The City of Seattle is in the middle of completely rebuilding its central waterfront including a seawall and the major transportation routes that dominate the waterfront. A recent value engineering study focused on the seawall replacement.

At one point, the seawall was to be part of a tunnel designed to replace the existing viaduct that handles a large amount of traffic into and through downtown Seattle. Now that the viaduct is being demolished and replaced by a tunnel to bypass the waterfront, the seawall is left as a standalone project. This presentation focuses on the role of Risk in the VE process; but it also presents and reenacts parts of the dramatic swashbuckling story of Seattle’s waterfront that continues even today with this bold seawall replacement project.

Background

The construction of Seattle’s waterfront is a bold and colorful story that goes back to the turn-of-the-century when much of the waterfront was created by sluicing the nearby hills into the bay; and then constructing a massive timber structure (along with sawdust, rocks, and other available debris) to hold up the waterfront highway and support the city behind.

Those daring engineers and civic leaders gave no thought of what the city would face a century later when this corridor was to become the heart of the city and need to be entirely replaced - while allowing the entire city’s commercial, recreational, and daily functions to continue uninterrupted.
The new seawall will be constructed of concrete and steel with the functional purpose of resisting erosion from the sea, as do most seawalls. But even more impacting in this case was the function to resist seismic forces that, when liquefied, could wash most of the city into the bay.

Figure 2 – Original project – Combined Tunnel and Seawall

Figure 3 – Current Seawall Project
RISK – CRAVE

The week prior to the VE study, the study team participated in a brief risk analysis. The risk analysis and VE for the seawall project was called a “CRAVE” or “Combined Risk Assessment VE” process. That term had been coined by Washington State DOT (WSDOT) to define a process that uses the same team to perform both a risk assessment and VE at the same time. The intent of the CRAVE process is to take advantage of the value methodology while focusing on risk identification and mitigation. It is intended to be more efficient than separate risk and VE workshops in that the same team is assigned for both the risk and VE perspective; therefore, saving much time in project understanding, estimating, and reporting phases than if two separate teams had to get to know the project. Seattle is not WSDOT, so they configured this study differently than the WSDOT approach.

“CRA” is a term used by WSDOT to describe a broad range of risk-based assessments being conducted within WSDOT. It is also a term used to describe a workshop process similar to, but less intense than the CEVP (Cost Estimate Validation Process), also used for more complex projects. Specifically, the process starts with a base estimate and adds to it the set of risk events that will cause the project to deter from that base estimate. The intent is to use the VE work plan including the Information, Speculative, Development, and Presentation phases to not only identify risk events, but to find alternative mitigation solutions.
Figure 4 - CRA Concept

The seawall “CRAVE” process indeed used the same team for each phase, but used different team leaders for the back-to-back processes. The first risk process was led by a competent risk specialist who kept the team focused on the project schedule (identified as the largest risk) and the resultant cost estimate Monte Carlo implications.

<table>
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<th>Risk ID</th>
<th>Category</th>
<th>Risk Name</th>
<th>Likelihood</th>
<th>Direct Cost Impact ($M)</th>
<th>Schedule Impact (cal. Mo)</th>
<th>Flowchart Activity Allocation</th>
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<td>Design</td>
<td>Light Penetrating Surface (LPS) Design</td>
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<td>1: +2</td>
<td>Minor</td>
<td></td>
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<td></td>
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<td></td>
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<td>3: 30%</td>
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<tr>
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<td>-50% of base temporary shoring wall cost (considering base cost uncertainty)</td>
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<td>90%</td>
<td>-0.25</td>
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</tr>
</tbody>
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Figure 5 – Risk Assessment Register

VE process – Functional Analysis

The VE component followed with a separate leader who focused on project functions and alternative solutions across the entire project – even beyond specific schedule/cost risk areas that had been identified during the previous week. This functional analysis quickly identified primary higher-order functions that are based on a risk well beyond project schedule and cost. These became the project’s highest order functions: Reduce Damage and Reduce Loss of Life in the event of a major seismic event. The design solution at hand (and the majority of the cost for this project) to mitigate this risk was to construct a massive concrete matt or anchor 40-feet deep and 40- to 60-feet wide for
the entire length of the waterfront, intended to dampen liquefaction and the movement of earth and sea that would result with a major 2,000- to 2,500-year event.

The VE team asked the question about that risk criteria (1,000-, 2,000-, or 2,500-year event?) and offered structural alternatives for the 1,000-year criteria that would result in a structure far smaller, less impacting, and less costly than a 2,000-year event. Since this is not a building to be permitted under the UBC, the 2,500-year event risk criteria was not applicable. Similarly, the AASHTO 2,000-year criteria for highway construction was negotiable since this stretch of highway would no longer be the high-traffic viaduct replacement as originally envisioned. (That, of course, is a now Seattle’s next big risk story as Seattle constructs the viaduct replacement tunnel realigned away from the waterfront.) Ultimately, the design teams were allowed to use the 1,000-year criteria and to downsize the primary seismic block.

