Root Cause Analysis Report

Interstate 5 Skagit River Bridge Collapse - Sept. 2016 Update

Problem Statement

Report Number	WA12.684	**RCA Owner**	Cory Boisoneau
Report Date	1/9/2014	**RCA Facilitator**	Cory Boisoneau

Focal Point: Bridge Collapse

When

Start Date: 5/23/2013	End Date: 5/23/2013
Start Time: 7:05pm	End Time:
Unique Timing	After oversized truck passed through outer lane of Interstate 5.

Where

Location	Skagit River Bridge on I-5
Location	Between Mount Vernon and Burlington in Washington State

Actual Impact

Customer Service	I-5 southbound closed for several weeks, impact on local businesses. Costs unknown	$0.00
Safety	Minor injuries	$0.00
Cost	Bridge rebuild/repair	$15,000,000.00
		Actual Impact Total: $15,000,000.00

Frequency	times Overall
Frequency Note	Records indicate that this bridge has been struck multiple times. However, none of the previous strikes caused any significant damage.

Potential Impact

Safety	Potential fatalities to drivers crossing bridge.	$0.00
Cost	Additional repair costs with increased damage.	$0.00
		Potential Impact Total: $0.00

Report Summaries

Executive Summary

DISCLAIMER: the contents of this RCA report and chart were taken from the National Transportation Safety Board (NTSB)'s investigation report and the University of Illinois at Urbana Champaign analysis. Sologic did not participate in the investigation, or the development of the solutions for this analysis. On May 23, 2013, at approximately 7:05 pm PDT, a truck-tractor in combination with a flatbed semitrailer hauling an oversize load (the oversize vehicle) was traveling south on Interstate 5 (I-5) near Mount Vernon, Washington. The oversize vehicle had a permit for the route of travel and was being led by a pilot/escort vehicle. As the oversize vehicle traveled across the I-5 bridge above the Skagit River, it struck the bridge, damaging its structure. As a result of contact damage to the bridge's truss structure, span 8 of the 12-span bridge collapsed into the Skagit River. Two passenger vehicles fell into the river. Two other vehicles were also damaged during the event. Eight vehicle occupants were involved in the bridge span collapse; three received minor injuries and five were uninjured. In order to prevent further collapses on this bridge, the bridge was rebuilt with an 18-foot clearance over all lanes and it has been recommended that the Federal Highway Administration develop a guide for eliminating or reducing bridge strikes. To prevent impacts such as this on other similar bridges, the Illinois analysis recommends selectively adding supports in key areas to distribute the load in the event of a collision. They also recommend automatic notifications from the pilot car's antenna to the truck driver, and to update the Department of Transportation's bridge database to reflect the lowest vertical height for all bridges.

Cause and Effect Summary

The bridge collapse was caused by a semi truck impacting a truss and multiple braces with sufficient force to fracture the bridge. The truck impacted the truss and multiple braces because it was traveling in the outside lane which was shorter in height than the inside lane. The truck was traveling in outside lane because the driver was unaware that the inside lane was designed for taller vehicles, he moved to right lane to let another truck pass, and the pilot car did not communicate the clearance issue. The driver was unaware of the lane height differences because his vehicle received a permit for the route, despite this particular bridge clearance being lower than the truck's height, there were no warning signs for clearance height, and no one informed the driver about differences in clearance in outside/inside lanes. The vehicle received a permit for a bridge, despite bridge clearance being lower than truck's height because the DOT automatically issues permits online, Washington DOT only keeps the maximum clearance in its bridge database, and a bridge database is used to issue permits. There were no warning signs for the clearance height because signage is not required by law for bridges over 14 feet (4.26m). The pilot car did not communicate clearance issues because the pilot car driver did not notice the antenna low-clearance detection, or because there was no low clearance detection by antenna (unclear which was the case). Regardless, the truck was following the pilot car too closely to react, even if escort had noticed and communicated. The driver did not notice the potential antenna low-clearance detection because the driver was distracted - talking on cell phone. There was potentially no low clearance detection by the antenna because the antenna was not straight, so it was not accurately measuring the full height. There was sufficient force to fracture the bridge because the mass of the truck was 88,700 lbs, its speed was approximately 60 mph, and the bridge was built using a fracture-critical, through truss design. Fracture-critical design means that failure of an essential part can cause overload/collapse. A through truss bridge design was used because it was a common bridge design when bridge was built in 1955.

Solutions

SO-0001	**Solution**	Change policy to report the lowest vertical clearance for bridges, rather than the highest—and periodically verify that data with LIDAR measurements. (From the University of Illinois at Urbana Champaign analysis)		
	Cause(s)	No one informed the driver about differences in clearance in outside/inside lanes		
	Note	Clearance can be affected by re-pavement, snow or other factors.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Identified
	Term		**Cost**	
SO-0002	**Solution**	Bridge rebuilt with 18 foot clearance across all lanes		
	Cause(s)	Outside lane height = 4.45m		
	Note			
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term		**Cost**	$15,000,000.00
SO-0003	**Solution**	Ask the Federal Highway Administration to develop a guide for states on how to prevent bridge strikes by vehicles, including collecting and sharing data, and evaluating and reviewing bridge strike countermeasures taken by states.		
	Cause(s)			
	Note			
	Assigned		**Criteria**	Not Checked
	Due		**Status**	Identified
	Term		**Cost**	
SO-0004	**Solution**	Install a sensor at the top of the antenna pole that automatically contacts the oversized vehicle if it hits an object. (From the University of Illinois at Urbana Champaign analysis)		
	Cause(s)	Pilot car did not communicate clearance issue		
	Note	This eliminates the drivers having to communicate quickly so the oversized vehicle can change course.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Identified

