Restoration and Replacement Options for a Utility Company Bridge

Project Description

Introduction

A utility company owns a steel bridge in one of its hydro electric power generation facilities. The site is in a remote location within a national park. The lead based paint on the bridge is peeling and flaking off into the river. The company requested one of the capstone design teams to come up with options to restore and/or replace the bridge.

Project-Specific Challenges

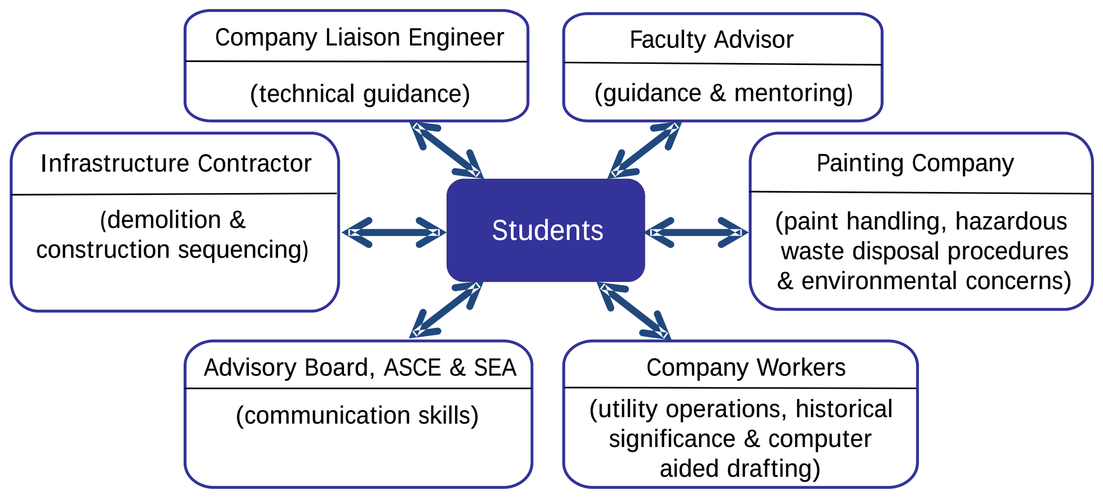
- Remote location of site makes transportation of construction materials and equipment difficult and expensive.
- Limited onsite storage space requires careful planning of material staging and work crew scheduling.
- Powerlines 40 ft above bridge deck limits height of construction equipment that could be used.
- Access to bridge underside restricted by lack of access hatches on bridge deck and insufficient clearance between underside of bridge and mean water level.

Student Collaboration with Faculty, Licensed Engineers and Allied Professionals

- A diverse team of four students worked with a faculty advisor and a company liaison (both **Professional Engineers**)

Fall	Winter	Spring
Site Visit and Written Proposal	Analysis and Design	Final Report and Presentation

- Interacted with allied professionals

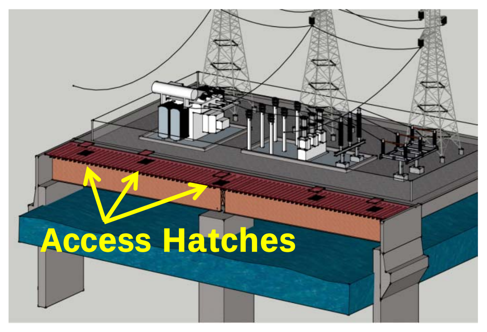


Restoration and Replacement Options

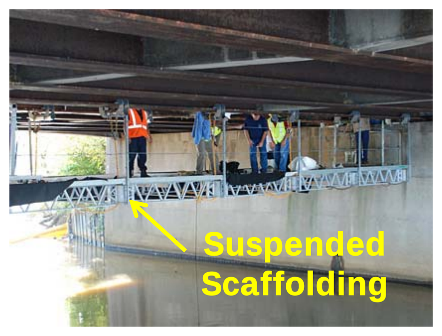
Option 1: Restoration of existing bridge through paint removal and repainting

Team recommended the process for lead paint removal, hazardous waste disposal and re-painting