This study then looked at the second primary function for the project – namely the need to resist the water and wave erosion of Puget Sound as it interfaces with the landside of the city. This is the primary function of most seawalls. The team offered several alternative precast configurations for the seawall panels and their supporting structures.

![Functional Analysis Diagram – Primary and Higher Order Functions](image-url)
It is unlikely that any typical project risk assessment would look at primary project functional criteria – even if that project function is clearly in itself a risk mitigation function. The separate risk study was no different. That focus was not part of the “CRA” portion of the study, but came in the separated VE portion.

To give credit to the basic risk assessment (CRA), that portion did identify schedule as one of the most critical “project” risks. This was corroborated during the criteria weighting exercise conducted at the beginning of the VE study. The risk phase had identified a few of those elements – namely the decision on best fish habitat enhancements (e.g. glass sidewalks for light penetration) and some concrete constructability issues – also related to environmental protection; and it did quantify those in terms of schedule and cost impact.

Figure 7 – Fish habitat sidewalk panels
Project Risk

The real breakthrough in this study came when the team decided to focus on a component that had been clearly identified as beyond the scope of the study. The Seattle waterfront not only supports a major city/state thoroughfare; it is also the conduit for a vast network of electrical, communications, water, and sanitary systems that service the waterfront piers and facilities, a large network of high-capacity utility mains that service the industrial and port areas south of the downtown waterfront. Each of the departments responsible for those systems was aware that the seawall project would interrupt and relocate most of their systems; and each of these departments was starting to approach the task of scoping and designing the replacement systems. Once again, the seawall design team was encouraged to stay on task, get the seawall designed and built within the next few years in time to support and coordinate with the demolition of the viaduct and tunnel construction; and let the utility departments focus on the utilities.
It was fairly obvious, however, to most of the design team and the study team members that the seawall project would in fact destroy most of those utility systems and that a major reconstruction of those systems was not feasible within the seawall project schedule. It was possible that the cost of reconstructing the utilities could exceed the cost of the seawall.

The study team kept on their risk hats and decided that it was important to look for ways to reduce utility impacts. They did so by maintaining focus on the seawall construction and seeking structured methodologies that could allow much of the utility system to remain intact or to be reconstructed outside of the seawall critical path.

The solution offered by this team was to use pinpoint jet grouting that can utilize insertion points carefully inserted between and around the utilities, forming a jet grout block below the utilities. This dramatically reduced the impact of utility reconfiguration.
on the project and allowed the city to do much of the work while maintaining access to waterfront businesses.

Figure 10 – Jet Grouting

**Impact Risks - Business**

As construction is well on its way, and the due date for reopening most waterfront businesses approaches, we can now enjoy some hindsight review of the risk and VE projections that were made several years ago. The city did in fact maintain access to most of the waterfront businesses with the exception of several large piers that were shut down during the first year of construction. A good part of the project cost (in excess of $20 million) was budgeted to remediate loss of business at these sites. Some of the businesses took advantage of this period and the impact funds, and completed major upgrades to their facilities. Others relocated temporarily, and others are riding out the construction during the offseason, counting on the City’s commitment to reopen for this
summer’s peak tourist season. The grouting process did not quite keep up with the hoped for schedule of completion in front of these piers; but the city has shut down construction and is providing temporary walkways during summertime tourism.

**Construction Risk – Dewatering**

Even though the deep ground grouting reduced the amount and depth of excavation; there was still a great deal of deep work, well below tide level and well into the groundwater on the east. Conventional damming and pumping would have required pumping groundwater and risk treating it as contaminated material. To reduce that risk, the project has employed ground freezing along the entire length of the project. Pipes with a super-cold saline solution are laid in and around the construction site, powered by industrial refrigeration units. The ground is frozen from pipe to pipe, forming a barrier structurally capable of blocking groundwater intrusion. They are connected to industrial refrigeration units the size of pickup trucks located along the east side of the site.

*Figure 11 – Ground freezing*
Construction Impact on existing structures

Potential structural impacts on the existing structures (mostly piers) have been monitored throughout construction. Most of the initial concern was for impact damage to the piers as they were cut off from their bridging structures. In July there was found to be small movement of the landward pier structures and some concern for the extent of that movement and potential damage on the piers. This was attributed to some of the deep ground grouting pressure. It has since subsided after curing, and has not extended beyond that initial movement.

Figure 12 – We are still open

Summary

I suspect that future generations will look back to the massive construction now underway and call those engineers swashbucklers. They will probably not care that we did it in only a few summers and that it was those risk and VE pioneers that helped make it happen so smoothly. I’m hoping then that we are still waiting for the 1,000-year event.
Risky Business

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