SafeCurves Diagnostic Report

What is the horizontal curve risk in the United States?

Revision	SafeCurves, v2024.1
Issue date	August 2, 2024

1. Introduction

As described in the Abley Primer "*Horizontal curves: What makes them so high risk and how can we improve outcomes*?"[1], managing the safety of road users traversing horizontal curves is a major issue for road agencies globally. In the United States over 23% of all fatal crashes occur on horizontal curves[2]. The average crash rate on horizontal curves is approximately three times higher compared to straight sections of road (FHWA, 2023).

The US Department of Transportation Federal Highway Administration (FHWA) recommends a systemic analysis be undertaken like a health screening for the road system[3]:

> *"Just as your doctor identifies risk factors for illness, systemic analysis identifies locations that are at highest risk for severe crashes. Practitioners can then prioritize projects based on risk and apply low-cost safety treatments to reduce severe crashes across the whole at-risk system."*
>
> FHWA

The purpose of this short report is to evaluate horizontal curve risk in the United States using SafeCurves, a new, data-driven, systemic approach. Further details regarding the technical methodologies used by SafeCurves can be found at www.abley.com/en-us/safecurves.

2. Analysis

2.1 Identify

SafeCurves: Identify[4] was applied to all paved rural roads within the United States with a speed limit ≥ 40 mph. This totalled 1,443,000 lane miles (or more simply, 847,364 centreline miles).

The road network was assessed in both directions of travel and road segments were classified into straights and horizontal curves. A total of 1,702,049 horizontal curves were identified by SafeCurves: Identify.

These horizontal curves were categorised into the following performance classes:

- Class 1 (unacceptable) (10%),
- Class 2 (undesirable) (12%), and
- Class 3 (desirable) (78%).

Class 1 and Class 2 curves are collectively referred to as 'out-of-context curves'.

[1] https://abley.com/en-us/safecurves-identify-primer
[2] Extracted from the US Department of Transportation National Highway Traffic Safety Administration Fatality Analysis Reporting System (FARS) 2013-2022, non-intersection crashes, excludes functional Class 1 roads. https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars
[3] https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-06/ddsa_systemic_analysis.pdf
[4] SafeCurves 2024.1, SC_ID 3.12.0 SC_PR 3.12.0 SC_IN 3.12.0

On average, there are 1,155 fatalities per year on out-of-context (Class 1 and Class 2) curves within the United States. The length of these curves represents 4% of the total analyzed network length, yet these curves represent 8% of all fatalities[5]. This is shown in Figure 2.1 and Figure 2.2.

This disproportionate relationship demonstrates the reality that more cognitive effort is required by a driver to successfully negotiate curves, so there is a greater probability a driver will make a mistake leading to a crash, and that the crash will result in a fatality. This underscores the importance of investigating roadway departures (RwD) and lane departure (or loss of control) crashes[6] on curves.

