



A Forensic HF/E Analysis of a Trip and Fall Injury Event Involving a Wheel Stop in a Parking Lot

M. S. Wogalter^(✉)

Psychology Department, North Carolina State University,
Raleigh, NC 27695-7650, USA
Wogalter@NCsu.edu

Abstract. Built (constructed) environments should have level surfaces to promote mobility and avoid injuries from trips and falls. Wheel stops (usually long concrete slabs with bolts to hold them in place) are sometimes placed in parking lots to limit and control how drivers position their vehicle in designated spaces. However, they present potential problems for pedestrians traversing through the area due to obstructed views and visual attention directed elsewhere. A forensic human factors and ergonomics (HFE) analysis of a specific scenario derived from a legal case is described. Issues and potential solutions are discussed.

Keywords: Wheel stop · Parking lot · Trip and fall · Forensic

1 Scenario

Mrs. Mary Lumens¹, age 68, was sitting comfortably at a booth at Snooty's Restaurant which is located near an Interstate 95 exit in South Carolina in the U.S. Her husband Elliott, age 71, had not yet arrived. She was also expecting to see her younger sister, Sally, and her husband, Bill, whom she had not seen for three years. They were driving through the area on their trip to Florida from Maryland. Her sister texted that they were about 15 miles (24 km) away and that was about 15 min ago. At that moment, she received a call from her husband indicating he had just pulled into the parking lot.

She picked Snooty's as the place to meet because it was located near their home, and it was the easiest way for her sister and husband to stop for an hour or two during their road trip since it was adjacent to the road that they would be traveling.

Snooty's was part of a huge gas station/truck stop combination, anchored and owned by Advanced Fuel, a division of Advanced Vehicle Fuel, Inc. They had 10 rows of pumps each able to handle 3 vehicles on each side, plus 8 additional lanes for tractor-trailers. The place was much larger than an average fueling station. The facility also included Snooty's restaurant and a small grocery/food store and touristy gift shop. The parking lot was huge, with spaces in the front, sides and back. Snooty's

¹ Names of persons, places and events are fictitious; resemblance to a specific event is coincidental.

restaurant was on the right side of building complex and it included a drive-through lane for food orders from vehicles.

Still on the cell phone and unable to find a space, Elliot says to Mary “When I pulled into the parking lot, I thought I saw your sister’s vehicle. I think they are already here. Have you seen them?” She replies, “They haven’t come into the restaurant yet. I am holding a booth. I’ll wait a little longer before texting them again. I’ll walk out to see if I see them.” She leaves her coat piled up on the seat of the booth with part of it coming up and touching the table so it would be visible that booth was already taken. Before she reaches the door, she tells the reception girl that she will be right back. Having never hung up, Elliot says into the phone, “I found a space—pulling into it now.” Mary steps outside the restaurant’s side door but sees only a mass of cars and then walks across to the other side of the drive-thru lane. She says into her phone “I do not see you.” He says, “I’m just getting out. Hold on.” She is scanning the entire side of the parking lot and she does not see him or her sister and brother in law. She says into the phone, “Where are you?” “I said I’m just getting out.” He stands up and closes the car door. Elliot sees her standing in the area near the drive through and begins waving and then yelling her name. Finally, she sees Elliot and waves back to him. She begins to go around a parked vehicle. Just as she makes it around the front passenger side of the vehicle, she sees below that she will need to step over a yellow parking stop. She does so with her left foot but as she follows with her right foot, something catches her shoe and suddenly she is falling. She reported later that she was almost able to grab the car’s side view mirror but misses and slides by it. Her husband reported that after getting out of his car, he saw her at the edge of the parking lot and he tried to get her attention by waving and yelling in her direction. She finally saw him, waved back and then she disappeared between the parked vehicles. Since there were many vehicles parked between them so he was not exactly sure where she was. After looking down each row of cars in the vicinity, he sees her down one row on the ground between the fenders of two cars bleeding and sobbing. Soon thereafter, Mary was carried into the restaurant by two gas station employees and was seated along the length in the first booth.

That day, the 18th of November 2015, changed Mary Lumens’ life as well as her husband’s. She broke her hip and left arm and wrist. It took her 6 months before she could use a walker because of the substantial injury to both places on her body. She has had extensive physical therapy for which she has had to travel 45 miles each way to an approved orthopedic center. Two years after the fall, she is able to walk on her own, but reports daily pain in her wrist.

