

Market Study for Aluminium Use in Roadway Bridges

Prepared for:

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May 2013

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Abstract: There are approximately 603,000 public roadway bridges in the USA and over 56,000 in Canada. The vast majority of them were built between the 1950s and 1970s and many are or will soon be structurally deficient. Over the next two decades the repair and rehabilitation of these bridges will impose a significant financial burden on the state and provincial budgets.

In this study the provincial, municipal and state highway bridges in the North Eastern United States and Eastern Canadian Provinces were investigated in-depth. The objective was to determine if aluminium might be used in future bridge building and rehabilitation projects, to which extent, and by which bridge authority.

Despite aluminium's obvious advantages of lightweight, corrosion resistance, recyclability, low temperature stability and design freedom, it has not yet been widely adopted by state and provincial departments of transportation. Currently it is primarily of interest for movable (bascule) bridge decks, temporary installations, lane add-ons and for fast turnaround projects. New developments in terms of alloys, large extrusions, and joining are making aluminium a much more viable alternative today than in the past – both technically and economically.

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1 Introduction

The recent focus on the poor condition of roadway bridges in North America has led to renewed efforts by the aluminium industry to re-examine the opportunities of increasing the use of aluminium in bridges for key structural components, especially the bridge deck. On-going analysis of the condition of roadway bridges have shown that in the US and Canada a substantial portion of bridges are structurally deficient and/or functionally obsolete. The recent bridge collapses and emergency shutdowns have driven government officials to significantly increase the levels of funding for bridge repair, rehabilitation and replacement. With this in mind, the focus of this study has been to identify opportunities for increasing the use of aluminium in bridges, the identification of leading players in the bridge sector and to define the market opportunities for companies to service the bridge industry with aluminium bridge components and systems.

This study focuses on the bridge markets in Eastern Canada and the North Eastern United States (rather than on the total North American market), since this region is more likely to be serviced from the aluminium producing region in Quebec. Specifically the study covers the provinces of New Brunswick, Ontario and Quebec and the States of Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, and Vermont. In addition, we reviewed recent aluminium bridge projects and research studies undertaken in Florida, Kentucky and Virginia.

The United States Federal Highway Administration (FHWA) maintains a database of the condition of the 603,000 bridges in the United States. This database is updated annually. In 2011, the latest available analysis, 12.1 percent of total US bridges were structurally deficient, down from 14.8 percent in 2008. In addition, another 14.8 percent of US bridges are functionally obsolete [1]. In the US, the average bridge age is 43 years, while the typical design life for a bridge is 50 years. According to the FHWA database, of the over 72,749 structurally deficient bridges in the United States (in 2011):

- 54.3 percent were constructed with structural steel
- 23.8 percent were built with reinforced concrete, and
- 6.7 percent with pre-stressed concrete [2].

Functionally obsolete refers to bridges that no longer meet the current traffic requirements, but these bridges are not deemed to be structurally deficient and therefore have lower priority in general for replacement than those structurally deficient. In the US, the bridge structural conditions are ranked on a scale of 0 through 9, with 9 being excellent and 0 and 1 being in danger of imminent collapse. Bridges being assigned a rating of 4 and lower are considered structurally deficient. This rating system is universally adopted throughout the US [3].

The American Association of State Highway Transportation Officers (AASHTO) estimated in 2008 that it would cost roughly \$140 billion to repair every deficient bridge in the country—about \$48 billion to repair structurally deficient bridges and \$91 billion to improve functionally obsolete bridges. The cost of eliminating all existing bridge deficiencies as they arise over the next 50 years is estimated at \$850 billion in 2006 dollars, equating to an average annual investment of \$17 billion. The US spent approximately \$8.1 billion on bridge repair, rehabilitation and replacement in 2008 [4].

Traditional bridge materials are steel, reinforced and pre-stressed concrete. Timber/wood or stone is currently only found in a small niche areas, primarily small rural bridges. A very small portion of bridges have used other materials such as aluminium or fiber reinforced composites (FRC). About 50 percent of the total bridges in Canada and the US can be classified as “short bridges” (less than 100 feet/ 30 meters).

