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**Group 4**

**07/02/2024**

**BUSI 785**

**Tacoma Narrows Bridge (1940) Case Analysis**

**I. Background**

The Tacoma Narrows Bridge was built and opened to the public on July 1, 1940 as the first suspension bridge to span over the Tacoma Narrows from Puget Sound to the Kitsap Peninsula in Washington state. The bridge cost $6.4 million and took 19 months to build (Tacoma Narrows Bridge History - Tale of Three Bridge - 1940, n.d.). As World War II was still ongoing, the military became interested in using more fields in the area as bases. As part of this strategy, the idea to build the Tacoma Narrows Bridge was first developed to connect the McChord Air Field south of Tacoma and the Puget Sound Navy Shipyard in Bremerton (Tacoma Narrows Bridge History - Community Connections - Creating the Narrows, n.d.).

Clark Eldridge was the original designer and engineer for the new suspension bridge, and he took on a conservative approach to the development of his plan developed a plan, however; its cost was well above what the state was willing to pay, so they brought on a prestigious civil engineer, Leon Moisseiff, to support the revised design of the bridge that would cost less. Additionally, Moisseiff took his untraditional approach to bridge designing a step further by deciding to not corporate trusses that would allow wind to pass through the structure, so instead, the wind had to move above and below the bridge creating a flow separation (Harish & Harish, 2023). Leon Moisseiff, who had also previously designed other suspension bridges such as the Golden Gate Bridge, proposed using much more shallow and narrow stiffening elements for the structure, which was unheard of at the time for a long-span suspension bridge (Tacoma Narrows Bridges, n.d.).

The Tacoma Narrows Bridge quickly earned its nickname as “Galloping Gertie,” in 1940 after the initial completion of the construction had been finalized because the bridge was oscillating to a point that it made the bridge look like it was galloping or (Tacoma Narrows Bridge History - Tale of Three Bridge - 1940, n.d.). As engineers were becoming increasingly concerned about the intense swaying, otherwise known as aeroelastic fluttering (Harish & Harish, 2023), of the bridge, especially in high winds.

In May, 1940, as the bridge was nearing its original opening day that coming July, it quickly became evident that the bridge was moving in the wind more than it should. Engineers then installed four hydraulic jacks to help mitigate the swaying, acting as shock absorbers, but the small remedy did not help much to offset the oscillating bridge (Tacoma Narrows Bridge History - Community Connections - Creating the Narrows, n.d.). The Toll Bridge Authority then brought on an engineering Professor from the University of Washington, F. Bert Farquharson, to help solve the issue of the Galloping Gertie. With a group of students, the professor carried out wind tunnel studies, which cost $14,500, over the course of four months. As Farquharson’s studies continued, a series of temporary solutions were being tested on the bridge itself through tie-down cables, placing diagonal wires between the cables and the main deck to reduce the oscillations. Similar to the initial attempt in May 1940, these temporary solutions were ineffective (Tacoma Narrows Bridge History - Community Connections - Creating the Narrows, n.d.).

Once the studies were finally completed on November 2, Professor Farquharson and his students presented their findings and proposed solutions to the State Toll Bridge Authority. On November 6, 1940, the professor and Eldridge sat down to create the plans to implement the proposed remedies by adding curved steel to the structure to deflect wind but unfortunately, it was too late. The next day, on November 7, 1940, the bridge ultimately collapsed during a windstorm (Tacoma Narrows Bridges, n.d.).

**II. Risk Analysis**

There were multiple risks that contributed to the collapse of the bridge (Exhibit 1). The two main risks were vulnerabilities related to suspension span design & vulnerabilities related to vertical oscillation. Additional risks were structural failure due to twisting motions, limited expert availability for critical studies, insufficient wind mitigation through girders, negative public perception due to bridge movements, and financial loss from structural damages.

The first risk is the risk of vulnerabilities related to suspension span design. There were two response plans to address this risk. The first response was to mitigate the risk by ensuring the design was approved by a respected engineer. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The second response was to mitigate the risk by contacting the designer to verify the issues with small waves in previous suspension span projects. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The trigger in place that would initiate the contingency plans was to review the bridge design. There were two contingency plans that were identified if triggering criteria were met. The first contingency plan was to task federal and state experts to review and approve the plans. The second contingency plan was to contract with Prof. Farquharson at the University of Washington for wind tunnel studies and remedies.

