical Advisory(T 5040.38) issued by FHWA provides guidance to State and local highway agencies on managing pavement surface friction. The technical advisory covers topics such as:
    - Test equipment for measuring pavement friction.

- The identification and classification of roadway locations with elevated crash rates.
- How to prioritize projects for improving pavement friction.
- The appropriate frequency and extent of friction testing on a highway network.
- How to determine a pavement friction management program's effectiveness.

Pavement friction management includes sound engineering practices to provide road surfaces with adequate and durable friction properties plus data collection and analysis to ensure the effectiveness of the engineering practices. The data collection and analysis component of an effective friction management program shall utilize pavement friction and friction-related data, crash data, and traffic data to:

- Evaluate pavement design, construction, and maintenance practices to ensure pavement surfaces with good friction characteristics are provided.
- Identify and investigate locations with elevated wet-weather crash rates relative to comparable locations for the purposes of minimizing locations with elevated friction-related crash rates.
- Provide data for use in prioritizing projects to improve highway safety.

Once network-level friction testing is completed, sites are evaluated for additional investigation or possible treatment. The approach recommend by the NCHRP Report 108 Guide for Pavement Friction is most commonly used to establish Investigatory Level and Intervention Level values for pavement friction and texture. These values are established based upon the specific needs of a facility (friction demand) and may be based in part on costs and benefits of providing specific friction levels on the network. Friction demand should be determined by the owner-agency for each road segment and be based upon factors such as traffic volume, geometrics (curves, grades, sight distance, etc.), potential for conflicting vehicle movements, and intersections. Research has shown that curves and intersections tend to lose friction at a faster rate than other roadway locations and thus justify a higher friction demand. Typically, once a pavement section falls below the investigatory threshold value, the specific pavement section is evaluated for friction-related crash potential. Once determined that the crash was related to lack of friction property at the location, appropriate remediation action is performed. This Investigatory Level can also be considered a "desirable" level for pavement friction based upon site requirements. Pavements that fall below the Intervention Level require the performance of some type of action. This Intervention Level can also be considered a "minimum" level for pavement friction based upon site requirements.

# Continuous Pavement Friction Measurement

The friction provided by a roadway surface affects how vehicles interact with the roadway. Measuring, monitoring and maintaining pavement friction can prevent many roadway departure, intersection and pedestrian and bicycle related crashes, resulting in fewer serious injuries and fatalities.

More than 50 years ago, National Cooperative Highway Research Program (NCHRP) Report 37 stated that "the lowest friction levels are found on high-speed roads, curves and approaches to intersections; in short, in locations at which high friction values are needed most."[2] Essentially, this research

[2] H.W. & Meyer W.E., *NCHRP Report 37 Tentative Skid-Resistance Requirements for Main Rural Highways*, Washington, D.C: Transportation Research Board (TRB) (1967)

recognized that friction varies as you travel down the road and that a clear friction "supply and demand" relationship exists and is a factor in determining the safety performance of a road. The current state of practice for high-speed friction measurement by State DOTs is the locked wheel skid trailer (LWST), which is a discrete, sample-based approach, and thus does not effectively differentiate the changes in friction along the route corridor.

CPFM is an established and proven approach that has been used for several decades in other countries and could revolutionize the role of pavement friction in framing an agency's understanding and management of the safety performance of their road network. This approach is commonly used by road authorities in many countries outside of the U.S. like Australia and New Zealand, and even by airport authorities in the U.S. to measure friction on runways.

A recent study by FHWA confirmed that CPFM data collected through the FHWA CPFM Demonstration Project with multiple states, combined with crash data and road characteristics, provide significant insight regarding whether friction improvements may reduce crashes. FHWA encourages the use of CPFM to provide comprehensive pavement friction data, combined with existing safety data and analysis, to create an overall pavement friction management program anchored in safety.

While aggregate testing and specifications, pavement mix designs, and rubber tire manufacturing have evolved in the years since FHWA published TA 5040.36, titled "Surface Texture for Asphalt and Concrete Pavements," the basic friction supply and demand relationship remains relevant. Research conducted in other countries has consistently found a relationship between pavement friction levels and safety. Research also shows programs that subsequently established maintenance values for friction that are grounded in safety performance tend to rely upon CPFM for monitoring.

