Collapse

Instructor Materials

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Introduction

This case highlights the challenges of planning and response in a high-vulnerability, multi-threat environment that is a nexus of multiple infrastructure modes. The exercises model robust critical thinking and small group processes to provide a blueprint for tackling the types of challenges faced by Critical Infrastructure Security and Resilience (CISR) professionals.[1] They also reinforce the learners' ability to recognize critical infrastructure, identify man-made and natural threats and vulnerabilities, prioritize hypotheses, pinpoint potential secondary affects, and think creatively to adapt risk management principles to a changing environment.

The exercises are keyed to the first several steps in the NIPP Risk Management Framework as well as the central learning objectives from the course. Exercise 1 puts learners in the shoes of a planner who is tasked with anticipating the full range of threats and vulnerabilities. It asks learners to enumerate additional information needs and develop an information collection and sharing strategy to augment planning efforts. Exercise 2 puts learners in the shoes of a responder, specifically the ICS lead officer, who must identify the range of possible causes of the collapse, prioritize them, and effectively communicate and issue guidance to responders. Exercise 3 builds on exercise 2 by asking learners to identify the potential secondary and tertiary effects and an information-sharing strategy to mitigate them. Through this series of tasks, students parse through the information in order to draw out meaningful courses of action. By working through the exercises in this manner, learners learn repeatable processes that can be used in any systems-based risk management process.

Most students will already be aware of the I-35W bridge collapse and generally familiar with its causes, but the goal of the exercises is to employ sound critical thinking about planning, response, and recovery activities, not simply to model the known outcome. As such, the exercises are designed to help the learner employ a robust and structured approach to these activities and explicitly identify the value added by using them. Many times, the value of technique lies in the conversation that it prompts about evidence, factors, assumptions, and gaps that would otherwise be overlooked. Learners should judge their performance, therefore, on how they have conducted their analyses rather than on the specific case outcome.

Exercise 1: Structured Planning Using Structured Brainstorming

Brainstorming is a process that follows specific rules and procedures designed to generate new ideas and concepts. The stimulus for creativity comes from two or more people bouncing ideas off each other. A brainstorming session usually exposes participants to a greater range of ideas and perspectives than any one person could generate alone, and this broadening of views typically results in a better product.

Structured Brainstorming is a systematic, twelve-step process (described below) for conducting group brainstorming. It is most often used to identify key drivers or all the forces and factors that may come into play in a given situation. If, however, a group is not possible, there is still value in thinking as imaginatively and divergently as possible by adjusting the technique for use by one person. The goal of brainstorming, whether used in a group or by oneself, is to think as exhaustively as possible.

Task: Identify all of the various types of vulnerabilities and threats posed to the Minneapolis I-35W Bridge.

Steps

Step 1: Gather a group of CISR learners.

Step 2: Pass out sticky notes and Sharpie-type pens or markers to all participants. Inform the team that there is no talking during the sticky-notes portion of the brainstorming exercise.

Step 3: Present the team with the following question: What are all threats and vulnerabilities to the I-35W Bridge?

Step 4: Ask the group to write down responses to the question with a few key words that will fit on a sticky note. After a response is written down, the participant gives it to the facilitator who then reads it aloud. Sharpie-type or felt-tip pens are used so that people can easily see what is written on the sticky notes later in the exercise.

Step 5: Place all the sticky notes on a wall randomly as they are called out. Treat all ideas the same. Encourage participants to build on one another's ideas.

Step 6: Usually an initial spurt of ideas is followed by pauses as participants contemplate the question. After five or ten minutes there is often a long pause of a minute or so. This slowing down suggests that the group has "emptied the barrel of the obvious" and is now on the verge of coming up with some fresh insights and ideas. Do not talk during this pause even if the silence is uncomfortable.

