The Deconstruction of the Champlain Bridge Montreal, Canada

The Zofnass Program at Harvard

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Prof. Spiro N. Pollalis prepared this case study with researcher Dimosthenis Lappas at the Zofnass Program as the basis for research and class discussion rather than illustrating either effective or ineffective handling of the design, the construction, or an administrative situation.

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The Zofnass Program at Harvard conducts applied research on the sustainability of infrastructure and cities' sustainability with the industry's support.

Abstract

Inaugurated in 1962, the Champlain Bridge in Montreal, Canada, suffered premature degradation caused by corrosion due to de-icing salts and the lack of an adequate drainage system in the bridge's original design. Despite repeated reinforcements and repairs, the deterioration only increased over the years, causing safety concerns. In 2011, it was decided to replace the bridge and then deconstruct the old structure. The bridge operator, The Jacques Cartier and Champlain Bridges Incorporated (JCCBI) is responsible for the deconstruction process, following a sustainable approach. Design-build was chosen as the project delivery method, and work on-site is scheduled to begin in the summer of 2020 when the bidding process will be complete. Favored by Canada's strict climate change policy and an integrated sustainability culture built within JCCBI, the deconstruction of the old Champlain Bridge aims to improve environmental performance for similar projects in terms of sustainability. The question is not whether the project will be sustainable but how sustainability innovation can be pursued and implemented most cost-effectively and efficiently. In countries and organizations where sustainability has been well-established and embedded in the culture, there is a need for strategic sustainability tools – besides the established sustainability rating tools – to shape the project and assist decision-making toward sustainability from a very early stage.

Table 1. Project data

Project Name:	**Champlain Bridge Deconstruction**
Sustainability Savings:	To be estimated once the project and its sustainability programs start. LCA and LCCA analysis will be conducted parallel to the project to measure environmental, cost, and community benefits.
Project Type:	Bridge deconstruction
Location:	Montreal, Canada
Area / Length:	3.4 km
Capacity:	Six lanes of vehicle traffic, three in each direction
Owner / Client :	Jacques Cartier and Champlain Bridges Incorporated (JCCBI)
Project Team:	Contractor: Nouvel Horizon St-Laurent, formed by Pomerleau Inc. and Delsan-A.I.M. Environmental Services Inc.
	Engineer/designer:
	Facility/project manager:
	Consultants: Parsons, Tetra Tech, Amec Foster Wheeler
Current Status:	Bidding process
Funding Model:	Public funding – Local tax revenues, federal funds, fares, bonds
Delivery Method:	Design-build
Overall Investment Cost:	Up to Can$ 400 million
Deconstruction Cost:	Can$225 million

Introduction

The Champlain Bridge crosses the St Lawrence River and connects Montreal to the South Shore and its surrounding area. The bridge, suffering from premature degradation, was shut down for traffic on June 28, 2019, after completing a replacement bridge 100 m downstream. Carrying an estimated 50 million annual trips and Can $ 20 billion in trade, during the 57 years of its operation, the Champlain Bridge was one of Canada's busiest bridges and the main gateway from points east to the continental corridor. The demolition of the bridge will begin in mid-2020 and is estimated to last three years. It is expected to cost around Can$225 million.

Fig. 1. Location of Champlain Bridge

The bridge has a total length of 3.4 km, with six lanes for vehicular traffic, three in each direction. It is divided into three sections, as indicated by the numbers 5, 6, and 7 in Fig. 2. Sections 5 and 7 consist of concrete spans made of seven prefabricated beams for each span, with infill strips. Section 6, composed of steel trusses, is the bridge's characteristic section and overhangs the St. Lawrence Seaway. The bridge deck of section 6 rests on massive piers made of reinforced concrete. Section 5 is 2,150 m long, section 7 is 528 m long, and section 6 is 763 m long, crossing over the St. Lawrence Seaway. The Great Lakes/St. Lawrence Seaway system is a vital waterway for the transportation of goods between the North American heartland and international markets. It runs 3,700 km along the St. Lawrence River and the five Great Lakes.