The second risk is the risk of vulnerabilities related to vertical oscillation. There were three response plans to address this risk. The first response was to mitigate the risk by installing four hydraulic jacks at towers as shock absorbers. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The second response was to mitigate the risk by placing temporary tie-down cables on the bridge's side spans. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The third response was to mitigate the risk by installing wind deflectors to reduce oscillations. The trigger in place that would initiate the contingency plans was to monitor the vertical oscillations and wind speed. If no improvement, continue with the contingency plan. There were two contingency plans that were identified if triggering criteria were met. The first contingency plan was to begin immediate repairs. The second contingency plan was to contract with Prof. Farquharson for wind tunnel studies and remedies.

The next risk is the risk of structural failure due to twisting motions. The response plan to address this risk was to mitigate the risk by contracting with Prof. Farquharson for wind tunnel studies and remedies. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The trigger in place that would initiate the contingency plan was to monitor for twisting motion and act on contingency if observed. The contingency plans that were identified if triggering criteria were met were to close the bridge and conduct studies to determine failure causes.

The next risk is the risk of limited expert availability for critical studies. The response plan to this risk was to accept the risk as evidenced by no action being taken to address the limited availability of the professor. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The trigger in place that would initiate the contingency plans was if Prof. Farquharson could not complete the studies due to other priorities. The contingency plan identified if the triggering criteria were met was to delay the wind tunnel studies and remediations until the professor is available.

The next risk is the risk of insufficient wind mitigation through girders. The response plan to address this risk was to mitigate the risk by covering the girders with curved steel to deflect wind. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The trigger in place that would initiate the contingency plan was to monitor the girders; if there was no improvement, continue with contingency. The contingency plans that were identified if triggering criteria were met were to cut holes in solid girders to allow wind passage.

The next risk is the risk of negative public perception due to bridge movements. The response plan to address this risk was to mitigate the risk by communicating that the 'bounce' was normal and under control. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The trigger in place that would initiate the contingency plans was whether the public concern escalates despite reassurances. The contingency plans that were identified if triggering criteria were met were to enhance safety measures and communicate improvements to the public.

The last risk is financial loss from structural damages. The response plan to address this risk was to transfer the risk by securing insurance policies for the bridge. (Tacoma Narrows Bridge History - Community Connections - Collapse, n.d.) The trigger in place that would initiate the contingency plan was to assess if the bridge was damaged. The contingency plans that were identified if triggering criteria were met were to file insurance claims if damages occurred.

**III. Project Management Analysis**

**1. Project Planning and Design**

The project didn't initially start out with a high appetite for risk, they actually called on more conservative engineers in the mid-nineteen twenties but realized they did not have the funding to be able to go through with the more conservative drawings. After realizing this, their future consultations with other engineers pushed for a drawing that stayed under budget at the expense of quality control and a longer timeline which is where I believe the project got off to the wrong start.

In the 1930’s, an engineer presented the idea of building a bridge with a design that went against many engineering theories at a fraction of the cost. This would be the first bridge to be built with girders of carbon steel anchored in concrete blocks rather than open lattice beams. It would also be the first to employ plate girders to support the roadbed. This should have brought about skepticism, but it didn't. The heavy political push to conform to a tight financial constraint contributed to the reason why decision makers looked over the risks involved with taking on a project where the design did not adequately account for aerodynamic forces.

**2. Execution and Monitoring**

The execution of the bridge itself went well overall and the construction quality was done properly, following the exact specifications of the drawings. The real problem during the monitoring and execution of the bridge were the direct actions that were not taken in order to fix things when it was clear that the bridge was not operating the way that it should be. Immediate actions needed to be taken when they saw the vertical oscillations that they did not take which caused it to collapse much sooner. I believe that something could have been done to save the bridge or at least cut the amount of costs in damages had immediate action taken place to resurrect the situation.

**IV. Lessons Learned**

While the disaster itself has been widely studied, the project management aspects leading up to the failure provide critical insights for future projects. This section focuses on four key lessons learned from the project management perspective: the importance of risk management, adequate funding and resource allocation, stakeholder management and communication, and continuous monitoring and testing.

**Importance of Risk Management**

The bridge's design failed to account for aerodynamic forces, a critical oversight given its susceptibility to wind (Tacoma Narrows Bridge History - Bridge - Lessons From Failure, n.d.). Effective risk management involves identifying potential risks and developing mitigation strategies. The engineering community underestimated wind-related risks, leading to the bridge's collapse(Tacoma Narrows Bridge History - Bridge - Lessons From Failure, n.d.). This highlights the need to incorporate emerging scientific knowledge and conduct thorough risk assessments during planning and design phases. Project managers should regularly update risk assessments with the latest research and implement design redundancies to mitigate unforeseen aerodynamic effects.