Team designed access hatches for workers to get to underside of bridge



Team contacted a scaffolding company to get details on suspended scaffolding



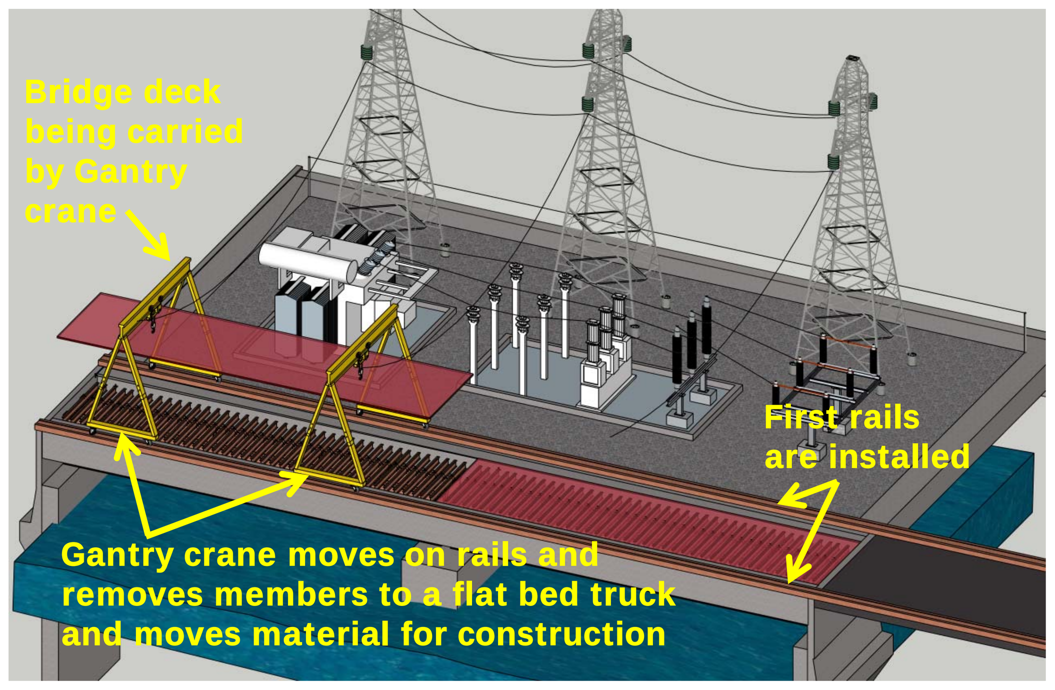
Team contacted a painting company and obtained details on lead removal and containment & painting process

Description	Cost ($)
Hatches (Qty 4)	6,000
Scaffolding/Containment	128,400
Painting	127,500
Loss of Revenue	18,000
Total	**279,000**

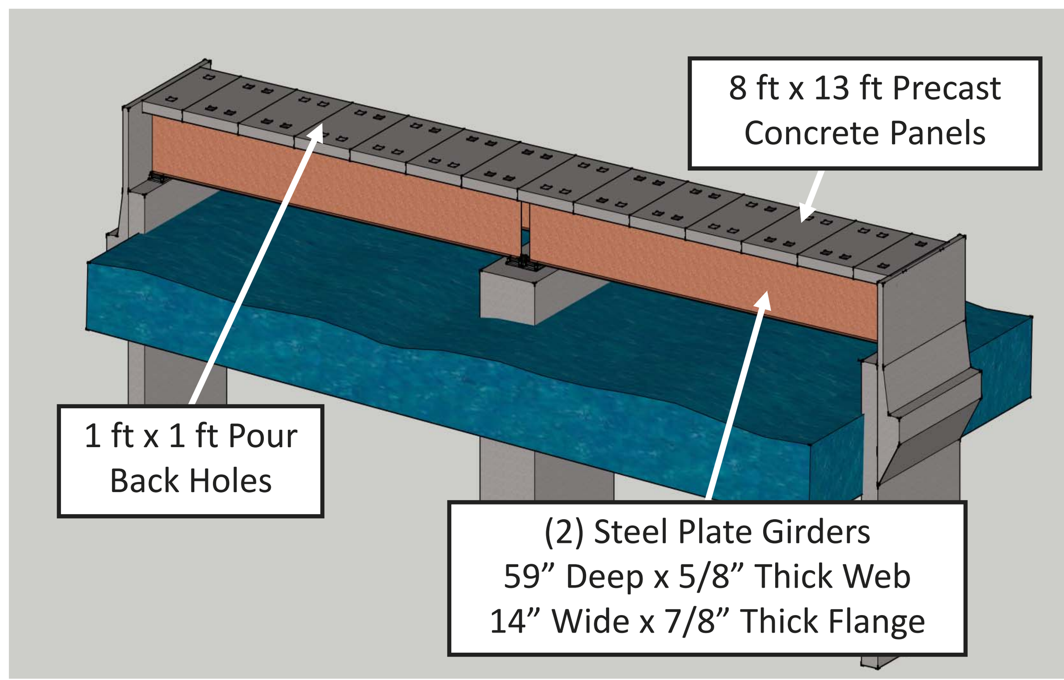
Option 2: Removing existing bridge and replacing with new bridge at same location