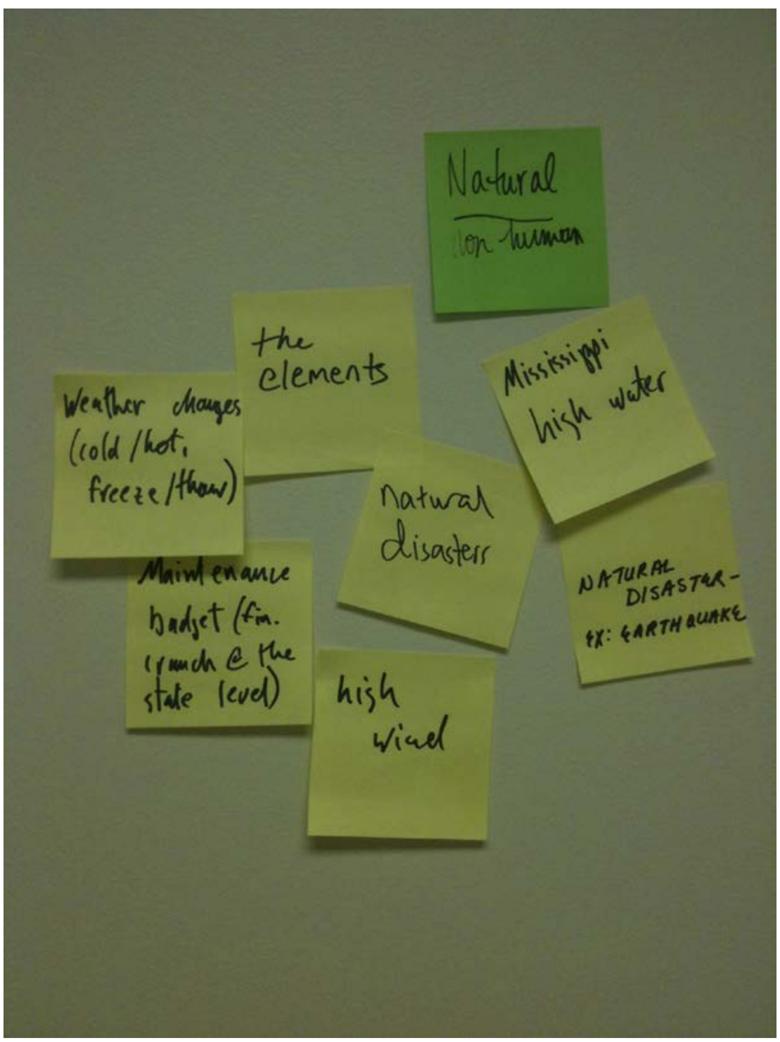
Examples of brainstormed threats and vulnerabilities appear below.

Figure 1: Examples of Initial Brainstorming Results

• Mississippi high water	• Weather Changes
• Wind	• Construction Error
• Collision or accident	• Human Error
• Minnesota Patriot Group	• Design problem
• Terrorist Targeting of Bridges	• Excess weight
• Erosion	• Too many vehicles
• Lock Failure	• High-load
• Boat Collision	• Change in river flow
• Natural Disaster	• Expected life span
• The elements	• Insider threat
• Age of Bridge	• Train derailment
• Lone Wolf	• Main North-South Interstate
• Main North-South Interstate	• Somali terrorists

Step 7: After two or three long pauses, conclude this divergent-thinking phase of the brainstorming session.

Figure 2: Brainstorm Affinity Cluster Example



Step 8: Ask all participants (or a small group) to go up to the wall and rearrange the sticky notes by affinity groups (groups that have some common characteristics). Some sticky notes may be moved several times, and some may be copied if the idea applies to more than one affinity group.

Step 9: When all sticky notes have been arranged, ask the group to select a word or phrase that best describes each grouping.

In our notional solution, participants created several affinity groups.

1. Vulnerabilities to the Nexus of Transportation Infrastructure at the Bridge Site

2. Exogenous Bridge Vulnerabilities

3. Endogenous Bridge Vulnerabilities

4. Natural Non-Human Threats and Vulnerabilities

5. Terrorist Threats

Step10: Look for sticky notes that do not fit neatly into any of the groups. Consider whether such an outlier is useless noise or the germ of an idea that deserves further attention.

Step 11: Assess what the group has accomplished.

Step 12: Present the results, describing the key themes or dimensions of the problem that deserve investigation.

The participants noted that the majority of threats and vulnerabilities were manmade.

