



Figure 1: The Pennsylvania Department of Transportation (PennDOT) is evaluating several alternatives for replacing the historic Cementon Bridge to understand the impact of risks and related mitigation actions.

Using SHRP2's Risk Management Approach to Assess Risk on Projects of All Complexities

Due in part to its proximity to historic properties, replacing the Cementon Bridge is a complex project with a high risk of cost overruns and schedule delays. To identify and proactively mitigate these risks, the Pennsylvania Department of Transportation (PennDOT) conducted a comprehensive in-house risk assessment using a product developed through the Federal Highway Administration's (FHWA's) Second Strategic Highway Research Program (SHRP2).

The Challenge: Calculating and Managing the Impact of Risks

PennDOT anticipates that construction of the new Cementon Bridge will begin in 2019, and design and construction combined will cost approximately \$20–23 million (base cost estimate). The current bridge is structurally deficient, functionally obsolete, and unable to safely and effectively accommodate current and future traffic needs. This project is not only critical to Pennsylvania's transportation infrastructure, but is also unusually complex, with many constraints that could threaten its on-time, on-budget completion (see Project Snapshot on page 2).

Although this project is large enough to justify a full probabilistic risk assessment, PennDOT chose an in-house risk management process that was both comprehensive and easy to apply so that once staff learned the process, they could use it on future projects of various sizes and types.



SHRP2 Solution: A Highly Flexible Risk Management Process and Template

Managing Risk in Rapid Renewal Projects was the ninth research project in the SHRP2 Renewal Focus Area and is also known as Renewal 09 (R09). The product uses an Excel-based template to guide teams through a risk management process to identify, evaluate, and mitigate risks (threats and opportunities). DOTs can adjust the template settings to fit their project's unique characteristics by defining the project's delivery method, base cost, and base schedule. The accompanying **R09 Guidebook** provides additional tools to assist with each step. During a two and half day workshop hosted by FHWA, PennDOT's team of project managers, in-house subject matter experts, and consultants applied the product's iterative process and R09 Excel-based template to the Cementon Bridge project to:

- Holistically identify potential risks
- Determine the likelihood of risk occurrence
- Calculate the associated schedule, cost, and disruption impacts
- Devise strategies to monitor and mitigate risks from planning to construction
- Assess the overall impact of mitigated and unmitigated risks on schedule, cost, and disruption
- Implement a risk management plan as part of their overall project delivery process

PennDOT applied the process to two alternatives they were considering, and will use the results to inform their final choice. The two alternatives, On-Line Accelerated Bridge Construction (ABC) and Downstream Alignment, are described at the top of page 3.

Figure 2: The Cementon Bridge project team discusses potential threats and opportunities while applying the R09 risk management process.

Project Snapshot: Cementon Bridge Replacement

- Four-span, 575-foot long bridge constructed in 1933
- Carries SR 0329 over the Lehigh River and serves as the primary link between Cementon and Northampton Borough
- Connects the Laurys Station and Northampton segments of the Delaware and Lehigh Trail
- Eligible for listing in the National Register of Historic Places (NRHP), and abuts several other NRHP properties including the Northampton Historic District, Lehigh Valley Railroad, Whitehall Cement Manufacturing Company, Colonel John Siegfried Tavern, and Siegfried Train Station
- Highly constrained location that abuts the Norfolk Southern Railroad and the Siegfried Cemetery
- Structure carries multiple utilities, including fiber optic data lines, a water main, and aerial high voltage power lines
- Determined to be structurally deficient and functionally obsolete
- Unable to safely accommodate current and future traffic needs due to its deteriorated structural condition, posted weight limit, and geometric constraints



Figure 3: The historic Siegfried Cemetery abuts the Cementon Bridge Project. One risk of the Downstream replacement alternative would be the impact of the project alignment on potential unmarked grave sites.

R09 Risk Management Process

The 7-step R09 risk management process, described below and in **Figure 4**, helped PennDOT identify the most severe risks (threats and opportunities) and most beneficial mitigations to reduce overall costs and time. Because the process is so efficient, PennDOT completed the full risk assessment on each of the two alternatives described on page 3 to help determine the best approach.

1 Project Scope/Strategy/Conditions

PennDOT kicked off the risk management process by familiarizing the team with the project scope, strategy, and conditions. The project manager discussed the two bridge replacement alternatives, funding, technical conditions affecting the project, political and external conditions, and performance (cost and schedule) estimates.

2 Structuring

Next, the team defined the base project scenario for duration/schedule and cost, without accounting for float, contingency, or inflation. The base performance data is entered into the R09 template and used as a comparison against the project unmitigated and mitigated performance, which includes the threats and opportunities that are identified, assessed, and managed. **Table 1** includes the base project performance results for each alternative.