Team recommended the Company to sell existing bridge for scrap metal (buyer responsible for lead paint removal); team designed replacement bridge

Team developed a construction sequence with a gantry crane system on rails to demolish existing bridge and to construct new bridge



After analyzing several bridge design configurations, team decided on a steel bridge; designed girders, precast concrete panel decking and pour back holes for connection



Description	Cost ($)
Demolition	37,000
Construction	87,000
Materials	106,000
Fabrication	40,000
Transportation	12,000
Loss of Revenue	18,000
Total	**300,000**

Preferred Option

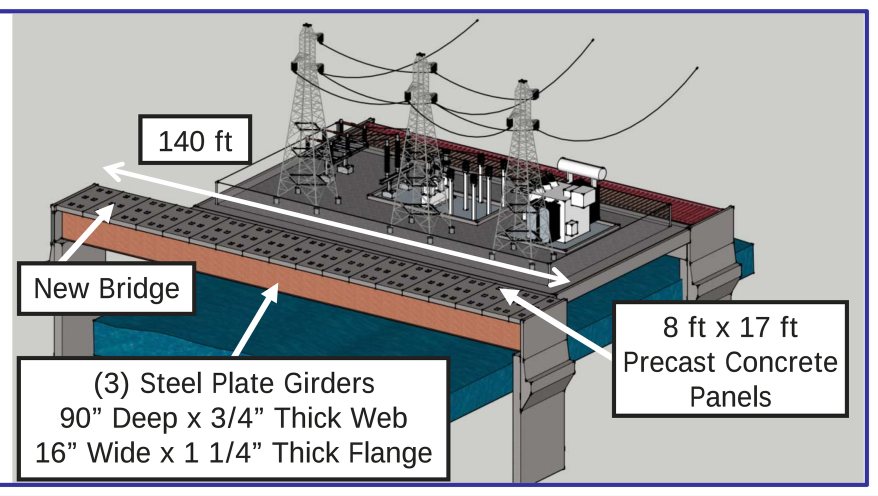
Option 3: Restoring and repurposing existing bridge and building new bridge at different location

Restore bridge per option 1 and build a new bridge at a different location

Existing bridge being open to public and its proximity to Powerhouse pose security concerns to Company.

Restored bridge will be used by utility personnel; all other traffic will be rerouted through new bridge.

Team designed a bridge with precast concrete panel supported on steel plate girders.



Description	Cost ($)
Site Preparation	645,200
Construction	521,100
Materials	207,200
Transportation	7,000
Lead paint removal	279,900
Total	**1,660,400**

Benefits to Public Safety

- Lead contamination could have adverse impact on health and safety of living beings. Team took precautions to prevent contamination during paint removal.
- Overhead powerlines were considered when planning the construction process in options 2 and 3.
- Security was of concern due to bridge being open to public and its proximity to utility operations. Option 3 addressed this concern.

