Structural, regulatory and human error were factors in Washington highway bridge collapse

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A key factor in the crash was the curved opening of the bridge. The posted height was the maximum in the center, not the lower curved section above the outer lanes, which the truck hit. Credit: Tim Stark

When an important bridge collapsed on Interstate 5 near Mount Vernon, Washington, in 2013, questions were raised about how such a catastrophic failure could occur. A new analysis by a team of civil engineering faculty at the University of Illinois at Urbana-Champaign outlines the many factors that led to the collapse, as well as steps that transportation departments can take to prevent such accidents on other bridges of similar design.

The analysis by Illinois civil engineering professors Tim Stark, Ray Benekohal, Larry Fahnestock and Jim LaFave was published in the American Society of Civil Engineers' *Journal of Performance of Constructed Facilities*.

"The bridge repair costs exceeded $15 million, and that doesn't account for the economic losses that the area felt because they and visitors no longer had access to the interstate," Stark said. "Even though this accident occurred three years ago, it's still very important because many bridges have this same design, not only in Washington but in other states."

The collapse on May 23, 2013, was precipitated when an oversized trailer clipped the top of the second cross-frame on the bridge. The analysis found several inciting factors, including regulatory ones—the truck had a permit to cross the bridge; structural ones—a minor impact caused a chain reaction that collapsed the bridge; and human error—miscommunication between the drivers of the truck hauling the oversized trailer and its pilot car.

How did an oversized vehicle receive a permit for a bridge with lower clearance than its height? Inaccurate record-keeping, Stark said. The opening of the bridge was curved, so that the clearance over the far lanes was lower than the clearance in the center lanes. However, the Washington Department of Transportation only keeps the maximum clearance in its bridge database, which is used to issue permits for oversized vehicles.

"The key issue in this case is the variable vertical bridge clearance," Stark said. "Many bridges have a square opening, so the clearance is the same across all lanes. The problem with this bridge was that it curved down over the edge lanes. The oversized trailer was 15 feet 9 inches tall. The database said the bridge was 17 feet 3 inches, which was in the center - almost two feet higher than the edges, which is where the oversized trailer was traveling."

Benekohal recommended that other states adopt the Illinois Department of Transportation's policy of reporting the lowest vertical clearance of a bridge, rather than the highest, and its periodic use of LIDAR to verify clearance numbers, which can be affected by repavement, snow or other factors.

The pilot car was the source of the human error factors detailed in the paper. Oversized vehicles have pilot cars to guide them, intended to help thwart the kind of scenario that led to the I-5 collapse. The pilot car has an antenna that is supposed to alert the driver if it hits a bridge or other structure, indicating that the clearance is too low for the following oversized vehicle to continue. Then the pilot driver must call the truck driver to tell him or her to adjust course.

"In this case, the pilot car either did not impact the bridge or the driver didn't hear the impact. They never called the truck, so that part of the safety mechanism failed," Stark said. "One solution we suggest is a sensor at the top of the pole that automatically contacts the oversized vehicle if it hits an object. This eliminates the drivers having to communicate quickly so the oversized vehicle can change course. Also, the pilot car antenna was not straight, so it was not accurately measuring the full height."

The structural analysis revealed that the impact to the second cross-frame, rather than the first, caused so much damage because the way it twisted pulled down the top of the bridge truss, which in turn caused the entire structure to fail.

"I think one of the interesting things about this failure is that the initial damage of where the truck hit was not a primary support, it was a cross beam, and the damage cascaded, causing the entire collapse," LaFave said. "We then looked at ways to reinforce bridges with this design, to increase the capacity and reduce the chance of this kind of failure occurring. We can selectively add supports so there are ways to redistribute the impact load, so the structure can remain stable and stay standing even if there's damage to a particular area."

The researchers hope that their recommendations can help address the differing factors that contributed to this incident, so that it will not be repeated. Updating databases to reflect minimum heights, automated reporting between the pilot car and the oversized vehicle, and structural reinforcement could prevent accidents and collapses like this one, increasing safety and preventing costly repairs, they said.

"A structural failure is obviously not desirable. However, the positive outcome is that we're taking the opportunity to learn from a failure," Fahnestock said. "We want to understand what happened so that we can be a part of preventing something like this from happening in the future, and thus provide a safer and more reliable infrastructure."

More information: Timothy D. Stark et al, I-5 Skagit River Bridge Collapse Review, *Journal of Performance of Constructed Facilities* (2016). DOI: 10.1061/(ASCE)CF.1943-5509.0000913

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