Analytic Value Added

Did our ideas group themselves into coherent affinity groups? Were there any outliers or sticky notes that seemed to belong in a group all by themselves? Did the outliers spark new lines of inquiry? Did the labels we generated for each group accurately capture the essence of that set of sticky notes? What additional information should we track down about the threats and vulnerabilities we generated? Where does that information reside and to whom should we speak about it?

In this case, the group found that while they generated many sticky notes for manmade vulnerabilities and threats posed by terrorists and endogenous bridge issues, they lacked specifics about these areas and would seek out more information about these particular areas from inspectors and the FBI. Also, the group noted that while natural causes could be at the root of the problem, there were far more vulnerabilities and threats posed to the bridge by manmade causes such as terrorism, design issues, and the colocation of numerous other transportation modes.

Exercise 2: Effective Response Using Hypothesis Generation and Paired Comparison

Multiple Hypothesis Generation is part of any rigorous analytic process because it helps to avoid common pitfalls such as coming to premature closure or being overly influenced by first impressions. Avoiding a rush to judgment is extremely important in a crisis situation. Instead, this technique helps to ensure that one has thought broadly and creatively about a range of possibilities. The goal is to develop an exhaustive list of hypotheses that can be scrutinized and tested against both existing evidence and new data that may become available in the future.

This case is well suited to the form of hypotheses generation outlined below, which employs a group process that can be used to think creatively about a range of possible explanations. Using a group helps to generate a large list of possible hypotheses; group the lists; and refine the groupings to arrive at a set of plausible, clearly stated hypotheses for further investigation.

Paired Comparison, or prioritization, is a quick way to rank hypotheses. The results can be taken individually or aggregated if one is working with others. While the ranked hypotheses are helpful to gain a sense for the group's leanings about the likelihood of the cause of the bridge collapse, it is the conversation and thinking surrounding those rankings that can offer insights and prompt thinking about gaps, assumptions, and collection strategies as a situation unfolds.

Task: Use Hypothesis Generation to create a list of alternative hypotheses that explain the I-35W Bridge Collapse.

Steps

Step 1: Ask each member of the group to write down on separate 3-by-5-inch cards or sticky notes up to three plausible alternative hypotheses or explanations. Think broadly and creatively but strive to incorporate the elements of a good hypothesis:

- It is written as a definite statement.
- It is based on observations and knowledge.
- It is testable and falsifiable.
- It contains a dependent and an independent variable.

The initial results may not be expressed by participants in this manner, but the final hypotheses produced should include these elements.

In our notional solution, participants offered the following hypotheses in this first round of hypothesis generation:

- There was a massive collision that resulted in the bridge collapse.
- Bridge collapsed due to structural failure/weight.
- Local terrorist attack (explosion).
- Terrorists have attacked the bridge.

- Local terrorist attack (boat collision, train derailment).
- There was a crash that weakened the structured.
- Accident (non-terror) boat collision.
- Structural failure (corrosion and erosion).
- Bridge collapsed due to naturally occurring event like flooding or weather.
- The bridge was struck by heat lightning that caused it to collapse.
- An unknown person/group destroyed the bridge via explosion/other cause.
- Structural failure delayed maintenance.
- There were too many cars on the bridge and it could not support them all.
- Train derailment (collision).
- Something went wrong with the construction equipment/workers that caused the bridge to collapse.
- Structural failure/weight.
- It was old with a heavy load.
- Some sort of unknown explosion.
- It was an explosion by terrorists.

Step 2: Collect the cards and display the results. Consolidate the hypotheses to avoid duplication. (See below)

Step 3: Aggregate the hypotheses into affinity groups and label each group.

The notional hypotheses were then grouped in this manner:

Collision-Related
There was a massive collision that resulted in the bridge collapse.
Accident (non-terror) boat collision.
Train derailment (collision).
There was a crash that weakened the structured.

Weight-Related
Bridge collapsed due to structural failure/weight.
Structural failure/weight.
It was old with a heavy load.
There were too many cars on the bridge and it could not support them all.
Something went wrong with the construction equipment/workers that caused the bridge to collapse.

Natural Underlying Cause
Structural failure (corrosion and erosion).
Bridge collapsed due to naturally occurring event like flooding or weather.
The bridge was struck by heat lightning that caused it to collapse.

Design Flaw
Structural failure delayed maintenance.