	Term	medium	**Cost**
SO-0005	**Solution**	For bridges with similar design: 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. (From the University of Illinois at Urbana Champaign analysis)	
	Cause(s)	Fracture-critical design	
	Note	Recommendation from University of Illinois at Urbana Champaign analysis	
	Assigned		**Criteria** Passed
	Due		**Status** Identified
	Term		**Cost**

Team

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Actions

AC-0001	**Action**	Causes Unknown
	Cause(s)	Truck following at 400 feet, or a five-second response time
	Assigned	
	Date	9/30/2016
AC-0002	**Action**	Causes Unknown
	Cause(s)	Pilot car antenna was not straight, so it was not accurately measuring the full height.
	Assigned	
	Date	9/30/2016
AC-0003	**Action**	Causes Unknown
	Cause(s)	Washington DOT only keeps the maximum clearance in its bridge database
	Assigned	
	Date	10/2/2016

Notes

NO-0001	**Note**	This steel through-truss bridge has a "fracture-critical" design with non-redundant load-bearing beams and joints that are each essential to the whole structure staying intact. An initial failure (perhaps by cracking) of a single essential part can sometimes overload other parts and make them fail, which quickly triggers a chain reaction of even more failures and causes the entire bridge span to collapse.
	Cause(s)	Fracture-critical design
NO-0002	**Note**	In WA, only overcrossings of less than 14 ft (4.3m) are required to have advance postings of height restrictions.
	Cause(s)	Sign not required by law for bridges over 14 feet (4.26m)
NO-0003	**Note**	Large vehicles should be in inside lane (5.2 m high)
	Cause(s)	Truck traveling in outside lane
NO-0004	**Note**	Clearance pole struck bridge, per NTSB report
	Cause(s)	Driver did not notice antenna low-clearance detection
NO-0005	**Note**	Even if the escort vehicle had communicated the bridge height danger to the truck, the truck would not have been able to react in time.
	Cause(s)	Truck following pilot car too closely to react

Chart Key
- Transitory
- Non Transitory
- Transitory Omission
- Non Transitory Omission
- Undefined
- Chart Quality Alert
- Focal Point
- Evidence
- Notes
- Solutions
- Actions

Bridge Collapse

Truck traveling in outside lane

Driver unaware inside lane designed for taller vehicles

AND OR

No warning signs for clearance height

Sign not required by law for bridges over 14 feet (4.26m)

14 feet (4.26 m) is the normal legal height limit

No one informed the driver about differences in clearance in outside/inside lanes

Solutions

Change policy to report the lowest vertical clearance for bridges, rather than the highest and periodically verify that data with LIDAR measurements. (From the University of Illinois at Urbana Champaign analysis)

Criteria Pass Status Identified

Clearance can be affected by re-pavement, snow or other factors.

Driver's vehicle received a permit for a bridge, despite bridge clearance being lower than truck's height

Bridge database used to issue permits

END

Terminated Because:

Other causual paths more productive

DOT automatically issues permits online

Washington DOT only keeps the maximum clearance in its bridge database

Moved to right lane to let another truck pass

END

Terminated Because:

Other causual paths more productive

Pilot car did not communicate clearance issue

OR

Driver did not notice antenna low-clearance detection

Driver distracted - talking on cell phone

There was no low clearance detection by antenna

Pilot car antenna was not straight, so it was not accurately measuring the full height.

Solutions

Install a sensor at the top of the antenna pole that automatically contacts the oversized vehicle if it hits an object. (From the University of Illinois at Urbana Champaign analysis)

Criteria Pass Status Identified

This eliminates the drivers having to communicate quickly so the oversized vehicle can change course.

Truck impacted truss and multiple braces

Truck following pilot car too closely to react

Truck following at 400 feet, or a five-second response time

Should have been 865 feet, allowing for a 10-second response time

END

Terminated Because:

Other causual paths more productive

Outside lane height = 4.45m

Connects To:

b Through truss bridge design

Solutions

Bridge rebuilt with 18 foot clearance across all lanes

Criteria Pass Status Validated

Truck height = 4.8m

END

Terminated Because:

Other causual paths more productive

Sufficient force to fracture bridge

Mass of truck 88,700 lbs

END

Terminated Because:

Other causual paths more productive

Speed of truck approx. 60 mph

END

Terminated Because:

Other causual paths more productive

Fracture-critical design

b

Through truss bridge design

Common bridge design when bridge was built in 1955

END

Terminated Because:

Other causual paths more productive

Failure of essential part can cause overload/collapse

END

Terminated Because:

Other causual paths more productive

Solutions

For bridges with similar design: 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. (From the University of Illinois at Urbana Champaign analysis)

Criteria Pass Status Identified

Recommendation from University of Illinois at Urbana Champaign analysis