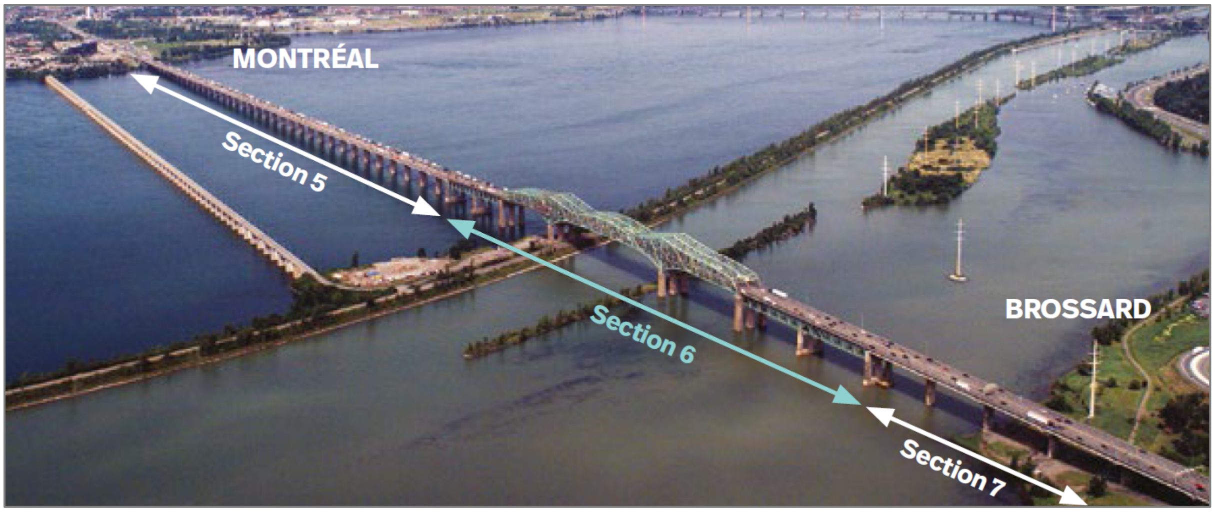

Fig. 2.The three sections of Champlain Bridge (source: JCCBI)

Jacques Cartier and Champlain Bridges Incorporated

The bridge was operated and maintained by The Jacques Cartier and Champlain Bridges Incorporated (JCCBI), responsible for and will oversee the deconstruction process. The JCCBI is a federal Crown corporation established in 1978; besides the Champlain Bridge, it is responsible for other major infrastructure assets in Montreal such as the Jacques Cartier Bridge, the Champlain Bridge Ice Control Structure (called “Estacade”), the Île des Sœurs Bypass Bridge, the federal sections of Bonaventure Expressway and the Honoré Mercier Bridge, as well as the Melocheville Tunnel. JCCBI is accountable to Parliament for the conduct of its affairs through the Minister of Infrastructure and Communities. It is funded by a parliamentary appropriation from the Government of Canada and by revenues from leases and permits. The agency budget for the fiscal year 2018-2019 was Can $ 342 million, including Can $ 292 million invested in major work.

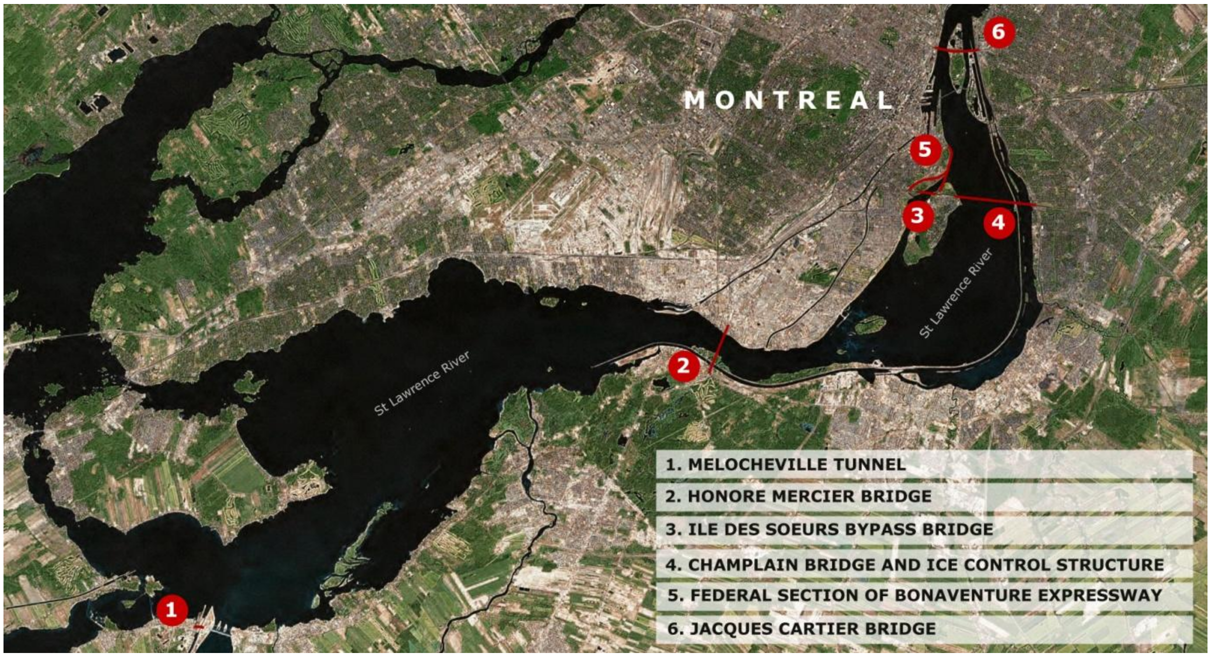

Fig.3. Assets managed by JCCBI

In the last ten years, JCCBI has grown from 50 employees to almost 200 people and has expanded its activities. In the last decade, the focus on engineering and maintenance of the JCCBI assets is enhanced to integrate sustainability and the projects' environmental and social benefits. Future projects include the development of public spaces on land managed by JCCBI. In parallel, there are efforts to implement the best governance for these lands, while maintaining good relations with the community stakeholders and involve them as much and as early as feasible in the process.