## CPFM: An International Best Practice

In the United Kingdom since the 1980s pavement friction of the English Strategic Road Network has been managed through a requirement to provide specific levels of skid resistance and texture depth, using CPFM as the basis for monitoring. A 1991 paper by Rogers and Gargett referenced a National Skidding Resistance Survey report that estimated this approach would result in 6 percent fewer casualties per year on trunk roads, and a benefit-cost ratio of 5.5-to-1.[3] In 2016, the Transport Research Laboratory published PPR 806, which further reviewed the relationship between crash risk and skid resistance. The study found that for curves and steep grades, roadways with higher skid resistance have a lower risk of collisions, even in wet conditions, and recommended that enhanced skid resistance treatments be prioritized for those sites.

In New Zealand, throughout the 1990s, the New Zealand Transport Agency (NZTA) sponsored road surface friction research and development and established their first skid resistance policy and specification in 1997, which required CPFM equipment be used for network skid resistance measurement. Consistent with the UK experience, the 1998 Transfund New Zealand Research Report 141 documented a statistically significant relationship between crashes and skid resistance at junctions, curves and steep grades, and indicated that wet road crashes could be reduced 45-61 percent at these locations with targeted enhanced skid resistance. Finally, a 2011 paper by Whitehead, et al, reviewed 11

[3] Rogers, M P and Gargett, T. "A Skidding Resistance Standard for the National Road Network." In *Highways & Transportation.* London, United Kingdom. Institution of Highways & Transportation. p. 10-13. (1991)

years of experience with the NZTA policy and found the benefit-cost ratio ranged between 13:1 and 35:1.

## Friction Measurement Equipment

One of the key steps to have a successful PFMP is to have good pavement data. In the field, either static or high-speed equipment can be used to measure pavement surface friction. For network-level data collection, static equipment can cause traffic delays due to lane closures and exposes users to dangerous roadway conditions. Also, given the number of lane-miles in a state, it is simply not practical to use static equipment. Additionally, it could result in secondary crashes due to drivers reacting to work zone deployment in traffic mix. High-speed equipment is the preferred method and offers the more practical alternative. There are two categories of high-speed test methods – continuous and non-continuous.

The LWST is a non-continuous friction measurement test. There are three general types of continuous pavement friction measurement (CPFM) equipment: fixed-slip (ASTM E 2340), sideway-force coefficient, and the variable-slip (ASTM E 1859) (Henry, 2000).

These high-speed methods are operated at a fixed speed, generally between 30-50 mph, while they simultaneously wet the surface with a user-defined, uniform water-film thickness on the pavement surface in front of the test wheel(s), usually 0.0197 inch (0.5 mm).

*A utility truck is prepared to start an LWST owned by the South Carolina DOT. Source: FHWA*

In the U.S., the locked-wheel technique using a LWST is the most commonly used method by most State DOTs (Henry, 2000).

A locked-wheel device measures friction by completely locking up the test wheel(s) and recording the average sliding force for a period of 3 seconds and reporting a 1 second average after reaching the fully-locked slip. Thus, with a 40-mph test speed, a 1 second test time is equivalent to testing the pavement surface for approximately 59 feet.

*Full view of the Sideway Force Coefficient Routine Investigation Machine (SCRIM Source: FHWA*