Concrete bridges are rather newer and generally have lower rates of deficiencies, and they make up an increasingly larger share of the bridge market. The combined market share for reinforced and pre-stressed concrete bridges in the United States is close to 70 percent of bridges built since 1980 (an increase from the period 1950-1959 where the concrete bridge market share was approximately 44 percent) [5].

In Canada, each province has its own bridge management system and rating system, with the exception of New Brunswick, Newfoundland and Labrador and the territories. Saskatchewan and British Columbia do not have bridge management systems, but have rating systems. There are approximately 56,000 bridges in Canada and approximately 25 percent are structurally deficient [6, 7]. In Quebec, approximately 40 percent of the bridges are structurally deficient. Canada’s bridges average age is 25 years, Quebec’s bridges average age is 31 years [7]. It is important to note that the different bridge management systems in Canada also don’t match the US FHWA standards, so it is difficult to make direct comparisons.

Aluminium is already widely used in bridge components such as guard rails and signage. The largest potential opportunity is for aluminium for bridge decks. Aluminium bridge decks are an attractive alternative to traditional steel and concrete deck materials because of the following characteristics: [17, 18, 19]

- **Light weight** (approximately 15 to 25 pounds per square foot) - Aluminium bridge decks are 70 to 80 percent lighter than concrete, reducing dead load, offering increased bridge width and capacity without the need to strengthen the supporting bridge elements (especially important for load-restricted bridges, historic bridges, movable bridges, and bridges with narrow roadways requiring expansions with bicycle paths or walkways). Facilitates rehabilitation versus replacement. Aluminium is also excellent for the seismic retrofitting of bridges.
- **Corrosion resistant and durable** - Aluminium bridge decks require no painting and minimal maintenance (more than 100 year bridge life without paint), and are better suited than steel or concrete where de-icing chemicals are used.
- **Accelerated Bridge Construction (ABC)** enables rapid construction / installation. In comparison, concrete typically requires extensive formwork and cure time. Reduced transportation costs for pre-fabricated modules.
- **May reduce initial and operating costs of movable bridges** - decrease costs for movable bridges and bridges with long spans where dead-weight is the main load.
- **May simplify assembly and construction/prefabrication** - shop-fabricated, friction stir welded (FSW), using multi-void extruded bridge deck panels with a shop-applied wearing surface to speed construction. Prefabricated aluminium deck panels can be installed faster than other systems and require no field welding.

- **Low-temperature toughness** makes aluminium ideal for bridges and other highway structures in colder climates (eliminates concerns about brittle fracture, even in the most severe Arctic weather).
- **Aluminium is the environmentally friendly “green” metal** (especially aluminium produced in Quebec and British Columbia from hydro generated power). Extrusions can be made with high recycling content. Aluminium components are recyclable and potentially even reusable.
- **Design freedom** / aesthetics/ formability of aluminium
- **Availability** of a wide variety of (large) cross-sectional shapes of aluminium extrusion has led to the expansion in use of aluminium mainly for bridge decks and increased the potential for its application in North America.
- **Improved Properties** and advances in the knowledge of aluminium’s mechanical behaviour and much improved alloys and tempers are now available. The structural engineering community is already using this knowledge coupled with the development and acceptance of necessary codes for the use of aluminium in construction.

In this report, the focus of the effort is on roadway bridges. The market can be segmented into the following bridge types, each of which has different requirements:

- **Bridge Decks** – Factory fabricated modules shipped to the site for installation – can be used in most bridges
- **Short Span Bridges (less than 30 meters)** - Deck and girders can be factory fabricated and complete bridge shipped to site
- **Bridge Rehabilitation Projects** - Accelerated bridge construction favours factory fabricated deck sections
- **Bascule (Lift & Rotating) Bridges** - Light weight important
- **Major Highway and Railroad Bridges** – Long span and major structures (e.g. Champlain Bridge, QC, Tappan Zee Bridge, NY)
- **Ancillary Aluminium Components** (e.g. walkways, guard rails, light posts, planking, signage, abutments, culverts)
- **Pedestrian Bridges** were specifically excluded although they represent the largest current opportunity for the use of aluminium in bridge construction.