Building a sustainability culture within the organization didn’t happen overnight; it was a gradual process. After a few years, the senior management and the board were fully engaged in the necessity and use of sustainability programs. One of the starting points to strengthen JCCBI’s environmental approach came 14 years ago when the corporation had to deal with a contaminated site in the vicinity of Bonaventure Expressway, linking the Champlain Bridge to downtown Montreal. For many years, that part of the shore of the St. Lawrence River had been used as a landfill for industrial and household waste, which caused major contamination problems threatening the water quality of the river. It took almost ten years, but in 2016, after joint efforts by federal, provincial, and municipal authorities, JCCBI launched the Solution Bonaventure Environmental Project. A 1.2-kilometer-long retaining wall was built using an innovative method called “deep soil mixing” – a first in Quebec – to contain and capture PCB-contaminated hydrocarbons and properly dispose of them.[1]

As Sandra Martel, CEO of JCCBI, recalls, “Until that time JCCBI was mostly engaged in repairs of the infrastructure assets with short-term solutions and limited budget. In parallel with global developments regarding the safety of bridge structures, the environmental aspects of this project changed the way we

[1] https://jacquescartierchamplain.ca/community-heritage/structures-and-projects/solution-bonaventure/innovative-project-stem-contaminated-water/?lang=en

view and maintain our assets. We became environmentally concerned and started putting in place long-term plans, highlighting to the government that we need more investments in our structures."[2]

Of course, the commitment of the Government of Canada to sustainability in recent years contributed toward that shift. All ministries and agencies have to contribute to the country's goal of reaching the Sustainable Development Goals (SDGs) of the United Nations. In parallel, the country has developed its own sustainability strategy that helps to answer Canadian sustainability objectives. As Vincent Guimont-Hébert, Sustainability Manager of JCCBI, mentions, "Under the Federal Sustainable Development Act, ministries and federal agencies are required to participate and contribute to national and international goals, but we wanted to go a bit further and integrate sustainability into all our core activities. That's what drove the sustainability programs on the deconstruction of the bridge."[3] In 2016, the mission and vision statement of the organization was changed to include sustainable development concepts. "That was the cornerstone in integrating sustainability into the culture of the organization. We then developed a sustainability policy internally, and from that policy, we introduced a sustainability strategy with a five-year action plan," Guimont-Hébert continues. For that reason, JCCBI developed its own strategic sustainability multi-criteria tool and started using the Envision rating system in their project development. The deconstruction of the old Champlain Bridge will be the biggest project of JCCBI for the next three years.

Fig.4. JCCBI mission, vision, and sustainability strategy (source: JCCBI)

[2] Teleconference with Prof. Spiro N. Pollalis, March 2020.
[3] Teleconference with Prof. Spiro N. Pollalis, January 2020.

Project development

Structural problems

In recent years, the Champlain Bridge has required ever-increasing maintenance and operation expenses to ensure its users' safety. The structure of the bridge has been severely degraded from the use of de-icing salt. When the bridge was designed, the engineering community didn’t have much information on de-icing salt's impacts on prestressed structures, which was a relatively new technology at that time. Because of that lack of knowledge, the bridge was not designed to drain properly. The salty water ended up infiltrating the edge girders of the structure, resulting in corrosion of the concrete's reinforcing steel and degradation.

Over the years, there have been significant maintenance requirements, such as the complete repainting of the steel structure, the replacement of the original concrete deck with a steel deck, development and implementation of the unique modular truss technology, and a large-scale emergency supporting beam installation. Ongoing maintenance activities have included pier repairs, steel repairs, deck joints' replacement, and girder reinforcements. During the end of its service life, the bridge has presented some unique challenges, to which JCCBI responded with exceptional measures, including reinforcement of several spans, installation of instrumentation to monitor the state of components of the bridge, introduction of a dynamic lane signal system, and implementation of an accelerated inspection cycle.[4]

It should also be noted that besides the maintenance challenges, the bridge was not designed to handle the current high volume of traffic, consisting of approximately 59 million vehicles annually, including 200,000 buses. For safety reasons, overweight vehicles were not allowed on the bridge during the last three years of its operation.

The decision to replace the bridge

Despite all these measures and repairs, the progressive deterioration of the bridge and the ever-increasing maintenance cost to ensure safety for users led in 2011 to the decision to replace the existing bridge. There was a debate about whether the bridge should be closed and repaired instead since it was less than 50 years old at that time. Still, after weighing all the factors, the political decision concluded with the replacement bridge solution. Of course, the main factor toward that decision was the condition of the bridge, since the inspection report concluded that the bridge would require very complex repair operations and costly annual maintenance. Moreover, the bridge is the most important commercial link in Canada regarding the flow of traffic and the value of commercial goods, with approximately $20 billion in international trade crossing it every year. Closing the bridge for a prolonged period would have had a significant effect on the local and regional economy. Therefore, although the upfront cost of replacing the bridge was much higher than repairing the old one, it was estimated that keeping the link

[4] Feasibility study on the deconstruction of the existing Champlain Bridge – Environmental Effects Evaluation Final Report, 2017.

running and investing in a new structure would bring more financial benefits from a macroeconomic point of view. Finally, the existing bridge had already reached its maximum capacity of vehicle traffic. At the same time, it could not accommodate any other transport modes, such as a mass transit corridor or bicycle/pedestrian circulation.