*Close up view of the SCRIM. Source: FHWA*

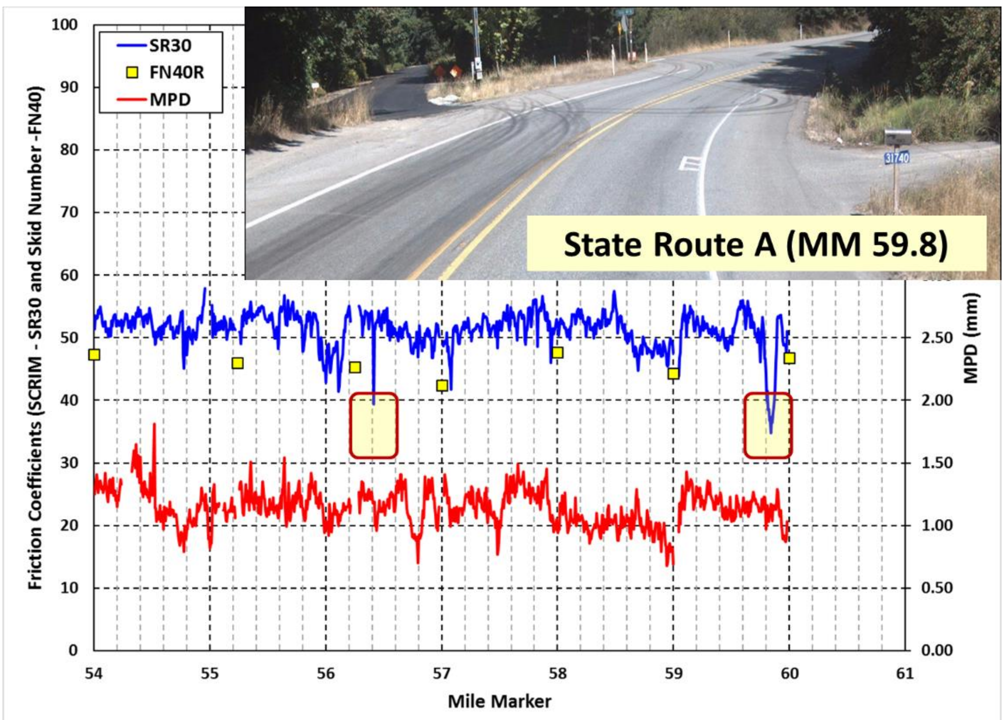
Since locked-wheel equipment relies on a fully locked wheel state to measure friction, the measurements can only be recorded periodically over short intervals of time, resulting in approximately one pavement friction test per mile. Alternatively, the high-speed continuous friction test methods allow for continuous friction measurement—where close to 100 percent of the pavement surface is tested, usually at 4-inch (0.1 meter) intervals. The sideway-force continuous friction measurement method uses a free-rolling test wheel with a fixed 20° slip-angle to measure side-force "transverse" friction. The SCRIM (Sideway-force Coefficient Routine Investigation Machine) records a measure of friction called a SCRIM Reading or SR (Hall, 2009).

The SCRIM used for this project included additional sensors to measure surface macrotexture and roadway surface geometry such as curvature, cross-slope, and longitudinal grade.

The pavement friction data collected using CPFM cover every foot of the road which is needed by a pro-active network-level process such as the Safety Performance Function (SPF)-Empirical-Bayes (EB) method. This high resolution is particularly important to identify potential friction problems on road sections with a high friction demand, such as curves and intersections. Due to the LWST standard practice of testing on a sampling basis and the challenge of testing in some curves and intersections, many times these road sections with lower friction in areas with a higher friction demand are not tested.

Figure 4 illustrates friction measurement taken using the LWST and the SCRIM. The graph zooms in on the friction measurements from mile 54 to mile 60, where the LWST is only measuring 59 ft every 1.0-mile. In this plot, the data collected with the CPFM detected a low friction spot in mile 59.8, which the LWST missed because in this section it did not do any measurements in the 0.1-miles between mile 59 and 60. Further investigation at this location revealed that the cause of this low friction section is probably exacerbated with the braking and turning operations vehicles are doing to turn left at this location. This phenomenon is typical of most intersections where vehicles are braking and thus polishing the pavement aggregates at a higher rate than would be found in another section of road where the traffic is not stopping due to the turning maneuvers.