Skills Developed

Technical

- Students learned to assess, analyze and make design recommendations for an existing structure
- Worked on a multi-faceted project with structural and environmental issues
- Worked with building codes, design specifications and computer aided drafting
- Students became familiar with paint and hazardous waste removal process, constructability and connection design

Communication

- Written – proposal, design calculations, final report, professional emails to sponsor
- Oral – presentations to senior design class, sponsor, local engineering chapters

Project Management

- Team work, scheduling, time management
- Rotating project manager responsibilities

Restoration and Replacement Options for a Utility Company Power House Bridge

Abstract

Project Description: A local hydro-electric power utility company (Company) requested one of our capstone civil engineering design teams to provide restoration and replacement options for one of its bridges containing lead paint. The bridge is in a remote location within a national park. The 111' long, single lane, two-span bridge has continuous steel grate decking supported by steel cross beams and girders. The lead paint on the structural members is flaking off into the powerhouse outflow that feeds into a nearby river, which is home to salmon, bald eagles and other species. The Company was concerned about the adverse impacts the lead contamination could have on the environment.

An initial site visit by the team revealed several project constraints: remote location makes the transport of construction materials and equipment difficult and expensive; overhead powerlines above the bridge deck require careful selection of construction equipment, access to underside of bridge for paint removal is only possible either via grated decking or from underside of bridge; security concerns due to the bridge's proximity to the power house.

The team came up with three design options: 1) restoration of bridge through paint removal and repainting, 2) removing the bridge and selling it for scrap metal, assuming that the buyer is responsible for lead paint removal, and constructing a new bridge at the same location, 3) restoring the bridge (option 1) and rerouting the traffic via a new bridge at a different location. The team took the above three options to 30% design. From the findings of the cost-benefits analysis, and in collaboration with the company, the team selected option 2 as the preferred alternative. This option was taken to 60% design entailing the connection design, construction sequencing for the demolition and reconstruction of the new bridge, and engineering drawing development.

Collaboration of Faculty, Students, Licensed Professional Engineers and other Allied Professionals: A diverse group of four students worked under the supervision of a faculty member and a liaison engineer from the Company, both Professional Engineers (PEs). This project also provided an opportunity for the students to interact with PEs within the local professional societies and the department advisory board. Furthermore the students interacted with a contractor, personnel from a painting company and scaffolding company to develop the protocol for removing the lead paint and repainting of structure. The team met with a Company historian to learn how to adhere to the rules of working within a national historical landmark. The students also worked with a computer aided drafter within the Company to develop professional quality engineering drawings.

Knowledge and Skills Gained: The students learned how to apply the technical knowledge gained in the classroom to a real life project and to develop professional skills in the area of oral and written communication, team work and project management skills. The project made the students aware of the multi-faceted nature of the engineering profession – the students had to interact with engineering and non-engineering personnel to come up with the final project deliverable which involved structural design, construction management and environmental considerations.

Benefits to Public Health, Safety and Welfare: The students were exposed to the fundamental canon of engineering which is protecting the health, safety and welfare of the public. The project involved: protecting the environment from lead contamination, keeping all construction work below the overhead powerlines, and investigating an option that alleviates the security concerns of the Company.

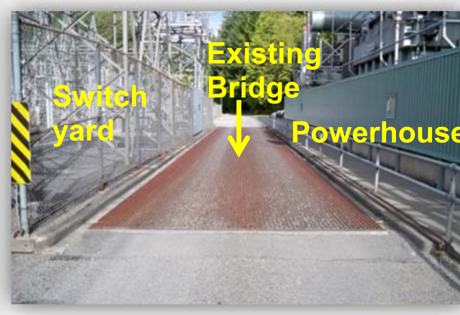
RESTORATION AND REPLACEMENT OPTIONS FOR A UTILITY COMPANY POWERHOUSE BRIDGE

I. Project Description

Introduction

A local hydroelectric power utility company (hereafter referred to as Company) requested one of our capstone design teams to provide restoration and replacement options for one of its bridges that has lead paint. The bridge is the only way for large equipment to access the Powerhouse making it vital for the ongoing power generation operations. The bridge is in a remote location within a national park. It is nestled between a Powerhouse and an adjacent switchyard as shown in the aerial view of Figure 1. The Powerhouse built in 1930 is designated as a national historical landmark.

a)