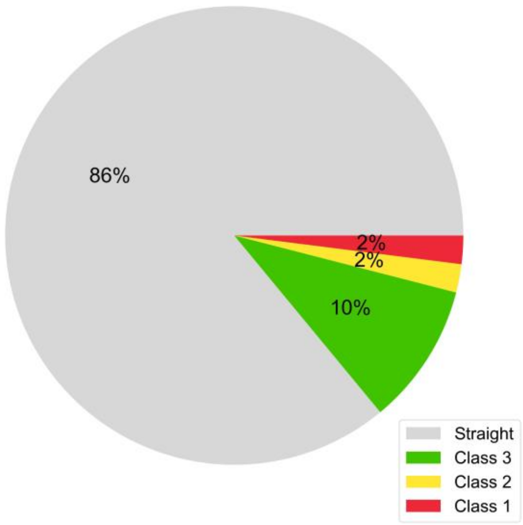

Figure 2.1 Length by segment type

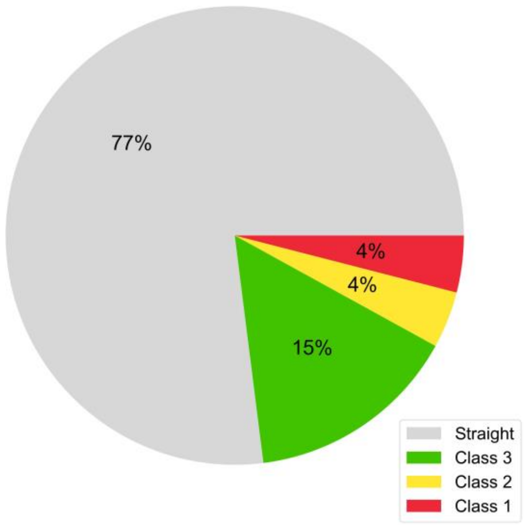

Figure 2.2 Fatalities by segment type

Unsurprisingly, the fatal crash rate per length of road is higher for out-of-context curves than other road segments. This is shown in Figure 2.3, which presents the average fatal crashes (per annum) per 1,000 miles (excluding intersections) by straight and curve class. For comparison, for the entire length of the I95 (Maine to Florida) for 2020 was 2 fatal crashes per 1,000 miles.[7]

[5] Extracted from the US Department of Transport National Highway Traffic Safety Administration Fatality Analysis Reporting System (FARS) 2010 - 2021, non-intersection crashes, excludes functional Class 1 roads https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars

[6] *"FHWA defines a roadway departure (RwD) crash as a crash which occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the traveled way. Another term our partners often use is lane departure, which is synonymous with RwD, since both include head-on collisions when a vehicle enters an opposing lane of traffic."* https://highways.dot.gov/safety/RwD

[7] Brian Tegtmeyer, USDOT, NHTSA National 911 Program, TRB 2nd TRB International Conference on Roadside Safety, June 2024

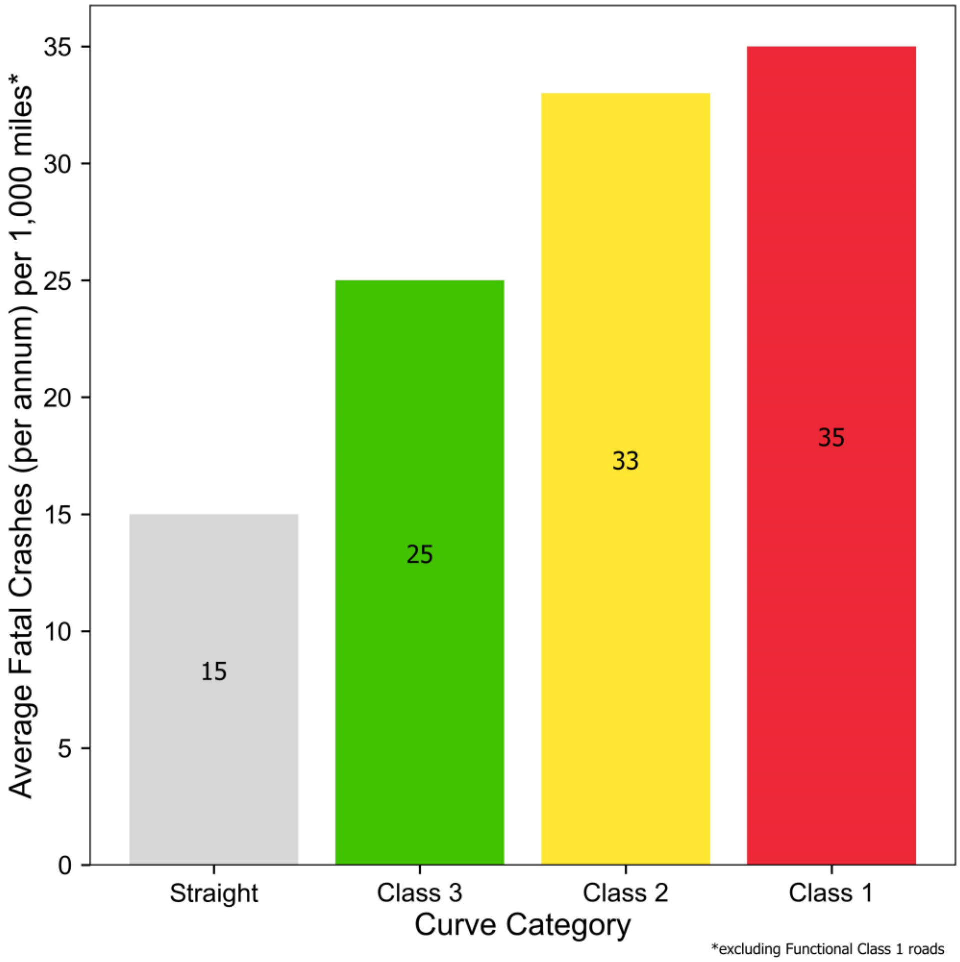

Figure 2.3 Fatal crash rate by segment type

The curve context by fatal crash rate analysis revealed:

- Out-of-context curves (Class 1 and Class 2), have an average weighted (by length) fatal crash rate that is **105% higher** than Straight or Class 3 curves.
- Out-of-context curves have an average weighted (by length) fatal crash rate that is **36% higher** than Class 3 curves.
- Class 1 curves have an unadjusted average fatal crash rate that is **40% higher** than Class 3 curves, and
- Class 1 curves have an unadjusted average fatal crash rate that is **133% higher** than Straights.

Therefore, targeting countermeasures to higher risk curves, and typically out-of-context curves, is prudent.

2.2 Prioritize

While it is possible to target interventions at individual high-risk curves across a network, the preferred approach is to systematically address out-of-context curves on a corridor basis. This approach generates greater consistency for a driver throughout the route and mitigates migration of crashes from one location on a corridor to another.

SafeCurves: Prioritize segments the network into corridors and identifies priority band thresholds based on the target proportion of network length: 10% in the “high” category (Category 1), 15% “medium-high” (Category 2), 20% “medium” (Category 3), and 20% “medium-low” (Category 4) and 35% “low” category (Category 5). SafeCurves: Prioritize then iterates and reconciles network length so an optimised 50% of the risk is within Category 1 corridors.

The objective of SafeCurves: Prioritize is to focus practitioner attention on those corridors where there is a high risk of curve roadway departure crashes, and equally where there is high potential for countermeasures to have a positive impact on trauma reduction. Importantly, the prioritization process easily allows agencies to direct limited resources to where they are best served.

The calculations for the prioritization process are complex. It for that reason the calculations are not undertaken until SafeCurves: Prioritize is about to be delivered to a customer. As an example of the outputs, the length of corridors disaggregated by the five risk prioritization categories for the State of Arkansas is shown in Figure 2.4. As a reminder, approximately 50% of the network risk is contained within Category 1 corridors and the other corridors contain the risk balance.