A pre-feasibility study was carried out in 2011 to examine various options for replacing the bridge, including both bridge and tunnel alternatives. The study considered transportation requirements, forecasted traffic demands, environmental aspects, implementation modes, and financial considerations. The study concluded that a new bridge was the preferred solution.[5]

The "super beam"

In early November 2013, an emergency further justified the decision to replace the bridge. The sensors installed by JCCBI on the edge girders of the bridge monitoring every little crack, started sending unusual deformations. In late November 2013, the bridge had to close entirely, and a 75-tonne, 56-meter steel support beam was installed to reinforce a cracked girder, called by the media, the "super beam." The "super beam" was installed above the weakened edge girder and reduced the bridge's traffic capacity by one lane. Normal traffic resumed five months later when the "super beam" was removed and replaced with permanent modular trusses installed underneath the edge girder. Before and following that incident, there was a series of interventions on the bridge to install new queen posts and steel beams under each of the bridge's edge girders that are still visible today.

Fig.5. Installation of the "super beam," November 2013 (source: JCCBI)

[5] Feasibility study on the deconstruction of the existing Champlain Bridge – Environmental Effects Evaluation Final Report, 2017.

The new Samuel De Champlain Bridge

The new Samuel De Champlain Bridge construction began in 2015, and it was completed four years later, with traffic rerouted from the old to the new bridge on July 1, 2019. The new cable-stayed bridge is located 100 m downstream from the old bridge (Fig. 6). It was built under a public-private partnership agreement, and Signature on the Saint Lawrence Group (SSL) will operate and maintain it for 30 years. The new cable-stayed bridge carries four lanes of motor traffic in each direction, including one lane reserved for buses. A separate bike path with a pedestrian strip runs along the bridge's north side, with a few observation decks for rest and views of Montreal’s skyline. A central mass transit corridor is still under construction and used by a light rail system (LRT) to be completed in 2021.

Fig. 6.The new Samuel De Champlain Bridge during construction (source: https://www.newchamplain.ca/)

Design-build process

The planning of the old Champlain Bridge's deconstruction began three years ago, and the design-build delivery process has been selected. In 2017, JCCBI commissioned the Parsons/Tetra Tech/Amec Foster Wheeler (PTA) Consortium to conduct a feasibility study on the deconstruction of the bridge and a targeted environmental analysis of the project. The feasibility study reviewed methods and options in four areas: (a) deconstruction method, (b) transportation of materials, (c) material recovery, and (d) asset enhancement. For each study area, various scenarios were examined and evaluated under a sustainable development set of criteria. The focus was on technical feasibility, economic viability, environmental impacts, and social acceptability. The project's overall cost was estimated to be $400 million, with a duration of up to three years.

With the support of financial and legal consultants and the experts of JCCBI, the same consortium prepared the design-build bid. The request for qualifications was issued in 2019 and four consortiums prequalified, two Canadian, one American, and one European enabled by the Canada-European Union free trade agreement of 2016. The prequalification was based on financial and qualitative criteria, evaluating the bidders' capacity and previous experience on similar projects. The four consortiums received a million dollars each to develop competitive proposals for the project between July 2019 and February 2020. The design-build contract for the de-construction project of the original Champlain Bridge was signed in June 2020 with Nouvel Horizon St-Laurent G.P., a group formed by Pomerleau Inc. and Delsan-A.I.M. Environmental Services Inc.

Main sustainability features of the project

JCCBI has emphasized sustainability in the design-build brief. It is the corporation's first design-build project in which the evaluation process will not be based entirely on the lowest bid that fulfills the project's technical requirements, but will also take into consideration qualitative characteristics.

Given that it was unprecedented for the corporation to include qualitative characteristics in their evaluation of bids, the board decided that 10% would be allocated to qualitative information, in addition to the cost. As Guimont-Hébert adds, "sustainability criteria are part of the 10%, but to guarantee sustainability innovation and benefits, we also included clauses in the contract for specific sustainability programs to which the selected consortium will have to contribute." The sustainability programs in the project are:

- Materials reuse and recycling targets, and materials traceability,
- Climate change mitigation (net-zero carbon target),
- Environmental protection and mitigation
- Envision® certification,
- Enhancement of land assets after deconstruction,
- Research and development (collaboration with universities and research bodies),
- Public participation (stakeholders consulting committee, public committees, workshop sessions, and online public consultation sessions).

Materials reuse and recycling program

The bridge's deconstruction will generate nearly 250,000 tons of concrete, 25,000 tons of steel, and 12,000 tons of asphalt.[6] Due to the massive volume of the materials that need to be removed from the site, JCCBI has set ambitious sustainability targets regarding handling and transportation. The most

[6] JCCBI – Material reuse fact sheet.

important and innovative is to favor the reuse of materials instead of just recycling (common practice). It is easy for concrete and asphalt to get the material down-cycled and reuse it locally as filling material and aggregates. When it comes to steel, though, the challenges are greater. Recycling steel is considered a sustainable practice but reusing it has much more environmental benefit. As Guimont-Hébert pinpoints, “After we announced the deconstruction project, we received calls from melting facilities in Asian countries inquiring about the steel of the bridge. There are big melting steel hubs in these countries, but unfortunately, the environmental and air quality laws are not as strict as they are in Canada. We also have such facilities here, but they are strongly regulated by air emissions regulations and targeted by a mandatory carbon market mechanism. These requests set up an alarm to us in terms of social responsibility and drove us to study the reuse versus recycling of materials option.”