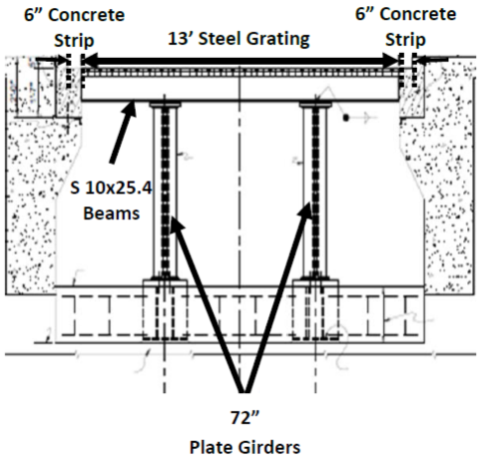
b)

Figure 1. Location and View of the Bridge, a) Aerial View, b) Elevation View

Figure 2 shows the cross sectional view of the existing bridge. It is a single lane, two-span structure crossing the outflow of the Powerhouse. The bridge has an approximate total span of 111 ft and a roadway width of 14 ft. The driving surface of the bridge consists of steel grate decking. The decking is supported by cross beams and the cross beams are in turn supported by 6 ft deep plate girders. The plate girders rest on bridge abutment at one end and the center support at the other.

Lead paint on the steel members (Figure 2b) is flaking off into the Powerhouse outflow which eventually feeds into a nearby river. The utility company is concerned about the environmental impact the lead contamination could have as the river and its surrounding is home to salmon, bald eagles and other species.

The Company requested the design team to analyze the options to restore and/or replace the existing bridge.



a)

b)

Figure 2. a) Cross Section of Existing Bridge; b) Plate Girders with Flaking Paint

Design Options Investigated and the Process

The team investigated three options – one to restore the existing bridge and the other two to replace the bridge.

Option 1: Restoring existing bridge through lead paint removal and repainting
Option 2: Removing existing bridge and replacing with new bridge at same location
Option 3: Restoring and repurposing existing bridge and building new bridge at different location

The options analysis involved the restoration process and 30% design of the new bridge (where relevant), cost comparison of the three options, and developing a decision matrix. Team chose a preferred alternative in consultation with the Company. Following that the team took the preferred option to 60% design which included connection design and construction sequencing.

Project Constraints and Site Specific Design Challenges

During the initial site visit with the liaison engineer from the Company, the students recognized several site-specific challenges and constraints they had to consider:
i) Limited accessibility and storage space: the remote location of the site makes the transport of construction equipment and materials expensive. Also, there is limited space for on-site storage and consequently, material staging and work crew scheduling should be carefully planned.
ii) Overhead restrictions: Powerlines cross the bridge about 40' above the deck. The company requires that power be turned off if any vehicle over 14' has to cross the bridge. This limits the machinery that could be used for demolition and installation of a new bridge.
iii) Access to underside of bridge: Access to the structural members for paint removal is either via the grated bridge deck or from underneath the bridge. The decking is welded continuously to the underside beams with no openings on the deck. If the crew were to access the underside of the bridge from the upper-side of the deck, an access hatch (or opening) has to be installed. Conversely if the crew were to access the structural members

from the underside of the bridge via a boat, there is insufficient clearance between the mean water level and the underside of the bridge. If a boat were to be used by the paint removal crew, the Powerhouse has to lower the water level, which adversely impacts power generation, resulting in loss of revenue.

30% Design of Alternatives

Option 1 – Restoration by paint removal

Work crew will access the underside of the bridge through the bridge deck. A suspended scaffolding installed underneath the bridge will provide a work platform for the crew. The team designed the access hatches as presented in Figure 3. The team contacted a scaffolding services company to obtain the details of its installation and the associated costs.