*Figure 4. Detail of Measurements SR A Between Mileposts 54 to 50.*



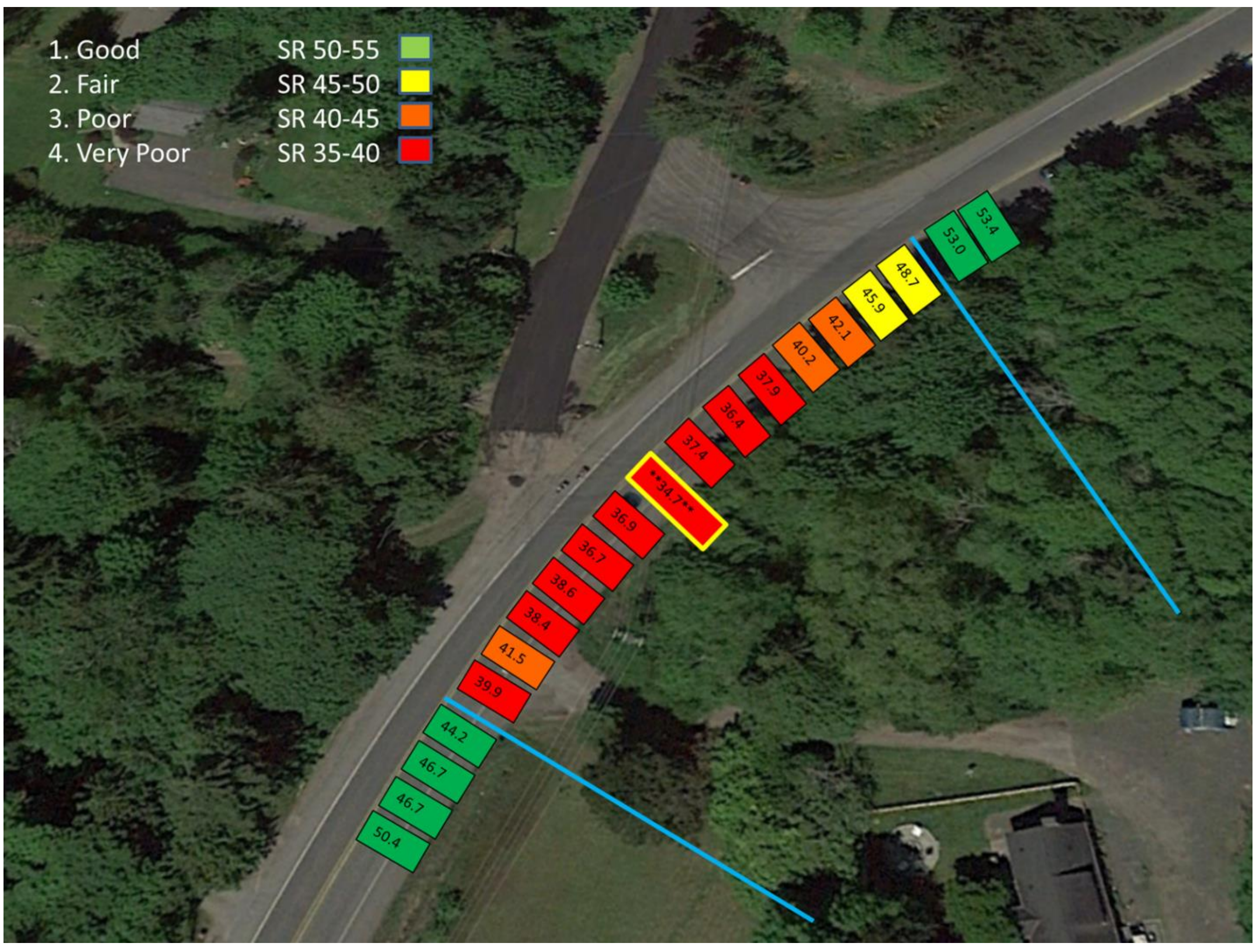

*Source: FHWA*

It is also interesting to note that this is one of the locations with the highest number of crashes on that route. For the whole road segment from miles 33 to 60, the location with the second highest number of crashes is mile marker (MM) 59.9, with 25 crashes from 2012 to 2015. Therefore, the section identified using the CPFM to collect the friction data but missed that location with deficient pavement friction with the LWST conducting one test per mile could be a good candidate for the installation of HFST. This information also illustrates the potential benefit of conducting CPFM before HFST installation to better identify the beginning and end points of the HFST for construction purposes. In addition, friction data can help State DOTs prioritize their pavement treatments as well as select the best treatments for each location.