Shortly after the injury event, the restaurant manager on duty produced an incident report. The description was not very detailed but because most of the form’s questions were not applicable to the particular injury event. Two South Carolina State police officers who were in the area also arrived at the scene shortly after the incident. The troopers took some notes but did not produce a final report. A formal accident report was not filed but their notes were transcribed. Mary’s sister and husband arrived only minutes after Mary’s fall. They spent several hours at the emergency room with her and Elliot before continuing their trip. They stopped again on their trip back eight days later.

2 Additional Background Information

A few months later Mary was deposed in a legal case that she and Elliot filed against the owners of the facility. “I saw the parking bumper or wheel stop, or whatever they are called.” She also said, “I can tell you that it was not as brightly colored yellow as it is today. We went out there last weekend to see if anything changed and found that some of the wheel stops had been repainted.”

Recorded both in the establishment’s and police reports, Mary stated that she tried to step over the wheel stop and believed that she had more than enough clearance but that her right foot got caught onto something in the process. The police report quoted her as saying, “After I fell I could see that there was a bolt sticking up out the parking stop and that the parking stop was not flat against the parking lot. I didn’t notice those aspects *until* after I was already down on the ground.”

Photos after Mary’s fall confirmed the attributes that Mary mentioned. The wheel stop (also known as a bumper stop, parking stop, tire bumper and other names) was warped and the bolt (sometimes called a lag bolt or rebar spike) was partly sticking out above the parking stop.

Parts of the huge parking lot were in disrepair. There were bolts sticking out of the asphalt without any wheel stop nearby and numerous broken wheel stops were scattered at various places. Many of the wheel stops were broken at or near the bolt holes—an apparent weak point. These tripping hazards can be missed (“fail to be noticed”) by pedestrians and have the potential to initiate a trip and fall.

The act of walking involves a motor-control system that is predominately automatic and unconscious. Of course parts of it are voluntarily and purposely initiated. For humans to react properly to obstacles in their way as they transverse the environment, visual and kinesthetic information needs to be processed as input. Unexpected or unusual aspects that are not prominent need to be enhanced and made salient so as not to be missed or else a misstep can be produced.

According to an engineering report produce by an expert retained in the resulting legal case, the subject wheel stop was composed of recycled plastic and opined that this material reacts to a greater extent to temperature changes than wheel stops traditionally composed of concrete. Wheel stops with recycled materials can result in substantial temperature-based distortion. With heat during the summer months it can expand and warp. These wheel stops may never completely return to the original horizontal shape when they contract in colder temperatures. Without this technical knowledge, the use of wheel stops made of recycled products would seem to be environmentally beneficial, i.e., doing the “green” thing by reducing landfill use. It was never determined in this case’s discovery phase whether recycled-plastic wheel stops can be made (differently formulated) to limit warping and distortion. There is an additional relevant effect of the expansion and contraction cycles. When the wheel stop expands it causes the ends to rise up from the pavement due to being held and limited by the bolts. This has the effect of applying pressure on the bolts’ heads and moving the bolts upwards. When the wheel stop contracts in cold temperatures, the bolts at each ends of the wheel stop may remain in a raised position. As a result, it sticks out above a flatter, contracted wheel stop. People navigating across the parking lot would have to notice that the bolts are

raised above the wheels stop so as to clear them when stepping directly over them or adjusting their direction to avoid them. The problem is that only a portion of the wheel stops might be visible because they are partially obscured by the front or rear end of parked vehicles. When used as intended, drivers move into a parking space up to the wheel stop to the point where (in most cases depending on clearance) the vehicle rests on top of the wheel stops, sometimes touching or nearly touching the tread of the tires. When a vehicle is parked on top of a wheel stop, only the sides of wheel stops may be exposed to pedestrians while the middle is covered. The wheel stops including the one involved in Mary's fall was in an area that pedestrians would foreseeably be navigating to go to and from the restaurant to their parked vehicle. There were no dedicated pedestrian walkways or sidewalks within this particular parking lot.