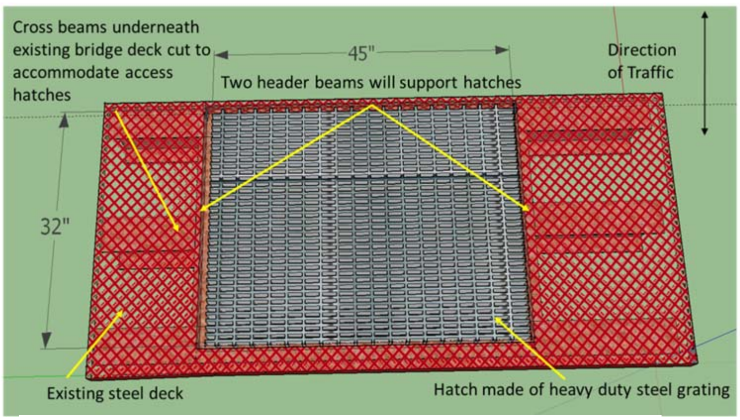


Figure 3. Hatches to Provide Access for Painting

Because the bridge is located over water near a public area, 100% containment is required for the lead abatement. This involves using tarps to encase the entire bridge and an air compressor inside the containment system to keep the air pressure below atmospheric to prevent lead particles escaping into the surroundings.

Lead paint will be removed through sandblasting – a process where fine sand is propelled at a high velocity to strip the surface of lead paint and rust. The resulting sand-rust-paint mixture is hazardous and has to be disposed following appropriate guidelines. After sandblasting, pressurized air is used to remove any sand/paint from the structure. Following the lead paint removal, the bridge will be painted using a five coat system: prime coat, prime stripe coat for the edges and corners, intermediate coat, intermediate stripe coat and top coat.

<u>Option 2</u>: Removal of existing bridge and replacement with new one at same location

In this option the Company will sell the bridge for scrap metal under the assumption that the buyer is responsible for the lead paint removal. The team analyzed several steel and concrete bridge configurations for the replacement bridge. Finally it designed a steel plate girder bridge with precast concrete decking.

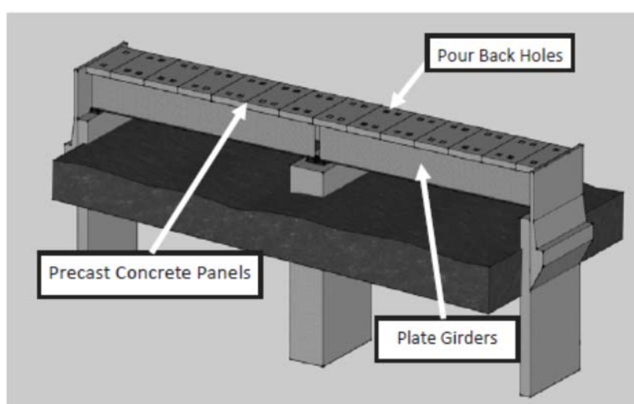


Figure 4. Replacement Bridge at Same Location

Figure 4 shows the configuration of the new bridge superstructure which will rest on the existing supports. Each span consists of two A572 steel plate girders with 59"x5/8" webs and 14"x7/8" flanges spaced at 8.5 ft spacing. The bridge deck consists of 8'x12' 11" precast concrete panels that are 14" thick. Each panel has 1'x1' pour back holes for the connection between the panel and the plate girders. The team also designed the necessary reinforcements for the panel decking.

<u>Option 3</u>: Restoration and repurposing existing bridge and building new bridge at different location

The existing bridge will be restored as described under option 1 and will be used by the Company personnel. All other traffic will be rerouted via a new bridge located away from the Powerhouse as shown in Figure 5. Relocation of the bridge alleviates the security concerns the Company has had due to the existing bridge's close proximity to the power operations.

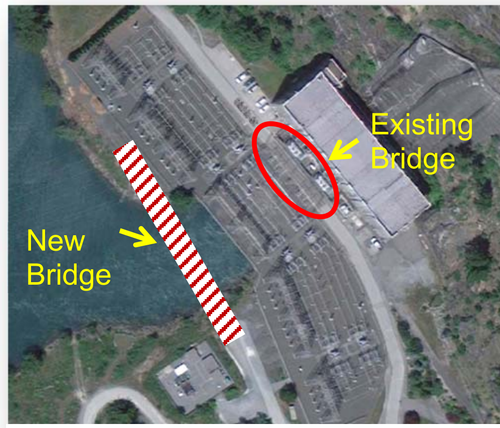


Figure 5. Replacement and Existing Bridge Locations

The proposed bridge is a 140' long, 17' wide single span structure. The driving surface will be 14' wide with 1/5' wide guard rails on each side of the road. The bridge decking will consist of 10" concrete slab. The decking will be supported by three A572 steel plate girders 4' center to center spacing with 90"x3/4"webs and 16"x1 ¼" flanges. The bridge foundations will consist of 10'x15'x2' spread footings at the approaches.