Figure 5 presents an alternative to visualize the continuous friction measurements using geospatial tools and colored scale to indicate the level in relation to the investigatory levels (IL) that are suggested for straight and curved sections.

Figure 5 presents a rough sketch to show the concept of what can be done with this tool to appreciate better the limits of the geometry and where friction test results become critical. The color scale is set approximately for the curve section SR30 friction IL of 50-55. The length of each section is 30 ft. The figure is in line with the quote that the highest friction demand sections of road often have the lowest available friction.[4] For this location, the LWST testing frequency of one test per mile missed the problem and friction would not be considered a potential factor, while the CPFM data clearly shows friction is a consideration that should be investigated further.

*Figure 5. GIS SCRIM SR measurements on State Route A MP 59.8 to 59.9*




*Source: FHWA*

[4] Kummer, H.W. and Meyer, W.E. *National Cooperative Highway Research Program (NCHRP) Report 37 Tentative Skid-Resistance Requirements for Main Rural Highways.* Transportation Research Board (TRB). Washington, D.C., (1967)

From the above discussion, friction data for safety performance is best measured with CPFM equipment. Spot friction measurement devices, like LWST, cannot safely and accurately collect friction data in curves or intersections, where the pavement polishes more quickly and adequate friction is so much more critical. Without CPFM equipment, agencies will have to assume the same friction over a mile or more. Safety practitioners can analyze the friction, crash, and roadway data to better understand and predict where friction-related crashes will occur to better target locations and more effectively install treatments.

## Benefits of Continuous Friction Measurement

Using CPFM to implement PFMP, State DOTs can analyze the friction, crash, and roadway data to better understand and predict where friction-related crashes will occur to better target locations and more effectively install treatments.

FHWA has conducted quantitative and qualitative assessments of the two testing methods. The continuous devices provide a much higher spatial coverage and reduce the chances of missing localized areas with lower friction. FHWA's assessments demonstrated the importance of having a higher resolution with examples that showed how the current LWST testing/sampling approach can miss critical locations, especially in locations where there is high demand for friction and more polishing of the pavement resulting from braking and turning maneuvers.

A recent study by FHWA confirmed that CPFM data, combined with crash data and road characteristics, provide significant insight regarding whether friction improvements may reduce crashes. FHWA encourages the use of CPFM to provide comprehensive pavement friction data, combined with existing safety data and analysis, to create an overall PFMP anchored in safety.

A published report, titled "Characterizing Road Safety Performance using Pavement Friction FHWA-SA-23-006," documents the development of safety performance functions (SPFs) that include friction and macrotexture on a variety of roadway facility types and categories (i.e., segments, intersections, curves, and ramps). The main objectives of the report were: (1) the development of Crash Modification Factors (CMFs), or Crash Modification Functions (CMFx) that make it possible to evaluate the effect of pavement friction changes on safety performance, which can then inform the cost effectiveness of pavement friction improvements; and (2) the establishment of performance or investigatory thresholds for friction based on roadway type and category. The analysis confirmed a strong statistical association between pavement surface frictional properties (friction and macrotexture) and crash rates. Lower crash rates were observed with higher friction and macrotexture.

The findings from this report support road agency efforts toward the institutionalization of Pavement Friction Management, one of the FHWA Proven Safety Countermeasures. The results may be used by road agencies to inform safety analyses at both the system/network and site/project levels to evaluate the impact and cost-effectiveness of pavement friction enhancement strategies and treatments.