3 Human Factors and Ergonomics (HF/E) Analysis

Mary Lumens (the plaintiff in the lawsuit) likely saw one or more wheel stops when she parked her car. Upon exiting the restaurant, there would be wheel stops in her visual field as she scanned the area but she probably did not give much (or any) attention to them. The bowing deformation and the end bolts sticking out are visible but they are not prominent features that would be quick to draw much or any attention (to an ordinary pedestrian). Much of Mary's attention was likely focused on looking for her husband and sister (and brother-in-law) and their cars. When Elliott got out of his vehicle, he saw Mary in the distance. He waved his arm back and forth and screamed her name to try to get her attention. During this time Mary's visual attention was focused on scanning the enormous lot, gazing outwards above the surfaces of hoods, roofs, racks, and trunks of different vehicles for family members. Thus, her gaze was mainly directed and focused on objects at varied distances in the parking lot, not down at her feet. Shortly after she seeing Elliott waving at her, she fell.

Thus there were several factors contributing to the trip and fall event. A lot of it concerns the relative use of visual attention and the partly obscured wheel stops. She was mainly looking elsewhere—focusing on areas above the vehicles. And many of the wheel stops in her immediate area could not be seen because parked vehicles were obstructing their view. Some of the wheel stops could not be seen until just coming upon them, just before a navigation response is needed. Only at these “near points” are they relevant to pedestrians to consider. Mary admitted seeing the subject wheel stop just before she was stepped over it to clear it. She also said, “I stepped plenty high to clear it,” but also remarked that at that time, she did not see the bolt sticking out above it. It was the bolt head that caught her left shoe and initiated the trip and fall. She did not recall whether the bolt was black or painted partly or fully yellow. Photos taken a few months after the event showed that some bolt heads and necks in the parking lot were freshly painted yellow and others were only partly painted. See Figs. 1, 2, and 3.

People trip and fall over wheel stops even without the problems of warping and the bolts sticking out (Bell, Collins, Dalsey, Sublet et al. 2010; Washington State Department of Labor and Industries 2010). This is because the presence of wheel stops can be missed in part due to (a) vehicles obstructing views of them, (b) some are not distinguishable from the surrounding environment (e.g., not in a distinct color), and



Fig. 1. Warped wheel stop with bolt raised above its surface.



Fig. 2. Close-up of a bolt sticking out.

their appearance in parking areas is so common and familiar that people pay little or no attention to them. Other potential issues include insufficient lighting, people looking elsewhere, people carrying or pushing large objects obscuring their view, attention distracted by cell phone use or by other tasks, among others.

3.1 Benefits of Wheel Stops

Wheel stops have intended benefits. One is that they can be used to control directional movement of vehicles in a parking lot, i.e., preventing vehicles from moving through certain areas. The main benefit is that they can control placement of parked vehicles.



Fig. 3. Wheel stop and bolt area viewed from above.

They are a barrier or guard to prevent vehicles from encroaching beyond a certain point. They provide guidance and enable alignment of vehicles to maximize the number of vehicles in a lot and to prevent directional rollaways.

Parking lots are not made just for vehicles; they are made for people, too—drivers, occupants and pedestrians (who are often the same people in different roles at different times). People expect parking lots and decks to be reasonably safe (e.g., Mendat and Wogalter 2003). Because pedestrians and vehicles often traverse the same space, parking lots ought to be designed to avoid collisions, particularly between pedestrians and vehicles. Without dedicated walkways, pedestrians need to traverse and change direction around and between multiple vehicles or in vehicular lanes. In the scenario that started this article, Mary Lumens, the injured party, was looking for particular people and cars in the distance at or about the time she tripped and fell. But it should be noted that many of the same factors are involved in other common scenarios such when one traverses towards the entrance of a shopping center or big-box store or in looking for their vehicle after exiting. There are numerous instances where people will look in an approximately horizontal direction or somewhat lower, but wheels stops under foot are almost 90° below that. With vehicles blocking views, wheel stops might be only be seen just before a relevant response is needed to step over or aside to avoid them. Given this, it is foreseeable that people will sometimes trip on them. Not all trips lead to a fall (sometimes people can catch themselves and readjust in time) and not all falls lead to a serious injury. Trips and falls that do not produce serious injury are seldom reported, and if a non-serious injury is reported (a critical incident that should cue the potential for future serious injury), they are usually not acted upon to correct the “alleged” problem. The property owners, Advance Vehicle Fuels, reported they had no records of any falls at this property. They have a document retention policy of 7 years after which paperwork is destroyed. The manager’s accident report was a new initiative that started earlier that same year. The corporate legal department receives all injury files.