The team initially researched other projects that might have used similar practices and came up with only one example, the Bay Bridge deconstruction project in San Francisco. To address social acceptability, the California Department of Transportation, responsible for the deconstruction, initiated a program for reusing parts of the bridge for cultural and artistic purposes. Although it made a positive impact on the local community, the program managed to reuse less than 1% of the bridge's steel. Since JCCBI developed its reuse program much earlier in the project, the corporation hopes to reuse a significantly higher percentage. JCCBI has already approached organizations and local authorities that might be interested in reusing parts of the bridge. As Sandra Martel, CEO of JCCBI, mentions, “pieces of the bridge that we used for reinforcement are only a few years old; we thought, for example, that the provincial transportation authority of Quebec that has similar structures might be interested in pieces such as the ‘super beam’.” The idea is to develop a detailed catalog of the reusable pieces of the bridge so that all interested parties will choose the pieces they want. To further ensure the reuse program, JCCBI has requested the contractor to reserve specific parts of the bridge – counting approximately 20% of the steel - to manage them independently. Besides approaching organizations and cities, JCCBI will also launch an online contest for the public to propose artistic, architectural, and recreational use for some pieces of the bridge.

For the remaining parts of the bridge, the contractor will have to reach specific targets on reusing and recycling; otherwise, there will be penalties. The objectives are to reuse or recycle 100% of the steel, at least 95% of the concrete and asphalt materials, with an overarching goal of 90% of all materials from the bridge. As Dominique Blouin, Deconstruction Project Director of JCCBI, underlines, “We have set pretty good goals for reuse and recycling, way beyond standard practice. Usually, you just recycle part of the materials on a deconstruction, it’s faster and cost-saving, and you don’t have time to make reuse programs. Requiring from the contractor parts of the structure to be reused and setting for the remaining materials, a recycling target of over 85% is something I haven’t seen before.”[7]

[7] Teleconference with Prof. Spiro N. Pollalis, January 2020.

Net-zero carbon program

To benefit the local economy and reduce greenhouse emissions from transportation, the contractor is also bound by the design-build requirements to recycle the materials within a 150 km radius from the project site. A traceability protocol will be implemented so that the materials can be properly tracked. This system is required to provide in-time georeferencing of all pieces, between the origin and the destination. Moreover, the project aims to achieve a neutrality target of greenhouse gas carbon, and the contractor will have to present a greenhouse gas compensation strategy. The strategy will have to be cost-competitive and follow specific verification standards with JCCBI's guarantee for the credibility of the compensation credits for ensuring a carbon-neutral project.

Envision® Rating Tool

To confirm the project's sustainable outcome, JCCBI has chosen to use the Envision® rating tool. As Emilie Bamard, Sustainability Specialist of JCCBI, explains, "This is the first time we will use Envision® in one of our projects, but we are currently trying to integrate it in all our processes when applicable, either for verification purposes or as a sustainability consulting tool through its self-assessment application."[8] The decision to use Envision® was made after JCCBI asked its external consultants to conduct a study on the available sustainability rating tools worldwide. The review recommended that Envision is the most suitable tool for the organization. Moreover, Envision was used for rating the construction of the new Champlain Bridge, and the JCCBI team had the opportunity to be fully informed on the process by the respective project team for the new bridge. The new bridge's difference is that JCCBI will run the Envision certification process for the deconstruction project, and the contractor will not lead it. As Guimont-Hébert explains, there were two reasons for that decision: "the first reason is that we want to build the expertise internally and be able to retain it to apply it to other projects, the second reason is related to the complexity of transferring sustainability programs responsibility to the contractor, who we think is best positioned to contribute to such innovative programs under our lead than to lead it himself. Since JCCBI will run the process internally, there is no specific award target contractually imposed on the contractor. Nevertheless, the self-assessment tool's application showed that the project is already reaching platinum level, so the team will aim for a platinum-level award.

JCCBI multi-criteria tool

Besides using Envision, JCCBI has developed its own sustainability decision support tool to apply at an early stage of their projects to assist in setting up their project sustainability strategy and comparing design options. The JCCBI multi-criteria tool has more than 60 qualitative criteria divided into four dimensions: environmental, economic, social, and technical. "We decided to add the fourth, technical dimension because we are managing complex technical projects, and it is important to know from a very early stage if a project option is meeting our technical objectives or not," Vincent Guimont-Hébert pinpoints. The criteria are drawn from the Global Report Initiative[9] (GRI) indicators and ISO 26000 with

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[8] Teleconference with Prof. Spiro N. Pollalis, December 2019.

[9] The GRI is a framework that organizations use to report on sustainability.

additions from Envision. The definition of each of the criteria is intentionally generic and on a high level. The tool's purpose is to compare scenarios at a very early stage before the more specific sustainability rating tools, such as Envision, become applicable. The tool is currently being used before the project design is defined. The first step of the tool is to describe the possible scenarios for developing the project. The applicable and discriminating criteria are identified and weighted for each dimension. A multidisciplinary team evaluates the scenarios following a Delphi method. After a sensitivity analysis, the recommended ones are shared with the upper management of JCCBI to make the final decision based on each option's weaknesses and strengths. For the Champlain Bridge deconstruction project, the evaluated scenarios compared all the available deconstruction methods, the possible ways for the reuse/recycling of the materials, the transportation methods, and the options for enhancing the assets left by the bridge. The outcomes helped JCCBI in setting the requirements and restrictions of the design-build terms of references. The tool's prime purpose is to set the direction of the project while safeguarding a sustainable outcome from the early planning stage.