Terrorism-Related
Some sort of unknown explosion.
Local terrorist attack (boat collision, train derailment).
An unknown person/group destroyed the bridge via explosion/other cause.
Local terrorist attack (explosion).
Terrorists have attacked the bridge.
It was an explosion by terrorists.

Step 4: Use problem restatement and consideration of the opposite to develop new ideas.

The group discussed each hypothesis and refined the list.

Step 5: Update the list of alternative hypotheses. (See list below)

Step 6: Clarify each hypothesis by asking, Who? What? When? Where? How? and Why?

The group stated the hypotheses as:

H1 A collision caused the bridge to collapse.
H2 Too much weight on the bridge caused it to collapse.
H3 A flaw in the design of the bridge caused it to collapse.
H4 Terrorists caused the bridge to collapse.
H5 A weather-related event caused the bridge to collapse.

Step 7: Select the most promising hypotheses for further exploration. See the list above.

Task: Use Paired Comparison to prioritize the hypotheses.

Steps

Step 1: Create a table with each of the hypotheses across the top and down the side. See Table 1 for a template. Use as many rows and columns as needed to accommodate the number of hypotheses to be prioritized.

Step 2: Looking at the cells below the diagonal row of dark blue cells, compare the item in the row with the one in the column. For each cell, decide which of the two items is of greater priority. The hypotheses may be compared by likelihood in this case, but ensure that the reason for the likelihood is noted, not simply taken for granted. For example, Hypothesis 2 is more likely than Hypothesis 3 because of X. Then, place an H2-✓ in the box comparing H2 and H3. See Table 1 for an example.

It is essential to determine the main criterion by which the hypotheses will be compared. In the notional table below, the criterion used for comparison was the safety and security of the site. The participants gave more weight to the hypothesis that affected immediate safety and security. In one case, there was a tie, so each of those hypotheses received .5 points.

Step 3: After comparing each set of hypotheses, count up all the checks for each hypothesis. For example, if there are three boxes with checks for H2, then that hypothesis receives a score of three points. Reorder the hypotheses according to this new prioritization as illustrated below.

Table 1: Paired Comparison Template

	H1 A collision caused the bridge to collapse.	**H2 Too much weight on the bridge caused it to collapse.**	**H3 A flaw in the design of the bridge caused it to collapse.**	**H4 Terrorists caused the bridge to collapse.**	**H5 A weather-related event caused the bridge to collapse.**
H1 A collision caused the bridge to collapse.					
H2 Too much weight on the bridge caused it to collapse.	H1-✓				
H3 A flaw in the design of the bridge caused it to collapse.	H1-✓	H2-✓ H3-✓			
H4 Terrorists caused the bridge to collapse.	H4-✓	H4-✓	H4-✓		
H5 A weather-related event caused the bridge to collapse.	H5-✓	H5-✓	H5-✓	H4-✓	

Scoring:
H4=4 Terrorists caused the bridge to collapse.
H5=3 A weather-related event caused the bridge to collapse.
H1=2 A collision caused the bridge to collapse.
H2=.5 Too much weight on the bridge caused it to collapse.
H3=.5 A flaw in the design of the bridge caused it to collapse.

Analytic Value Added

Which hypotheses should be explored further? Do any of the hypotheses highlight gaps that should be filled or assumptions that should be challenged?

In our notional solution, the newly prioritized list indicates that responders first must rule out any terrorist or weather-related event that may affect the response. Furthermore, given the construction on the bridge at the time of the collapse, responders must consider whether or not a weight or design issue may create unsafe conditions for responders. The process suggests that even if the cause of the problem was a design flaw or a collision, it is first necessary to rule out these other possible causes to ensure safety and security of the disaster site.

Prioritization may be used in this manner for planning activities as well. The most important aspects are the identification of the full range of issues to be prioritized and the criteria by which they will be ranked. When multiple criteria are present, it may be necessary to conduct multiple paired comparisons to consider the ways in which the various decision criteria may affect the ranking. This process helps ensure that all the permutations are fully explicated and discussed.

Exercise 3: Understanding Secondary Effects Using Starbursting

Anticipating secondary effects is particularly difficult, especially in crisis situations when time is of the essence. Starbursting can quickly stimulate useful thinking because it uses prompts to generate a great number of ideas in a short amount of time. This process allows one to consider the issue at hand from many different perspectives, thereby increasing the chances that one may uncover a heretofore unconsidered question or new idea that will yield new insights.