Selection of Preferred Alternative

Upon completion of the preliminary analysis, the team estimated the cost of each option, developed a decision matrix to evaluate the options and to select a preferred alternative. Cost estimate for option 1 covered hatch construction, scaffolding and containment system installation, paint removal and re-painting. For option 2, the cost estimate included demolition, labor and material costs, transportation of materials, fabrication, and loss of revenue due to power shut down for lowering of water. Cost estimate for option 3 included the restoration of the existing bridge (option 1), site preparation, material, and construction cost.

The team considered five criteria to evaluate the options: (i) <u>security and safety</u> of the employees and surroundings, (ii) <u>economic impact</u> involving future maintenance cost and loss of revenue due to Power house closure during construction, (iii) <u>environmental impact</u> as it relates to sustainability, air and water quality, and habitat, (iv) <u>construction cost</u>, (v) <u>historical impact</u> covers aesthetic considerations due to the historic landmark nature of the site. Each criterion was weighted from 1 to 5 - higher the weight more significant the criterion. Each option was then ranked on a scale of 1 to 4 on how well it addressed the criterion – 1 if addresses the criterion very well and 4 if addresses it poorly.

Table 1 summarizes the cost, weights and rankings for the three options. Based on the findings, option 2 of removing the existing bridge and replacing it with a new bridge was chosen to be the preferred option due to its low cost and lowest weighted ranking.

Table 1. Cost Estimate and Decision Matrix for the Three Options

		Option 1 Repaint Bridge	**Option 2 Replace Bridge**	**Option 3 New Bridge**
	Cost ($)	279,900	300,000	1,660,400
Category	Weight Based on Importance			
Security and Safety	4	3	3	1
Economic Impact	3	4	2	1
Environmental	4	1	2	3
Construction Cost	3	1	1	4
Historical Impact	2	1	1	4
Weighted Ranking		33	**31**	39

60% Design of Preferred Alternative

The team took the preferred alternative to a 60% design. This consisted of the design of the structural connections, AutoCAD drawings and the construction sequencing.

For the construction sequencing portion of the deliverable, the team developed details of mobilization, environmental controls, impact of construction activities to the Powerhouse operations, demolition of the existing bridge and installation of the new bridge. Mobilization encompassed equipment and personnel need for the project, staging area for equipment and materials, job trailers, and temporary utility hookups. Environmental controls covered spill prevention and procedures in the event of a spill, and the process for refueling any machinery. The team also prescribed routes for the Company personnel to access the Powerhouse during construction.

The team recommended a gantry crane system (shown in the poster) for the demolition and replacement of the bridge. This system will be comprised of a trolley and hoist connected to a simple frame; the frame will move on motorized wheels and run longitudinally along the bridge on fixed tracks. The gantry crane has the advantage of keeping all the construction work below 14 ft thus eliminating interruption of Powerhouse operations. The track and trolley system will be extended beyond the bridge footprint facilitating the loading and unloading of materials onto trailer trucks. Following that the team provided a detailed demolition and construction sequence for the bridge.

II. Collaboration of Faculty, Students and Licensed Professional Engineers

Students in our engineering program complete a year-long, industrially sponsored, real life capstone project. A diverse group of four students (a female, a Hispanic, an African American and a Caucasian) worked on this project under the supervision of a liaison engineer from the Company and a structural engineering faculty member from the university, both licensed professional engineers. The senior design course is taught by a faculty member who is also a licensed professional engineer. The students met weekly with the faculty advisor and with their sponsor liaison. The faculty members and the liaison provided feedback on the proposal and report throughout the academic year.

In fall and spring quarters the team presented their work to the Company. Diverse groups of professionals attended these presentations. Although the students found these presentations to be quite challenging due to the extensive knowledge and experience of the audience and the questions asked, they believed it provided an opportunity for professional growth.