Environmental mitigation measures

The contractor is responsible for selecting the deconstruction method. However, the feasibility study excluded some options and bound the contractor to use ways to not have adverse environmental impacts. For example, it prohibits using explosives to demolish the bridge's piers and footings to protect both the ecosystem of the St. Lawrence River and the neighboring residential areas from nuisance. JCCBI has set up several mitigation and compensation programs for protecting the biodiversity of the river that go beyond the local laws and regulations. Measures include the relocation of 400 cliff swallows nesting under the bridge, one of the biggest listed colonies in Quebec, and compensation for various aquatic and fish species with a special status, such as lake sturgeon shad, American eel, and striped bass. Simulations of hydraulic conditions were conducted to check the impact of piers needed for the deconstruction. About 200 separate mitigation measures have been proposed to mitigate the various effects on the environmental components. To ensure compliance with these environmental requirements, JCCBI will require the contractor to implement an environmental management plan based on ISO 14001:2015. This system will enable monitoring and tracking of the mitigation measures and will provide accountability.[10] Besides protecting biodiversity, mitigation measures to limit the project's impacts on the community will also be implemented, especially regarding inconveniences caused by noise, dust, and traffic. A real-time georeferencing system will also be implemented to follow all material movements from their origin to their final destination.

Public consultation and stakeholders' involvement

Public acceptability has been very high in the agenda of the project team. An extensive multi-platform advertising campaign communicated the project to the public, followed by several activities that invited the public to engage with the project and share their ideas. People of Montreal and its south shore could express their opinions on five aspects: sustainable development, environmental protection,

[10] Deconstruction of the existing Champlain Bridge – Targeted Environmental Analysis Summary – April 2019.

material reuse, research and development, and redevelopment of the land released by the bridge's removal. JCCBI identified a broad and diverse range of stakeholders. They were grouped into five broad categories: Governance (governments, band councils, municipalities, elected officials, etc.), Community (residents, community groups, environmental organizations, etc.), Users (car drivers, fishermen, pleasure boaters, cyclists, etc.), Economic Partners (suppliers, subcontractors, workers), and Experts (industry associations, research centers, laboratories, etc.). Furthermore, in coordination with the adjacent cities' administrations, an advisory committee has been created, including representatives from Montreal and Brossard's cities, representatives from environmental and cultural organizations, representatives from citizens associations, and an expert from Montreal's architectural heritage association. The committee follows the project closely and meets every quarter to provide advice and expertise during the process.

Assets enhancement program

The program in which the public is expected to make the most significant contribution is the assets enhancement program named Héritage Champlain. The Champlain Bridge's deconstruction will free up 7 hectares along the river shoreline for redevelopment, including the Champlain Bridge Estacade. JCCBI sees this redevelopment as an opportunity to create a unique site, provide the community with enhanced access to the St. Lawrence River, preserve the shoreline, and preserve the bridge's components to commemorate its part in Montreal's history.

The project team consulted various successful redevelopment projects worldwide, such as the High Line in New York, to identify the optimum function program and governance scenario for assets under JCCBI's responsibility. The aim is for the new public spaces to promote activities and attractions organized near the river and give residents a sense of ownership over these newly freed-up spaces. A new station on Nun's Island of the LRT line crossing the new Champlain Bridge will provide easy public transport access to the redevelopment area.

The enhancement program is not part of the design-build process; however, the contractor will be informed of the bridge sections that need to be preserved. JCCBI will make the final decision on the program in 2021 after incorporating the public consultation process outcomes between May and June of 2019. As Guimont-Hébert explains, "We held three information days to allow the public to meet our experts, participate in workshops, and submit their ideas. The process produced approximately 4,000 inputs that we had to review. In December 2019, we did a co-design workshop with 80 people interested in participating more actively in the process, and we got closer to a final concept. Our design consultants are currently drawing the first sketches of the proposal, including the parts of the bridge, to preserve, and we aim in 2021 to reveal the final proposal."

Research and development program

During its lifetime, the Champlain Bridge has focused on numerous studies and analyses that have led to various reinforcements and repairs. For JCCBI, the deconstruction of the bridge provides an opportunity to acquire new data and knowledge to better manage and improve the longevity of its current assets and share this expertise with the community and other interested bodies. JCCBI has set up a research and development program through its Research and Applications department and collaborates with various research institutes and universities. Ten research projects were selected, aiming to significantly advance the current knowledge about infrastructure performance and sustainability on similar structures. More information on the ten research projects can be found in Appendix A.

Epilogue

The deconstruction of the Champlain Bridge aspires to substantially improve the sustainability outcome for similar projects. Although the actual deconstruction is just starting (as of August 2020), the focus on sustainability during the pre-planning and the planning stages ensures a better outcome, confirmed by a pre-application of the Envision rating system.