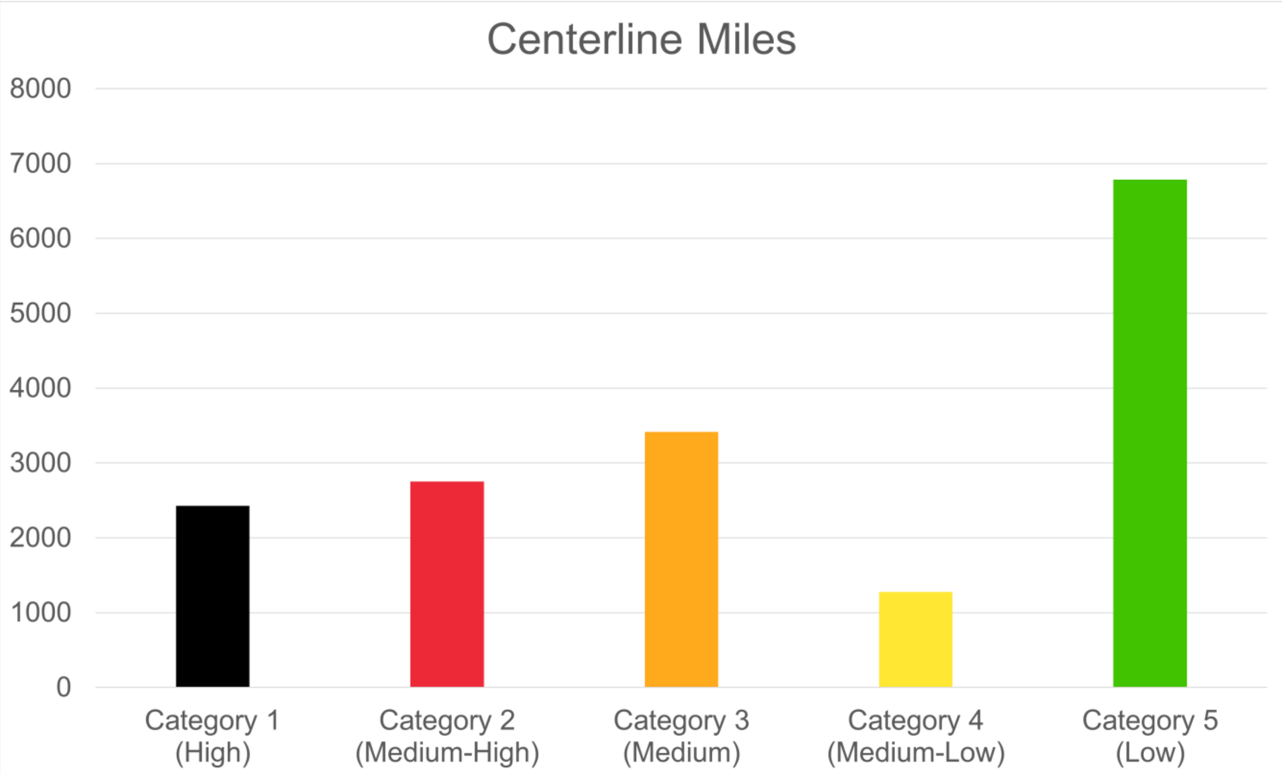

Figure 2.4 Arkansas corridor priority by length

2.3 Interventions

There are many interventions that can be implemented to reduce roadway departure crashes on curves, and especially out-of-context curves. One of the simplest interventions is using uniform and consistent signage, as mandated across the United States using the Manual for Uniform Control Devices (MUTCD)[8].

Applying both the 2009 Edition[9] and 11th Edition[10] MUTCD using SafeCurves: Interventions[11] has provided:

- the exact horizontal alignment sign position (for both isolated and grouped curves),
- the horizontal alignment sign type (W1-1, W1-2, W1-3, W1-4, W1-5, W1-8, W1-11), and

[8] https://mutcd.fhwa.dot.gov/index.htm
[9] https://mutcd.fhwa.dot.gov/kno_2009r1r2r3.htm
[10] https://mutcd.fhwa.dot.gov/kno_11th_Edition.htm
[11] SafeCurves v2024.1, SC_ID 3.12.0 SC_PR 3.12.0 SC_IN 3.12.0

- advisory speed (plaque) (W13-1P).

As noted, the exact sign position has been determined for isolated curves and a series of curves that are grouped together. There is usually a significant amount of effort required to assess grouped curves when applying MUTCD because each curve needs to be tested to determine if it forms part of an earlier group of curves, is part of a new group of curves, or is isolated.

SafeCurves: Interventions identified a total of 829,263 horizontal alignment signs (excluding W1-8) across the United States. The proportion of those signs is disaggregated into grouped and isolated signs as shown in Figure 2.5.

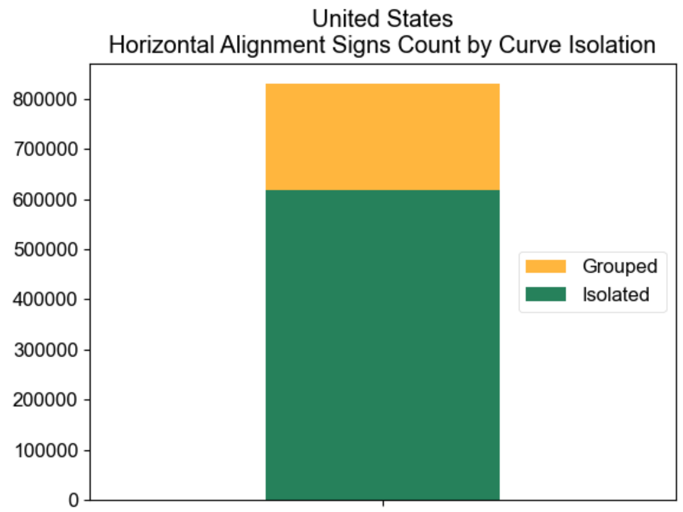

Figure 2.5 Grouped and isolated curves

The SafeCurves: Interventions assessment enables a consistent approach, where the justification for every horizontal alignment sign and advisory speed (plaque) is known and the reasons are explained for why the sign is required, recommended or optional. In doing so, SafeCurves: Interventions provides an auditable output.