Task: Starburst the potential secondary effects of the I-35W Bridge collapse.

Steps

Step 1: Use the template in Figure 1.3 or draw a six-pointed star and write one of the following words at each point of the star: Who? What? When? Where? How? Why?

Step 2: Start the brainstorming session, using one of the words at a time to generate questions about the topic. Do not try to answer the questions as they are identified; just focus on generating as many questions as possible about the possible secondary effects of the bridge collapse.

For the notional solution below, participants asked, "How could 'where' the bridge collapsed create a secondary effect?"

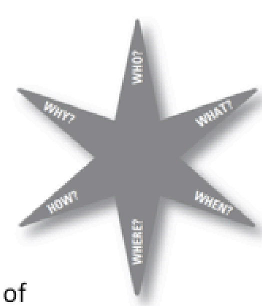
Step 3: After generating questions that start with each of the six words, the group should either prioritize the issues to be answered or sort the questions into logical categories.

Figure 3: Startbursting Secondary Effects of the I-35W Bridge Collapse

- New security/need to close other bridges.
- Redesign/re-evaluate bridges
- Certification/Education
- Political fall-out.

- Economic disruption
- Loss of life
- Possible follow-on attack?
- High economic costs

- HAZMAT/chemical issues
- Powerlines
- River Traffic stopped
- Secondary Collapse of non-trussed section



- Secondary Explosion?
- Settling of bridge debris
- Terrorist-related targeting of responders
- Chemicals
- Is natural event over?

- Traffic (rerouting)
- Nightfall/Timing issues?
- Heat of Day?
- Water-level?

- Commercial impact.
- Traffic Flow/Congestion
- River/Shipping
- Rail line/Shipping
- Economic Losses

Analytic Value Added

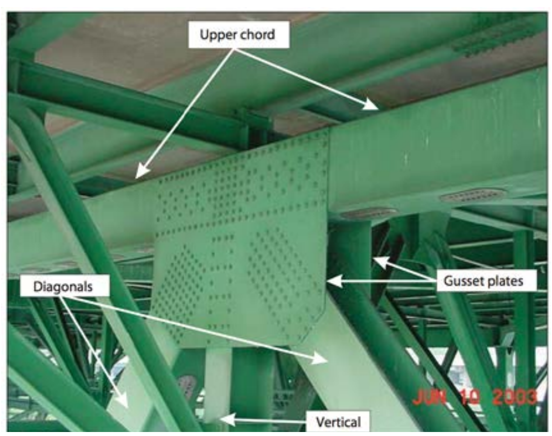
Do any of the questions point directly or indirectly to secondary effects? Does the timing, location, size, or apparent nature of the incident point to any areas for further consideration?

For the notional solution, participants found that they identified not only more immediate secondary effects such as the possibility of chemicals related to the rail cars or the possibility of a secondary collapse, but also latent tertiary effects that might not be felt for some time, such as the full affect on commercial activities. Issues surrounding safety and security figured prominently in the Starbursting process, and participants found that the process of using the points of the star to prompt additional thinking yielded a final list of potential effects that far exceeded their own initial lists.

Collapse: Case Conclusion

By all accounts, the emergency response to the I-35W Bridge collapse was rapid and well-coordinated.[2] The motion-activated camera captured a portion of the bridge collapse at 6:05 p.m., and a 911 call alerted Minnesota State Patrol dispatchers of the incident within the same minute. After verification via the Minnesota highway camera system, the first call from the joint Minneapolis fire and police dispatch went out at 6:07 p.m., and the dispatch followed up only a minute later with an interstate radio system distress call for all available emergency assistance providers to respond to the I-35W Bridge. Within five minutes, the first Minneapolis Police Department unit arrived on the scene, followed a minute later by the first of 19 engines from the Minneapolis Fire Department; Hennepin County Sherriff's office personnel arrived at 6:14 p.m., just nine minutes after the first distress call. The Hennepin County Medical Center disaster plan swung into action, alerting other local hospitals, calling in additional medical personnel, and dispatching all available ambulances to the scene, where first responders and over 100 local citizens had already begun pulling victims from the rubble. By 7:27 p.m., the Incident Commander and the Sherriff's Office switched from rescue to recovery mode.