Two factors will help achieve higher sustainable performance for the project. The first is the firm commitment of Canada to climate change mitigation. All public organizations and agencies have to follow and report yearly on the sustainability programs they implement toward the country’s circular economy targets and a low-carbon future. So there is top-down orientation in sustainability, and as Guimont-Hébert emphasizes, “In Canada with the environmental laws and regulations in place, when you work on a major project it is not that hard to score high on sustainability scoring schemes only by implementing the mitigation measures and the mandatory consultation processes. The challenge is to push the initiatives further to improve the project's sustainable performance and possibly influence the industry to do better.”

Second, JCCBI has integrated sustainability into its processes. Most organizations have their sustainability practice isolated in an environmental or even a communications department, not incorporating sustainable thinking in their core activities. Instead, JCCBI has involved its upper management in the process. The CEO, CFO, and senior directors are responsible for integrating the agency’s sustainability vision (Fig. 4). Every two months, there is a review within the organization on the sustainability action plan's progress. Based on that review, sustainability is integrated into all applicable project development decisions. The JCCBI tools and programs' support, such as the multi-criteria tool and the Envision rating system. Due to this commitment to sustainability, innovative programs for a deconstruction project were made possible, such as reuse versus recycling and the shoreline's redevelopment after the deconstruction called ‘Héritage Champlain’ public consultation. As Martel mentions, “Our mission is to extend the useful life of our structures as much as possible. In this case, we did not see the Champlain bridge deconstruction only as a dismantling project, we thought instead of how we can add value and make more out of it, how can we make this project beneficial for the community and the country.”

Regarding the impact the sustainability programs might have on the project's cost, both Martel and Dominique Blouin estimate that this will not be significant because of the programs' upfront introduction in the design-build process, which allows the contractor to be competitive and cost-effective. Martel estimates the additional cost to be less than 1% to 2% of the total budget. Guimont-Hébert adds, “however, there are social and environmental benefits from the project, which are difficult to monetize, for example, the benefits from reusing parts of the bridge for artistic, recreational, and architectural projects that will improve quality of life.” The question here is not whether the project will be sustainable or not regarding cost. The project is obligated to be sustainable by the federal sustainable development law; the earlier the sustainability strategy, combined with innovation, is embedded in the project, the greater the possibility of reducing the cost and improving the outcome. The Champlain Bridge deconstruction project showcases that for industries and regions in which sustainability has been embedded in their way of thinking, the sustainability rating tools need to be complemented by strategic sustainability tools and programs to pursue innovation pre-planning phase of a project.

Sources

The case study was based on:

- Teleconference with Sandra Martel, CEO of JCCBI, in March 2020.
- Teleconferences with Dominique Blouin, Deconstruction Project Director of JCCBI, in January 2020.
- Teleconference with Vincent Guimont-Hébert, Sustainability Manager of JCCBI, and Emilie Bamard, Sustainability Specialist of JCCBI, in December 2019.
- Online sources:

  - https://jacquescartierchamplain.ca/community-heritage/structures-and-projects/solution-bonaventure/innovative-project-stem-contaminated-water/?lang=en
  - https://jacquescartierchamplain.ca/community-heritage/structures-and-projects/solution-bonaventure/launch-of-an-innovative-project/?lang=en
  - https://jacquescartierchamplain.ca/our-corporation/publications/?lang=en
  - https://jacquescartierchamplain.ca/operation-super-beam-on-the-champlain-bridge/?lang=en
  - https://www.canada.ca/en/office-infrastructure/news/2019/02/deconstruction-plans-for-the-current-champlain-bridge-on-track.html
  - https://www.cbc.ca/news/canada/montreal/champlain-bridge-demolition-1.5132884
  - https://www.champlaindeconstruction.ca/champlainbridge

Appendix A – Research & Development Program

After a competition among Canadian research bodies launched in June 2019, JCCBI selected ten projects that will be carried out during the deconstruction.[11]

Study of the Compressive Strength of Steel Truss Bridges Made of Assembled Parts

+ **Researchers:** Robert Tremblay (Polytechnique Montréal) / Nicolas Boissonnade (Université Laval)
+ **Research body:** Polytechnique Montréal

Older major steel truss bridges are made of chords consisting of assembled parts. Current standards do not account for the flexibility and strength of these connecting parts. This project aims to develop calculation methods to evaluate these chords' compressive strength to determine their flexural and shear rigidity.

+ **Goals:** Reduce uncertainty during the evaluation of bearing capacity to better pinpoint rehabilitation strategies.

Experiments and Design Guidelines for Repair and Strengthening of Steel Bridges Using Externally Bonded Lightweight High Modulus Carbon-FRP Plates

+ **Researchers:** Brahim Benmokrane (Université de Sherbrooke) / Omar Chaallal (École de technologie supérieure)
+ **Research body:** Université de Sherbrooke

Carbon-fiber-reinforced polymers (CFRPs) are increasingly used to rehabilitate concrete infrastructure, but so far, this material has not been used on steel structures. However, CFRPs offers many advantages because of their high rigidity compared to more conventional methods (bolting and welding), and they are starting to be used to rehabilitate steel structures.

+ **Goals:** Study the feasibility of using CFRPs to repair steel structures and develop analytical models to reliably predict the contribution of CFRPs to strength, while estimating the service life of this type of reinforced steel components under cyclic fatigue loads.