The results show that the total quantum of horizontal alignment signs remains the same between the MUTCD 2009 and 11th Editions for the United States at 829,263 curve signs (excluding W1-8), albeit the blend between required, recommended and optional signs vary between MUTCD versions as shown in Figure 2.6.

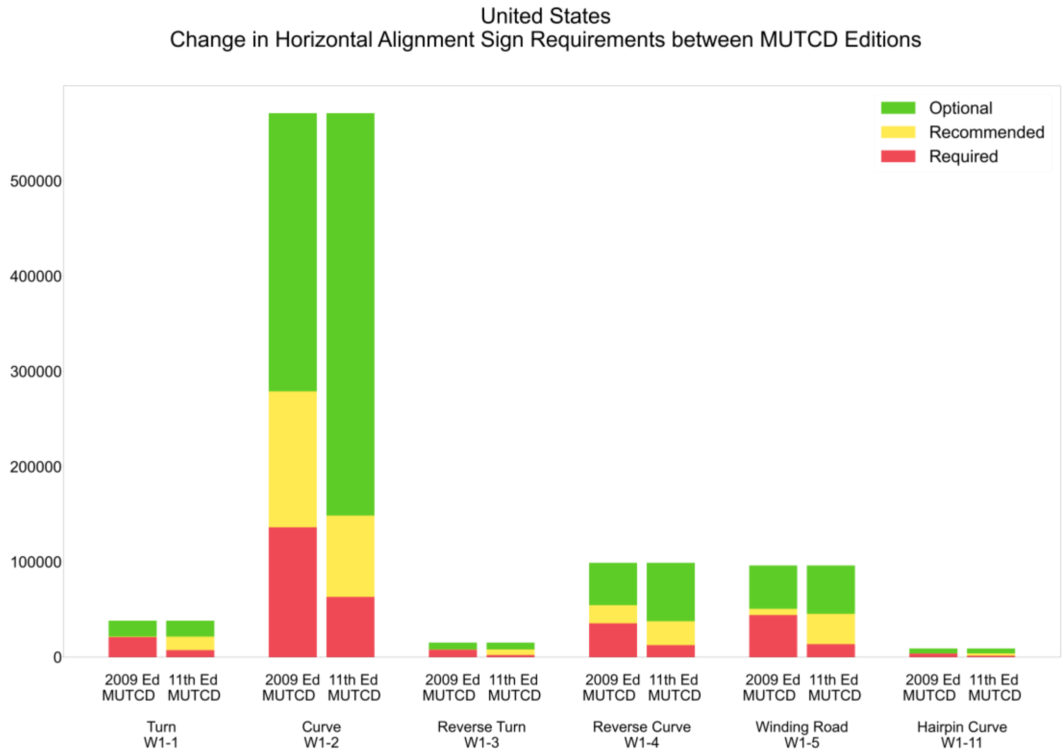

Figure 2.6 Changes in sign mandates between 2009 and 11th Edition MUTCD

The MUTCD 11th Edition changes the requirement for chevrons from a speed differential of 5mph to a speed differential of 20mph. The consequence is the quantum of chevron alignment signs (W1-8) has reduced from 2,238,440 to 736,144.

Providing drivers with relevant, uniform and consistent driving information is a critical component for road safety. Following MUTCD is an important way to achieve this road safety outcome. SafeCurves: Interventions supports practitioners to implement MUTCD accurately and efficiently.

3. Summary

This paper demonstrates how SafeCurves offers practitioners a proactive, systemic way to address risk at horizontal curves on their network, and provides a quantified example for the United States. Specifically, it has described the importance of:

- **SafeCurves: Identify**, which highlights those roadway segment types where practitioners should direct their attention i.e. out-of-context curves. Across the United States on average there are 1,155 fatalities per year on out-of-context curves. Out-of-context curves represent 4% of road segments but contain 8% of fatalities. The average crash rate for out-of-context curves weighted (by length) is **105% higher** than Straight or Class 3 curves. Every curve has been classified based on a proactive road safety assessment as:
  - 78% Class 3 (within context)
  - 22% or 270,611 out-of-context curves
    - 12% Class 2, and
    - 10% Class 1
- **SafeCurves: Prioritize**, which emphasizes that practitioners should direct their efforts at a corridor level focusing on Priority 1 corridors before other corridors. Priority 1 corridors represent a target 10% of a jurisdiction's network length but contains 50% of the overall risk.