Figure 4: R09 Risk Management Process

Table 1: Base Project Summary

	Alternative A: On-Line Accelerated Bridge Construction (ABC)	Alternative B: Downstream Alignment
Base Cost in Year of Expenditures (YOE)	\$22.54 M	\$20.41 M
Construction Notice to Proceed	6/30/2019	12/29/2019
Construction Completion Date	3/29/2022	9/12/2022

Alternative A: On-Line Accelerated Bridge Construction (ABC)

- Involves constructing a new bridge superstructure, adjacent to the existing structure, and new piers and abutments under the existing structure, while traffic is maintained on the existing structure
- The existing superstructure will be removed and new pier and abutment seats will be built, and the new superstructure will “slide in” during a short-term bridge closure and traffic/pedestrian detour
- Benefits: Maintains the existing alignment, which minimizes impacts to the ROW, environment, and abutting railroad
- Disadvantages: Higher cost, high uncertainty in contractor bids and capability, utilities will need to be moved twice, and traffic will be detoured during the slide in

Alternative B: Downstream Alignment

- Involves constructing a new bridge downstream while traffic is maintained on the existing bridge
- Roadway tie-ins will be constructed to connect SR 0329 to the new bridge
- Benefits: Minimizes impact to utilities and maintains traffic on the bridge throughout construction
- Disadvantages: New alignment would include a ROW acquisition with residential displacements, involvement of the Pennsylvania Public Utility Commission (PUC), and relocation of the railroad crossing

“ The R09 workshop identified a lot of risks with the ABC alternative that the Downstream alternative may alleviate. R09 may lead PennDOT to a different decision about these alternatives than what was previously anticipated. ”
 – Brian Shunk, PennDOT

3 Risk Identification

The project team then identified the threats and opportunities that could affect the project’s base performance. Threats can degrade project performance, while opportunities can enhance project performance. PennDOT identified 44 threats and 3 opportunities for Alternative A, and 34 threats and 7 opportunities for Alternative B. Threats and opportunities were documented in the risk register developed in the R09 template and categorized by when they are most likely to occur (e.g., construction, preliminary design/environmental process, procurement, etc.). This step captures a comprehensive, non-overlapping list of threats and opportunities, rather than screening out issues prematurely.

4 Risk Assessment

In this step, PennDOT assessed the probability of occurrence, mean cost impact and mean schedule impact of each threat and opportunity. They can be assessed qualitatively using pre-defined ratings that are linked to a range of values, or quantitatively, using direct mean values. Both assessment methods are applied for probability of occurrence (percentage of occurrence), mean cost change (in dollars), and mean duration change (in months). For example, PennDOT noted that for Alternative A, the Department of Environmental Protection may not want to issue a permit for the causeway due to its size and the impact to the migration pattern of a species of fish called “shad” which inhabit the Lehigh River. PennDOT assessed this risk as having a very high probability of occurrence (85% likelihood). Additionally, this risk was assessed as having a high mean impact (8 months) and a low mean cost impact (\$370,000). Once all of the threats and opportunities were assessed, the R09 template calculated and documented their mean severity to help the project team address the most severe threats and beneficial opportunities (see **Table 2**).

Alternative A (On-Line ABC)	Alternative B (Downstream)
1) Preferred alternative proves unfeasible due to constructability concerns	1) Design supplement for Preliminary Engineering (PE) for Downstream alternative
2) High contractor bid price due to bridge slide technology based on project complexity and PennDOT’s minimal experience	2) Preliminary Engineering will require additional time delaying the schedule
3) Pennsylvania Department of Environmental Protection (DEP) does not issue permit for causeway	3) Impact to grave sites during construction due to unknown extent of cemetery boundaries

5 Risk Analysis

Using the outputs from steps 2 to 4, PennDOT combined the base performance data and risk assessments to calculate the impact of each threat and opportunity on project performance measures (i.e., schedule, uninflated and inflated cost) if they remained unmitigated (see **Table 3**). Understanding the impact of unmitigated threats will help PennDOT make informed decisions from planning to construction.

Table 3: Comparison of Base Project Performance and Unmitigated Project Performance				
		Base	Unmitigated	Difference
Alternative A (On-Line ABC)	Base Cost (YOE)	\$22.54 M	\$29.07 M	\$6.53 M
	Construction Notice to Proceed	6/30/2019	3/17/2021	21 months
	Construction Completion Date	3/29/2022	2/6/2024	23 months
Alternative B (Downstream)	Base Cost (YOE)	\$20.41 M	\$24.21 M	\$3.80 M
	Construction Notice to Proceed	12/29/2019	2/26/2021	14 months
	Construction Completion Date	9/12/2022	12/18/2023	15 months

6 Risk Management Planning

PennDOT then planned potential actions to mitigate the top 15 threats and the 2 highest severity opportunities from the unmitigated risk register for Alternative A, and the top 7 threats for Alternative B (see **Table 4** for examples). For example, the team recommended performing a constructability review, which would include external experts, to mitigate potential feasibility concerns for Alternative A.