As the Incident Commander arrived on the scene, he did not know the cause of the enormous 1,000-foot long bridge collapse, and had to assess the situation quickly. There were a number of hazards to be considered. In addition to the instability of the bridge itself, downed power lines in close proximity to water, and multiple vehicle fires, the bridge had fallen across a railway track carrying railcars with unidentified chemicals. The specter of possible terrorism also loomed large. Just the previous year, the Minneapolis Federal Bureau of Investigation (FBI) Office issued a Domestic Terrorism Threat Assessment and identified special interest, left- and right-wing groups, lone-wolf actors and international terrorists operating in the area.[3] The sudden collapse of the bridge raised questions about the possibility of a bomb that authorities could not immediately rule out.[4] Within 25 hours of the collapse, the area was designated a crime scene for that very reason.[5] The Investigation Chief directed a Special Operations Commander to determine if the disaster was a criminal or terrorist act or an accident using explosive ordnance teams from the Twin Cities area. The NTSB had to consider a range of possible hypotheses about the cause of the accident as well, and detailed these structural and environmental factors in its final report.



NTSB Report photo of the infamous I-35W gusset plates as of June 2003.

Ultimately, however, the NTSB investigation determined that the underlying cause of the collapse was not terrorism or criminal activity. Neither was negligence in inspection regimes or upkeep to blame. Instead, the NTSB found that the primary cause of the collapse was flaws in the 40-year-old design of the bridge itself in combination with other factors relating to the ongoing and previous construction on the bridge:

> The National Transportation Safety Board determines that the probable cause of the collapse of the I-35W bridge in Minneapolis, Minnesota, was the inadequate load capacity, due to a design error by Sverdrup & Parcel and Associates, Inc., of the gusset plates at the U10 nodes, which failed under a combination of (1) substantial increases in the weight of the bridge, which resulted from previous bridge modifications, and (2) the traffic and concentrated construction loads on the bridge on the day of the collapse. Contributing to the design error was the failure of Sverdrup & Parcel's quality control procedures to ensure that the appropriate main truss gusset plate calculations were performed for the I-35W bridge and the inadequate design review by Federal and State transportation officials. Contributing to the accident was the generally accepted practice among Federal and State transportation officials of giving inadequate attention to gusset plates during inspections for conditions of distortion, such as bowing, and of excluding gusset plates in load rating analyses.[6] (See photo above and Figure 5 below.)