**Adequate Funding and Resource Allocation**

Funding constraints significantly impacted the Tacoma Narrows Bridge project. The original design by Clark Eldridge, estimated at $11,000,000, was rejected by the Public Works Administration (PWA) for being too costly (PLS, 2022). Instead, they approved a cheaper design by Leon Moisseiff, reducing the budget to $7,000,000 (PLS, 2022). This decision led to a lighter, more flexible structure by eliminating stiffening trusses to cut costs, compromising the bridge's integrity. Prioritizing safety over cost is essential. Adequate funding and resource allocation are critical for meeting design and construction standards. Project managers should ensure a realistic budget that prioritizes safety and quality, and secure contingency funds for unforeseen costs without compromising design integrity.

**Stakeholder Management and Communication**

Effective stakeholder management and communication are vital for project success. In the case of the Tacoma Narrows Bridge, there were significant conflicts between engineers and financiers (PLS, 2022). Engineers' concerns about the design's vulnerability were overridden by financial constraints imposed by stakeholders (PLS, 2022). This misalignment and lack of effective communication likely led to critical design flaws being overlooked. Project managers must ensure all stakeholder voices are heard and maintain clear communication to align goals with technical requirements and ensure collaborative decision-making. They should facilitate regular, transparent communication channels among stakeholders and establish a conflict resolution mechanism to integrate technical and financial concerns effectively.

**Continuous Monitoring and Testing**

Continuous monitoring and testing during the construction phase are essential for identifying and addressing potential issues early. The Tacoma Narrows Bridge exhibited significant vertical movements even before its completion, indicating underlying structural problems that were not adequately addressed (PLS, 2022). Wind tunnel tests and structural health monitoring, such as those conducted by Professor Farquharson, were used to understand the bridge's behavior under various conditions, but the measures were insufficient to prevent the collapse (PLS, 2022). Regular and rigorous testing could have highlighted these vulnerabilities sooner, allowing for timely corrective measures. Continuous monitoring ensures early detection of performance deviations, enabling proactive management. Project managers should implement structural health monitoring, conduct regular wind tunnel tests, and develop a response plan with immediate mitigation measures, such as additional bracing or load restrictions.

Exhibit 1. **Risk Response Matrix**

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| **Description** | **Response Plan** | **Contingency Plan** | **Trigger** |
| Vulnerabilities related to suspension span design | Mitigation: Ensure design is approved by a respected engineer.  Mitigation: Contact designer to verify issue with small waves in previous suspension span projects. | Task Federal and state and experts to review and approve the plans.  Contract with Prof. Farquharson at the University of Washington for wind tunnel studies and remedies. | Review of bridge design. |
| Vulnerabilities related to vertical oscillation | Mitigation: Install four hydraulic jacks at towers as shock absorbers.  Mitigation: Place temporary tie-down cables on the bridge's side spans.  Mitigation: Install wind deflectors to reduce oscillations. | Begin immediate repairs.  Contract with Prof. Farquharson for wind tunnel studies and remedies. | Monitor vertical oscillations and wind speed. If no improvement, continue with Contingency Plan. |
| Structural failure due to twisting motions | Mitigate: Contract with Prof. Farquharson for wind tunnel studies and remedies. | Close the bridge and conduct studies to determine failure causes. | Monitor for twisting motion and act on contingency if observed. |
| Limited expert availability for critical studies | Accept: No action was taken to address the limited availability of the professor. | Delay the wind tunnel studies and remediations until the professor is available. | Prof. Farquharson cannot complete the studies due to priorities. |
| Insufficient wind mitigation through girders | Mitigation: Cover girders with curved steel to deflect wind. | Cut holes in solid girders to allow wind passage. | Monitor the girders; if no improvement, continue with contingency. |
| Negative public perception due to bridge movements | Mitigation: Communicate that the 'bounce' was normal and under control. | Enhance safety measures and communicate improvements. | Public concern escalates despite reassurances. |
| Financial loss from structural damages | Transfer: Secure insurance policies for the bridge. | File insurance claims if damages occur. | Act on insurance if the bridge is damaged. |

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