3.2 Bowed Wheel Stop with Bolts Sticking Out

With a bowed wheel stop, a higher rise in the step is needed to go over it. An alternative is to step aside to avoid it. Warpage of the two ends of the wheel stop is not the full story about potential for height misapprehension. Several inches away from the ends of the subject wheel stop are large metal bolts intended to attach and retain the wheel stop on the parking lot surface. In the subject parking lot, many of the wheel stops, including the subject one, had bolt heads raised above the top surface. As described earlier, apparently the bolts were pulled up by the warping ends of the wheel stops and reached their apex in the hottest temperatures with the greatest expansion of the wheel stop's size. With cooler temperatures the wheel stop contracts in size and tends to straighten back out and down (but often not returning to their original state). However, with the contraction in cooler temperatures, the bolts do not return to their original position. The bolts do not come back down (or at least not all of the way) often staying in their apex position, protruding higher than the wheel stops themselves. Clearly, the bolt heads should never be higher than the wheel stop. It is a hazard when positioned over and above the wheel stop. People might not see them when stepping over the wheel stop and the bolt could "catch" the foot, shoe, or pant leg causing a misstep, a trip event, and potentially a serious fall.

Fractions of inches can be the difference between successful navigation or the catching of the foot in motion and causing a trip event. The Americans with Disabilities Act (ADA) of 1990 defines a "trip hazard" as any vertical change over 1/4 in. or more at any joint or crack. Protrusions of one-eighth inch can cause a misstep (e.g., Cohen and Pauls 2006). It can catch the foot, shoes, etc. and cause a tripping event. In most localities, there are no specific regulations or laws controlling the design and placement of wheel stops in parking lots. However, human factors/ergonomics (HF/E) principles can be applied to this domain. HF/E research and principles can be applied to predict and explain safety problems in built external environments such as parking lots. Perturbations on surfaces in built environments where the public traverse is a necessary concern for property owners and management. So in order to avoid a trip and fall incident and the serious injury that might result, small, less-prominent perturbations on the surfaces in which pedestrians traverse should be a concern and should be dealt with. Bolts sticking above the surface of wheel stops are a hazard that should be controlled. It should be removed, guarded by barrier, or at least, warned about.

At some point after the Mary's trip and fall, some of the wheel stops had been repainted the same bright yellow color. Some of the bolts heads and neck were coated with yellow paint (although not all of them). It is unclear whether the subject bolt was painted at the time of Mrs. Lumen's fall. Neither of the Lumens' remembered, and neither the accident report nor the police's notes mention the bolt's coloration. No photographs were taken immediately after the incident of the parking lot or the particular wheel stop. The lack of anyone noting the bolts having yellow paint on them at the time of the event suggests that the wheel stop bolt may not have been painted or incompletely covered in paint at the time of the fall. The bolt being painted *or not* could contribute to the fall. If it was painted, then under certain viewing angles it might not be seen because it was the same color of the wheel stop, i.e., there is a lack of figure-ground color contrast with the wheel stop. If the subject bolt was unpainted or mostly

unpainted, and thus mostly a dark gray color, then it could blend in with the surrounding dark gray asphalt. Viewing angles could make it very difficult to see the bolts. The raised bolt in Fig. 3 is not visually prominent.

Clearly the owner/management should have better maintained the parking lot. After Mary's fall, the parking stops were likely repainted but other forms of maintenance and repair were not performed, such as removal of the broken pieces of wheel stops scattered in the lot and the removal of mostly-bent bolts sticking out of the pavement (without any wheel stop attached). Bolts were sticking up beyond the top surfaces of all unbroken wheel stops.

3.3 Hazard-Control Hierarchy

The concept of the hazard control is relevant to this incident. The basic hazard-control hierarchy is a generalized set of prioritized strategies of designing out, guarding against and warning about potential dangers.