# Conclusion

The main conclusions from the experience and data analysis of the FHWA Pavement Friction Management Demonstration Project conducted in collaboration with more than 15 states in the past several years, can be summarized as follows:

- The data collection and the analysis reports confirmed a strong association between crashes and continuously-measured frictional pavement properties (friction and macrotexture).
    - Therefore, a proactive pavement friction management program can help reduce the number of crashes and associated fatalities.
- It was possible to identify investigatory levels for frictional properties using the SCRIM (SR and MPD) measurements for most roadway categories and pavement types.
    - The analysis based on the SCRIM results allowed the determination of illustrative investigatory levels for the five friction demand categories considered and to associate them with a level of crash "risk."
- The collection of continuous friction and macrotexture data through the adoption of CPFM instead of the traditional sampling approach using a LWST can have a significant impact on crash reductions, and it is cost-effective for supporting a pro-active pavement friction management program.
    - Measuring friction continuously, especially when complemented by macrotexture and road geometry data, provides a more effective method for identifying the most critical sections and allow focusing the safety improvement efforts on the higher risk locations, such as intersections and curves.
    - Providing an appropriate level of macrotexture is also critical for high-speed roadway segments.
    - A cost of data collection per mile comparison showed that CPFM data collection costs are lower than those using the traditional LWST approach and measures the entire length of the network instead of just a sample.
- The application of the SPF/EB analysis method, in conjunction with continuous measurement of the pavement friction, macrotexture and road geometry, allows the identification of sites with the highest potential payoff for pavement friction improvements.
- The Safety Performance Functions (SPFx) developed in the FHWA publication Characterizing Road Safety Performance using Pavement Friction show that potential reduction of up to 30 percent of total crashes can be achieved with a 10-point increase in SCRIM Friction Number (SFN40).
- The KYTC learned from the data collected by CPFM that increasing friction could save many lives and prevent serious injuries as well as save Kentucky residents more than $1 billion per year.
- One action that can help agencies achieve a safe system is to provide adequate friction at curves and intersections where it is needed most.
- Pavement friction treatments, such as HFST, can be better targeted and result in more efficient and effective installations when using continuous pavement friction data along with crash and roadway data.

## Case studies

**Case study:** Kentucky Pilots New Friction Management Approach

In Kentucky, 60-70 percent of their yearly highway fatalities are the result of roadway departures. Those crashes have an annual economic impact of over $10 billion, as well as life-changing effects on Kentucky residents. Over the year, the Kentucky Transportation Cabinet (KYTC) reframed the way they think about roadway fatalities overall from crash-based approach to much more proactive and about preventing the next crash, not reacting to the last one. KYTC focus their crash reduction strategy by managing friction on their roadways.

Recently, the KYTC piloted a program that uses CPFM to better measure and manage friction on Kentucky roadways. CPFM equipment measures pavement friction continuously, through tangents, curves, and intersections at speeds as high as 50 mph, eliminating data gaps created by other friction-testing methods that are not continuous. KYTC used CPFM to collect friction data on 15,118 lane miles of its 63,878 total lane miles. Data were collected on interstates, parkways, and State primary and secondary routes, as well as ramps on all these facility types.

*Source: Texas Transportation Institute*

The data included friction coefficient (SFN40), texture (mean profile depth), curve radius, grade, cross slope, and GPS coordinates. This information was incorporated into the State's Linear Referencing System (LRS) and then the roadway network was divided into 0.1-mile-long analysis segments. Each segment was assigned to a site category, such as curves with a radius of less than 300 feet, curves 300-700 feet, intersections, tangents, etc. From there, KYTC developed a network-level safety performance function that helped predict the crash reduction for each site category along the various KYTC-managed route systems if friction were increased by 10 points. A 10-point increase in friction corresponds to increasing a pavement's coefficient of friction by a value of 0.1. The analysis showed that a 10-point increase in average friction across the network would lead to a crash reduction of over 10 percent of all crashes. By using CPFM, the KYTC learned how increasing friction could save many lives and prevent serious injuries as well as save Kentucky residents more than $1 billion per year.

Treatments such as resurfacing, microsurfacing, chip seals, shot blasting, and diamond grinding typically provide a 10-point or higher increase in friction. Other treatments, such as HFST can provide a 30-40 point or higher increase in friction. With a wide variety of friction treatment options available, KYTC is confident that utilizing CPFM will allow for better management of pavement friction and over time will achieve a 10-point increase in average friction across their roadway network.