- **Safe Curves: Interventions**, which provides uniform and consistent signage requirements for MUTCD compliance. Every horizontal alignment sign has been located, the sign type specified, and if appropriate the advisory speed (plaque) listed. For the United States the number of horizontal alignment signs is 829,263.

4. Discussion

The 2022 US Department of Transportation National Roadway Safety Strategy (NRSS)[12] adopted the safe system approach as the guiding paradigm to address roadway safety. One of the five objectives of the safe system approach is safer roads. SafeCurves helps practitioners accelerate towards providing safer roads, thereby enabling safer travel.

4.1 What is done now to identify risk at horizontal curves?

Traditionally, safety issues at horizontal curves are detected by looking at crash data to identify blackspots and reveal crash trends. However, relying on crash data to identify high-risk sites is a reactive approach to managing safety, as practitioners must wait for crashes to occur before deficiencies can be addressed. This approach can sometimes amount to chasing crash hotspots while failing to identify where serious crashes could occur in the future. This is particularly problematic on lower volume roads where crashes tend to be sporadic and more difficult to predict.

In-field approaches such as the ball-bank indicator method are used to set curve advisory speeds. This can be very time consuming and labour intensive.

4.2 What are the benefits of SafeCurves?

> *"There are two major benefits provided by SafeCurves:*
>
> *1) the data is immediately available and the data is current, and*
>
> *2) obtaining the data is efficient and has been proven as valid.*
>
> *Together when coupled with great local practice, SafeCurves accelerates better road safety outcomes."*
>
> Steve Abley

- **Immediate and current.** SafeCurves data is available now and is based on the latest information driven by thousands of vehicles every day. If a manual inspection were undertaken of every curve in United States, it would take 2.94 years of continuous travel time 24 hours a day, 7 days a week and 52 weeks a year. This continuous travel time ignores additional travel to and from base, non-sequential travel, hours worked on a normal working day, allowance for weekends, holidays, sickness and alike or the suitable resources. It also ignores other disbenefits of infield tests such as health and safety risks. SafeCurves is continuously updated to provide an ongoing live dataset so countermeasures can be considered now, improving road safety faster than previously possible.
- **Efficient and valid.** SafeCurves data is less expensive than other assessment methods and as described, the resource requirements associated with other methods can be extensive. For example, when undertaking infield testing using the ball-bank indicator method, that method requires two people in the vehicle, testing equipment and multiple runs through a single curve to obtain the recommended advisory speed. The FHWA states the ball-bank indicator method *"… can be subjective"*[13]*.* SafeCurves has been validated against various external datasets and been proven to be trustworthy and at least within the confidence provided by other methods.

[12] https:// www.transportation.gov/NRSS.
[13] https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa1122/ch3.cfm Section 3.6.

There are also other benefits of SafeCurves such as identifying risk, prioritizing that risk and proving why signs are justified at a specific location. All this is provided in an auditable format to enable faster progress towards greater road safety outcomes.

About Abley (www.abley.com)

Abley is a professional services firm with a deep understanding of road safety. The firm is based in New Zealand and undertakes commissions in multiple international jurisdictions transferring knowledge and improving road safety for all. The team has developed the Abley SafeSystem suite of products and relevant to this paper, SafeCurves.

About SafeCurves (http://www.abley.com/en-us/safecurves)

SafeCurves leverages the expertise of our professionals and extends their reach so we can help our customers achieve their road safety goals, faster and at less cost. SafeCurves comprises three modules: Identify, Prioritize and Interventions.

> *"If you would like to learn more about the number of out-of-context curves in your jurisdiction, contact me for a free report.*
>
> *Abley is keen to accelerate better road safety outcomes."*
>
> Steve Abley

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Steve is a professional engineer, founder and Chief Executive of Abley. The firm is strong supporter of the safe system approach and a trusted advisor to many governments and agencies of government. Abley extends its technical reach through the Abley SafeSystem suite of products – including SafeCurves.

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