A highly effective method of hazard control to prevent tripping from wheel stops is to not use them, i.e., eliminate them. If wheel stops are used, they should be made so they do no warp or change shape with expected temperature variations. There might be a way to make wheel stops with recycled material that does not warp, but if it cannot be done, then different material that does not warp such as conventional concrete should be used. Another set of design issues concerns the bolts and the associated holes. The wheel stop's bolt holes should have had a larger cylinder space for the bolt neck and a large inset space to bury the bolt head deeper into the wheel stop so that it stays below the surface. With heat and expansion, the bolt would not be pulled up, because with a wider hole, so that any expansion of the wheel stop would not move the bolt out of position, and any change in the wheel stop by expansion and contraction would slide by the bolt. A large inset space would allow some movement of the bolt without it having an apex height above the surface of the wheel stop. A deeper inset space would allow a bolt head to lie fully (and remain) below the surface of the wheel stop. At the original installation the rounded bolt head was too large to fit in a small inset space that was present, leaving part of the bolt head above wheel stop's top surface. This was an incorrect combination of wheel stop and bolt head type. The bolt head should always be below (or at least flush with) the top surface of the wheel stop.

Guarding is the second prioritized method of hazard control. Wheel stops themselves are a form of guarding for vehicle placement. There are other forms of guarding that are better and safer than wheel stops such as the use of taller guards/barriers that can be seen above vehicles. In fact, around the periphery of the subject gas station/restaurant building were tall, vertically mounted poles (pipes) to prevent vehicle encroachment and to enable people to see them above the vehicles. Also large bollards or planters could demark areas for parking. These barriers can control vehicular placement, and are more visible to pedestrians.

Warning about the hazard is the third method. Painting the parking stops yellow was a method of making the parking stops more conspicuous. However, the bolt heads—whether painted yellow or not—will still be a hazard because of inadequate contrast with the contextual environment. The relatively small size of the raised bolts makes its detection difficult. Furthermore, pedestrians only get a brief exposure to the wheel stop

just before a relevant response is needed, and people are foreseeably looking in a different direction, i.e., above the vehicles. Thus, the hazard-control strategies of design changes to reduce the hazard and guarding against the hazard are likely to provide greater safety than markings for the wheel stop in this case. Even if the bolt were to be made a more distinguishable color, the hazard is not reduced by much.

4 Discussion and Conclusions

The injury from falling can be a life-changing event. Falling, as a general category leads to more emergency room visits than other accident causes, particularly in the younger and older age groups (e.g., NEISS 2017). This is why owners, operators, and managers of properties that invite the general public should be aware that they could be liable in a lawsuit for a serious injury if it is determined that their property's characteristics were causative for a fall. Thus, property owners, operators and managers need to scrutinize their space to determine if there are hazards to pedestrians, and if so to consider the prioritized strategies of redesign, guarding and warning to control the potential of a fall hazard. Clearly, they need to ensure public areas are maintained and repaired.

Parking stops are known to be involved in trip and fall accidents. Fortunately many people do not trip because they see the hazard and avoid it. Trips do not always result in a fall. Sometimes people can catch themselves and not fall. And those that fall may not get severely hurt. Undoubtedly, a lot of missteps involving wheel stops go unreported. The problem is that some people who trip and fall can get severely hurt, particularly older adults who tend to be less adept physically and perceptually than younger adults. Older adults are more fragile, tend to receive more severe injuries in these events, and they may never fully recover from the resultant injury. The hazard in this case is made worse because the wheel stops' ends were raised due to warping arising from anticipatable environmental exposure. The warping problem is made worse due to the bolts being forced out of the ground. Because the bolts that attach the wheel stops to the pavement are not a prominent feature (small size, low contrast), their position above the surface of the wheel stop may not be noticed.

People assume that the ground on a built/developed environment will be reasonably flat, and if not, then it should be guarded or well marked (e.g., Cohen and LaRue 2019). This is the reason that built environments need to be examined and analyzed in order to know what hazards need to be controlled. Property owners and managers need to inspect their property frequently to ensure there are no hazards due to bad configurations, poor maintenance, etc. The basic ideas of the hazard-control hierarchy of designing out (eliminating or reducing hazards), guarding against hazards (better barriers), and warning (marking) are useful. There are many ways to control the hazards associated with wheel stops. Wheel stops can be eliminated, or if used, be made of nonwarping material and use a better-designed connecting mechanism. Tall poles, bollards, and large planters could provide guarding. Using only warnings does not likely solve the bolt problem.

The case resolved in a confidential settlement before trial.

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