Performance Assessment of Painting Systems Applied to Steel Structures

+ **Researcher:** Nafiseh Ebrahimi (NRCC)
+ **Research body:** National Research Council of Canada

The painting of steel bridges plays a significant role in preserving these structures against long-term corrosion. For this study, samples of steel components from the Champlain Bridge will be studied in the laboratory. Simultaneously, historical data on surface preparations, different types of paint, and climate conditions will be examined to understand long-term deterioration.

+ **Goals:** Assess the impact of complex parameters that have affected the performance of paint applied to the bridge and issue recommendations for improvements that apply to JCCBI's other steel structures and the structures belonging to other managers.

Advanced Techniques for Condition Assessment of the Champlain Bridge After 57 Years of Service

+ **Researchers:** Leonardo F. M. Sanchez and Beatriz Martin-Perez (University of Ottawa)
+ **Research body:** University of Ottawa

To evaluate the performance of concrete structural components over their expected service life, effective and reliable tools are required to correlate reductions in the mechanical properties of used materials with structural consequences. For this project, advanced and non-destructive microscopic and mechanical techniques will correlate the type and extent of damage of the affected material with mechanical and durability losses. Automated tools based on machine learning techniques under development will be applied to bridge components to increase the speed and accuracy of diagnosing the affected structural components.

+ **Goal:** Increase the speed and accuracy of the diagnosis of the affected structural components.

Evaluation of the Real Condition and Mechanical Performance and Durability of Concrete Elements of the Bridge

[11] Source: JCCBI.

+ **Researchers:** Benoît Fournier and David Conciatori (Université Laval)

+ **Research body:** Université Laval

For the managers of civil engineering structures, diagnosing actual actions and future behavior is a significant challenge. This project aims to implement a multidisciplinary analysis of the condition assessment of the bridge's concrete components through destructive and non-destructive methods, focusing on problems related to corrosion and alkali-aggregate reaction.

+ **Goal:** Better understand the influence of exposure conditions on the causes, magnitude, and mechanisms of degradation in different concrete structural components to better calibrate a predictive damage model.

Improvement of Hysteretic Behavior of Fretted Elastomeric Bearings for Seismic Isolation of Bridges

+ **Researcher:** Lotfi Guizani (École de Technologie supérieure)

+ **Research body:** École de Technologie supérieure

In areas with moderate seismic activity, such as most Quebec, basic seismic isolation using fretted bearings appears to be an effective solution. However, the absorption rate from fretted bearings remains limited. An evaluation of the hysteretic characteristics of the bridge's fretted bearings under various load and temperature conditions will be carried out to develop avenues for improvement.

+ **Goals:** Efficiently improve the absorption rate of fretted bearings and study the long-term reliability of structures with behavioral data collection.

Critical Analysis and Performance Monitoring of Surface Repairs of Concrete Elements

+ **Researchers:** Richard Gagné (Université de Sherbrooke) / Benoît Bissonnette (Université Laval)

+ **Research body:** Université de Sherbrooke

The different surface repairs of concrete elements applied to the bridge in recent years show varying durability and behavior levels. The project components include damage mapping, the sampling of different bridge elements, and laboratory characterization.

+ **Goals:** Evaluate the performance of surface repairs of concrete elements while accounting for repaired damage, the type of surface preparation, materials or products, deployment techniques, and climate conditions.

Evaluation of the Performance of CFRP Reinforcements and Development of a Model for Predicting Their Lifetime

+ **Researcher:** Radhouane Masmoudi (Université de Sherbrooke)

+ **Research body:** Université de Sherbrooke

Carbon-fiber-reinforced polymers (CFRPs) were widely used on the Champlain Bridge as a reinforcement technique. This project consists of an experimental program and laboratory tests to better understand bonding and fatigue properties while accounting for the phasing of the bridge's work.

+ **Goals:** Assess the residual capacity of concrete components rehabilitated with this technique and study its durability by analyzing the degradation level using prediction models.

Assessment of Corrosion and Evaluation of the Degree and Distribution of Corrosion on Response of Girders

+ **Researcher:** Denis Mitchell (Université McGill)

+ **Research body:** Université McGill

Evaluating the performance of prestressed girders that have degraded due to corrosion is a major issue. Some innovative exterior repair solutions used on the bridge's prestressed girders will be evaluated to confirm hypotheses.

+ **Goals:** Better understand the degradation process of prestressing cables due to external influences, the redistribution of loads between cables, and their performance in different states of degradation.

Evaluation of the Residual Bearing Capacity of the Intermediate Slabs and Reinforcement with UHPC

+ **Researchers:** Jean-Philippe Charron and Mahdi Ben Ftima (Polytechnique Montréal)

+ **Research body:** Polytechnique Montréal

Conventional tools currently used to assess deck slabs' residual strength do not consider the rapid failure of corroded reinforcements. This project will involve new condition assessment techniques and consist of an experimental program using the bridge’s intermediate slabs in a realistic context.

+ **Goals:** Provide a complete solution that includes a theoretical and actual evaluation of the residual capacity of deck slabs and a sustainable reinforcement method using ultra-high-performance fiber-reinforced concrete (UHPC).