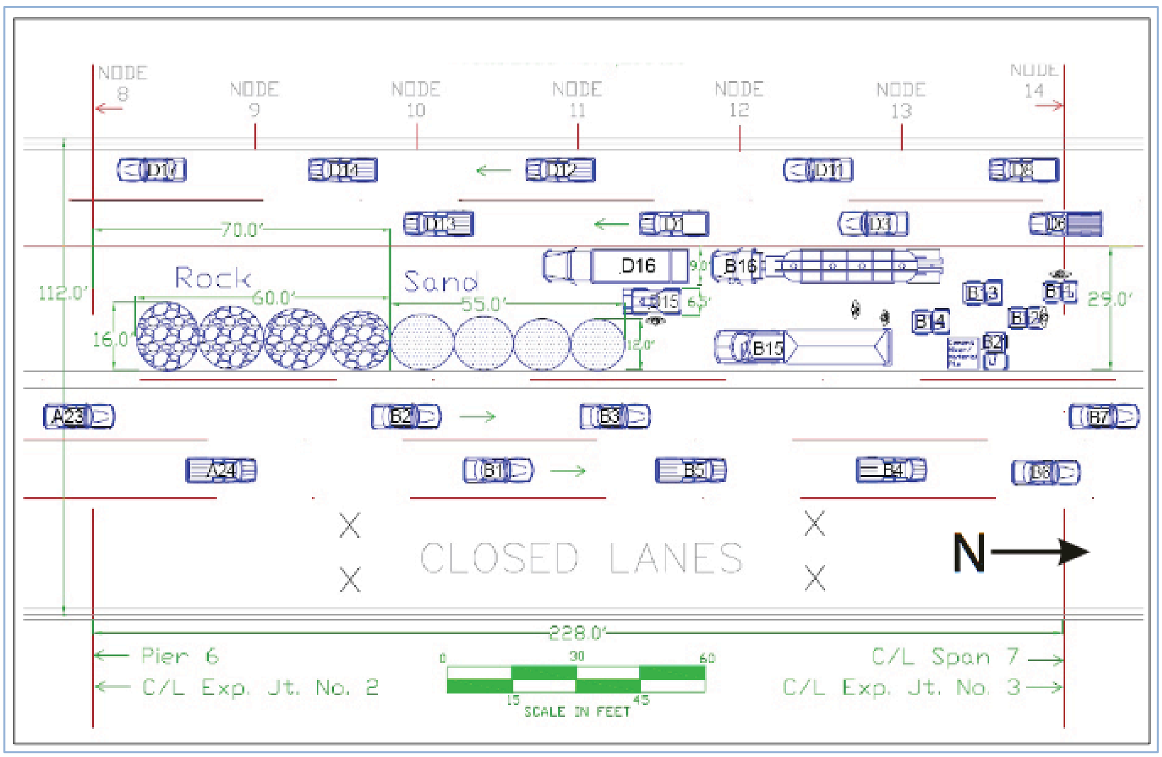


Figure 4: NTSB schematic of the I-35W Bridge Deck at the time of the collapse including lane closures and construction equipment and material staging.

The response and recovery efforts in the immediate aftermath of the collapse stand as exemplars of efficient and effective interagency cooperation. Within 13 months of the collapse, Minneapolis replaced the I-35W Bridge with the new St. Anthony Falls Bridge pictured below at a cost of $234,000,000. The new bridge has 10 lanes of traffic, wide shoulders, and an estimated 100-year life span. It opened to traffic in September 2008.

The remarkably short construction timeline did not offset the $400,000 a day in economic losses experienced in Minneapolis after the collapse, but the design has garnered many awards in the years since the bridge's construction.[7]

The St. Anthony Falls Bridge replaced the fallen I-35W Bridge in September 2008. Photo courtesy of the design-build firm Flatiron.

At the national level, however, numerous concerns remain about the state of bridge infrastructure. Despite the lessons of the tragedy, 12 percent of Minnesota's 13,131 bridges were still considered structurally deficit or functionally obsolete in 2010, and 26.7% of bridges nationwide fall into these categories.[8] Although bridges that are classified as structurally deficient does not mean they are in danger of collapsing, it does mean that they are substandard.[9] These deficiencies contribute to what one bridge engineer calls "a perfect storm regarding our bridges," including exorbitant construction costs, the dramatic increase in traffic, and the age of the bridges themselves.[10] With estimated funding needs for repairs far exceeding actual funding levels, the potential for additional collapses — whether through natural disaster, human errors, or attacks — is ever present.

[1] For more examples of cases that employ these types of structured analytic techniques, please see Sarah Miller Beebe and Randolph H. Pherson, *Cases in Intelligence Analysis: Structured Analytic Techniques in Action*, Washington, DC, CQ Press, 2012.

[2] NTSB, 127

[3] U.S. Fire Administration, *I-35W Bridge Collapse and Response, Minneapolis, MN*, USFA-TR-166/August 2007, http://www.usfa.dhs.gov/downloads/pdf/publications/tr_166.pdf, pp 17-18.

[4] *Ibid.*

[5] NTSB, 127.

[6] NTSB, xiv.

[7] I-35W St. Anthony Falls Website, Minnesota Department of Transportation, http://projects.dot.state.mn.us/35wbridge/index.html.

[8] "Status of the Nation's Highways, Bridges, and Transit: 2006 Conditions and Performance Report to Congress." Federal Highway Administration: 2006. http://www.fhwa.dot.gov/policy/2006cpr/es03h.htm.

[9] For more information on the bridge classification system, please see: the Federal Highway Administration website at http://www.fhwa.dot.gov/policy/2004cpr/chap3c.htm#body.

[10] Jeremy Herb, "150,000 U.S. bridges are still rated deficient," *Minneapolis Star Tribune*, July 21, 2010.