This approach enables KYTC to shift their focus from high-volume roads and freeways to save lives on lower-volume roads because the lower volume roadway can have more challenging geometry and contextual issues that friction management can help. KYTC is using the CPFM data to identify locations where friction enhancements may be worthwhile. Transportation practitioners at KYTC plan to use their experience with CPFM in many ways going forward. They are using friction and texture data to identify locations for the installation of HFST. KYTC believes CPFM is an opportunity to make significant strides in reducing severe crashes nationwide and help them achieve their safety goals.

**Case Study:** Improving Pavement Friction for Safety at a Florida Signalized Intersection

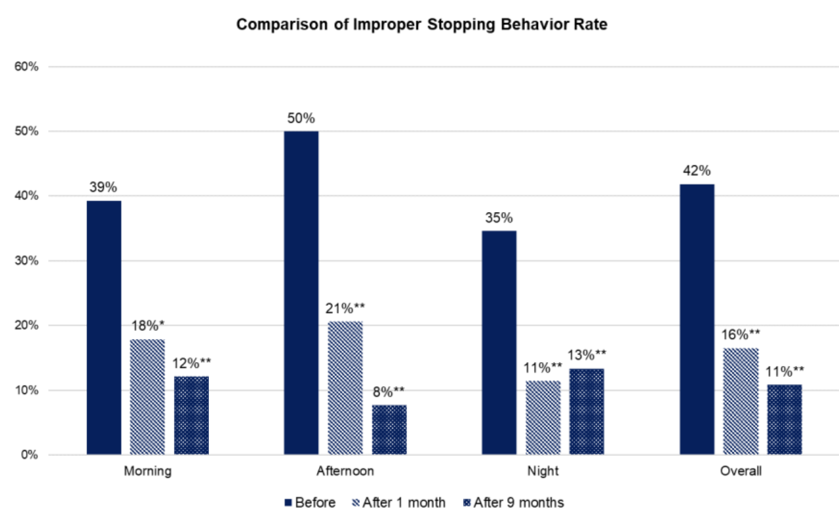
In 2019, the Florida Department of Transportation (FDOT) conducted intersection Road Safety Audits (RSAs) using CPFM data from the FHWA Pavement Friction Management Program demonstration project. The CPFM data revealed where pavement friction and macrotexture in intersection areas was significantly less than the adjacent pavement sections, prompting an RSA team recommendation to consider installing HFST, which was completed at one intersection in 2020.

*HFST on Hillsborough Ave. at Central Ave. Source: FDOT*

*Application of HFST to Hillsborough Ave. using fully-automated installation. Source: FDOT*

While the original intent was to reduce friction-related crashes at this intersection, HFST has demonstrated potential safety benefits to pedestrians by reducing crosswalk incursions through improvement in stopping behavior. The Center for Urban Transportation Research (CUTR) at the University of South Florida analyzed stopping behavior through a review of video captured at the intersection. Specifically, the researchers documented crosswalk incursions while the traffic light was red at three different periods of the day (morning and afternoon rush hours and late night). Stopping behavior was analyzed prior to HFST application, then at one month and nine months after application.

This analysis revealed a 26 percent overall reduction in improper stopping behavior one month after HFST application and 31 percent reduction nine months after application. While crash reduction benefits have not yet been quantified for this intersection, a reduction in crosswalk incursions demonstrates another important safety benefit of HFST for intersection applications. Data collection methods using a sample-based approach do not adequately characterize the pavement friction in high friction demand locations for in-depth safety analysis. A holistic approach to CPFM—which for this case study included starting with continuous pavement friction measurement, incorporating friction data into safety assessments, and implementing friction improvements—can benefit all road users.




Overall, 31-percent reduction in crosswalk incursions at 1 and 9 months after HFST application.

*Results from analysis of stopping behavior at Central Ave. intersection before and after HFST application. Source: CUTR*

Based on this experience, the Florida DOT has incorporated the following steps to foster a safe road environment:

- Include pavement friction as a parameter in road safety performance modeling
- Establish friction performance thresholds based on context
- Proactively and systemically manage friction
- Deploy proven friction improvement treatments foster a safe road environment

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