The team made an oral presentation to the department's advisory board consisting of a dozen local licensed practitioners in early winter quarter describing their project scope and plan of action. Members of the advisory board also attended the end of the academic year presentation at a University event, details of which are provided under Section V.

III. Benefit to Public Health, Safety and Welfare

The impetus for the project was the lead paint on the structure. Lead contamination can have an adverse impact on the health and safety of living beings. Students took special precautions to prevent contamination of the environment when planning the paint removal process.

The overhead powerlines above the bridge were a safety concern and had to be taken into account when planning the construction sequence. The team selected machinery meeting this constraint when planning the construction process for the bridge removal and replacement.

The Company has had security concerns due to the close proximity of the existing bridge to the utility operation because the bridge is currently open to public. Taking this security concern into account, the Team investigated the option of repurposing the existing bridge for Company operations and rerouting the traffic via a new bridge in a new location (option 3). Although this option was not selected as the preferred alternative, the team provided the leg work in the event the Company decides to revisit this option at a later date.

IV. Multidiscipline and/or Allied Profession Participation

A **contractor involved in infrastructure construction** worked with the team and provided advice on paint removal logistics and construction sequencing. The contractor facilitated meetings with a **scaffolding service provider** and a **painting company**. At the latter stages of the project, the Company assigned a **drafter** to assist the team with developing professional quality engineering drawings of the student design. The team provided mark ups on the engineering drawings for the drafter to revise as done in professional practice. The team met with the Company's **historian** to understand the historical significance of the project site and for guidance on preferred modifications to the bridge.

V. Knowledge and Skills Gained

The project enabled the students to develop the following: technical skills, oral and written communication skills, project management and leadership skills, ability to work in a team setting and to interact with clients.

a) Technical skills

The students learned how to take a project from brainstorming stage to final design. During this project they acquired the skill to use the following tools:

- Design Specifications: 2012 AASHTO LRFD Bridge Design Specifications, American Concrete Institute (ACI) Building Code Requirement for Structural Concrete, 2014 Steel Design Manual, State Bridge Design Manual and Standard Specifications,
- Software: SAP2000 for the determination of internal force demands.
- Microsoft Excel to organize and automate design calculations
- Computer aided drafting: AutoCAD 2015

Students have had limited exposure to the above design manuals and specifications, codes and software in their classes. But they had the opportunity to work with them intensively on the project with the help of the faculty advisor and the liaison engineer. Furthermore, students had the opportunity to interact with a contractor to learn about the paint removal process and construction sequencing for the demolition and installation of a new bridge.

b) Communication skills

The students submitted a written proposal to the Company at the end of fall quarter outlining their understanding of the project, scope of work, plan of implementation, and schedule. At the end of spring quarter, they submitted a final report describing the work done, engineering drawing, calculation and other deliverables requested by the sponsor.

Throughout the year the students presented their project progress to their peers and the department faculty members with audio visual aids. In addition, students presented their proposed work to the Company at the end of fall quarter and then presented their final design at the end of spring quarter. The academic year concluded with a major event on campus where the team presented its work to the entire university community, sponsors of all the senior capstone projects, prospective sponsors, advisory board members, friends, family and alumni through oral presentations and a poster session.

c) Project Management and Leadership skills

The student team met with the faculty advisor and the liaison each week. Each team member served as the project manager (PM) for part of the academic year. The PM was responsible for setting up the team meetings, developing the meeting agenda, conducting the meetings, assigning tasks and following up on action items. The PM was also responsible for contacting the liaison and the faculty advisor in between team meetings, when needed. The team provided formative feedback through the course instructor to the project manager.

VI. Summary

A team of four civil engineering seniors developed design options to restore and/or replace a bridge containing lead paint for a utility Company. The project was completed under the supervision of a liaison engineer from the Company and two faculty members all licensed professional engineers. Through this project the team learned how to apply the technical skills learned in the engineering courses to a real life project. Moreover, the students developed project management, leadership and communication skills, and client relationships with licensed professional engineers. The students became aware of the fundamental canon of our profession - the health, safety and welfare of the public.