Table 4: Example of Mitigation Actions from PennDOT's Strategy Register		
Risk Description	Mitigation Action	Applicable Design Alternative
Preferred alternative proves unfeasible due to constructability concerns	Perform constructability review including external experts and implement results	Alternative A
High contractor bid price due to bridge slide technology based on project complexity and PennDOT's minimal experience	Perform cost review including external experts to review cost estimates and implement suggested changes. Extend advertisement period and improve information sharing during advertisement process (e.g., publish unofficial plans and specs for review or consider a Value Engineering/Accelerated Construction Technology Transfer session)	Alternative A
Impact to grave sites during construction due to unknown extent of cemetery boundaries	Conduct additional subsurface investigation and testing during design and develop relocation plan if grave sites encountered	Alternative B

“ Even though it was early in the project, bringing together PennDOT staff and consultants helped us identify risks that we may not have otherwise. Since we are still in the preliminary design phase, there is time to coordinate among agencies to best address risks. That's the real benefit to the whole R09 product—it's a great way to identify risks ahead of time and know what you're up against. ”

– Laura Montgomery, McCormick Taylor, Consultant Project Manager

Using the R09 template, the project team assessed the impact of the mitigation actions (using mean values or pre-defined ratings) on project cost and schedule. This results in a mitigated risk register which documents the resulting project performance impacts if the selected mitigations are applied (see **Table 5**).

Table 5: Top Risks from PennDOT's Mitigated Risk Register (ranked by mean severity)	
Alternative A (On-Line ABC)	Alternative B (Downstream)
1) High contractor bid price due to bridge slide technology based on project complexity and PennDOT's minimal experience	1) Design supplement for Preliminary Engineering (PE) for Downstream alternative
2) Preferred alternative proves unfeasible due to constructability concerns	2) Preliminary Engineering will require additional time delaying the schedule
3) Public may find the 14-day closure for the bridge replacement unacceptable	3) Alternative proves unreasonable under the National Environmental Policy Act (NEPA) due to impacts on cemetery

Next, PennDOT used their mitigated risk register to conduct a final performance analysis. **Table 6** compares the project cost and construction duration between the base, unmitigated, and mitigated project performance for each alternative. The mitigated performance includes all residual risk (the portion of the threats and opportunities that remains after mitigation).

Table 6: Comparison of Base Project Performance, Unmitigated Performance, and Mitigated Performance					
		Base	Unmitigated	Mitigated	Mitigation Savings
Alternative A (On-Line ABC)	Cost (YOE)	\$22.54 M	\$29.07 M	\$25.50 M	\$3.57M
	Construction Notice to Proceed	6/30/2019	3/17/2021	4/20/2020	11 months
	Construction Completion Date	3/29/2022	2/6/2024	2/8/2023	12 months
Alternative B (Downstream)	Cost (YOE)	\$20.41 M	\$24.21 M	\$24.80 M	-\$590,000 (additional costs)
	Construction Notice to Proceed	12/29/2019	2/26/2021	10/18/2021	Delayed 7.8 months
	Construction Completion Date	9/12/2022	12/18/2023	7/18/2024	Delayed 7.1 months

Note that for Alternative B, the mitigated performance is more costly and delays the schedule beyond the unmitigated performance. In this case, PennDOT may choose to forego mitigations if the risks themselves are less costly than the mitigations.

As a result of this exercise, PennDOT had a much better understanding of the risks associated with both alternatives and planned a follow up meeting to discuss the project in further detail and come to a conclusion on a recommended alternative.

7 Risk Management Implementation

To finalize the risk management plan, PennDOT identified who within the agency would be responsible for implementing each risk mitigation action to ensure risks continued to be monitored throughout the project lifecycle. The responsible person is the key individual responsible to facilitate and manage implementation of the action selected.

Implementation Benefits

Applying the R09 risk management process has already helped PennDOT to:

- Effectively evaluate two alternatives and their associated risks
- Create a risk management plan to mitigate and monitor risks
- Develop a clearer understanding and better define the project's scope, strategies, and conditions earlier in the planning stages and prior to construction
- Use the risk assessment data to explore proposed project strategies, document potential mitigations, and evaluate their benefit/cost ratio

PennDOT will continue to use R09 to re-evaluate risks based on changing information leading up to the Cementon Bridge construction phase, scheduled to begin in 2019.



Figure 5: The Cementon Bridge carries SR 0329 over the Lehigh River in eastern Pennsylvania.



Save Lives



Save Money



Save Time

Resources to Help You Use Managing Risk in Rapid Renewal Projects

The product's **guidebook** is available on the Transportation Research Board website:

<http://www.trb.org/Main/Blurbs/168369.aspx>.

To learn more and to download the **Excel-based template**, visit <http://www.fhwa.dot.gov/GoShrp2/Solutions/Renewal/R09> or contact:

- Carlos F. Figueroa, P.E. (FHWA Office of Infrastructure) at carlos.figueroa@dot.gov
- Keith Platte, P.E. (AASHTO) at kplatte@aaashto.org
- Brian Shunk, P.E., Risk Program Manager (PennDOT) at bshunk@pa.gov



Implementing SHRP2

The second Strategic Highway Research Program (SHRP2) is a national partnership of the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the Transportation Research Board. Together, these partners conducted research and are deploying resulting products to help the transportation community enhance productivity, boost efficiency, increase safety, and improve the reliability of the Nation's highway system.

The Pennsylvania Department of Transportation (PennDOT) applied Managing Risk in Rapid Renewal Projects on the Cementon Bridge replacement project as part of the **SHRP2 Implementation Assistance Program**.