Aluminium has been used in bridges for 80 years but has until now never made it beyond niche applications and demonstration projects. Nine bridges were built in North America with aluminium beams and girders between 1946 and 1963; six still exist [8]. A complete list of all modern aluminium bridges, especially the ones in Europe, is not currently publicly available.

In the 1990s, new initiatives were undertaken in North America, Europe and Japan, to develop and promote the use of aluminium extrusions for use in bridge decks. In Norway and Sweden, approximately 80 bridge decks have been built from aluminium since 1990, replacing timber or concrete [9]. Five new bridges were built or rehabilitated in the US since the mid 1990s using extruded aluminium for the bridge deck [10, 11, 12].

In the US Reynolds Aluminum pioneered the development of an extruded bridge deck design incorporating an epoxy/sand wear surface. Reynolds installed two bridges for the Virginia DOT in the mid 1990s. The program stopped when Alcoa acquired Reynolds in 1998 and the plant producing aluminium bridge decks went through various ownerships. The bridges are still functioning well [12]. The Kentucky Transportation Cabinet contracted with Bayards Aluminium Constructies, B.V in the Netherlands to build two aluminium deck bridges in 2005. Extrusions for both deck systems were sourced from Sapa in Europe, fabricated at Bayards plant in the Netherlands, shipped to Kentucky and field erected [13].

Sapa acquired the Reynolds extruded bridge deck technology with the merging of Sapa and Alcoa's extrusion operations in 2007. Sapa reactivated the aluminium bridge deck business in the US market in 2008 and upgraded the Reynolds technology through the use of friction stir welding (FSW) to join the deck extrusions together. FSW is seen as a game changing technology because of the much higher performance of a friction stir weld than an arc weld. In addition these decks have much lower distortion and are likely to have easier installation than alternative bridge designs. Sapa delivered a single bridge incorporating a friction stir welded extrusion version of the Reynolds design to the Massachusetts Department of Transport in 2012[14, 15].

An example of the Sapa bridge friction stir welded bridge deck is shown in Figure 1. Sapa has since exited the bridge deck business and licensed its technology to a former employee who is pursuing the market for aluminium bridge decks as an independent systems integrator Sapa remains as the supplier of the extrusions and outsources the fabrication to a specialist in friction stir welding.

Figure 1: Sapa bridge deck



Source : www.sapagroup.com

2 Current Situation in Canada

The condition of Canada's structurally deficient bridges varies considerably from province to province. There is significant investment required to deal with the high level of structural deficiency in Canadian bridges. More than 40 percent of the bridges currently in use in Canada were built over 50 years ago, and a significant number of these structures need strengthening, rehabilitation, or replacement. [6, 8]

The bridge management system (BMS) used in Canada shows that Canadian bridges have a mean service life of 43.3 years. This means that in 2007 Canada's bridges had passed 57% of their useful life. This ratio for bridges in Quebec was 72%. Table 1 shows the average bridge age by province and also shows the comparable public infrastructure showing that bridges are typically considerably older than other public infrastructure [8].

Table 1: Average age (years) of public infrastructure in Canada

Province	Highways and roads	Bridges and overpasses	Water supply systems	Wastewater Treatment	Sewer Systems	Total
Canada average	14.9	24.5	14.8	17.8	17.9	16.3
Newfoundland and Labrador	16.4	20.9	14.3	17.6	20.9	17.2
Prince Edward Island	13.9	15.6	14.8	22.8	20.0	15.5
Nova Scotia	16.3	28.6	17.0	16.8	19.7	18.0
New Brunswick	15.2	21.2	16.7	18.4	18.4	16.9
Quebec	15.2	31.0	18.5	19.1	18.1	17.2
Ontario	13.9	24.1	13.1	16.9	18.3	15.4
Manitoba	17.1	22.4	15.3	18.5	17.3	17.7
Saskatchewan	16.7	23.3	15.1	17.6	20.5	17.6
Alberta	14.4	23.0	14.0	17.7	16.3	15.6
British Columbia	15.8	23.0	11.4	17.2	16.9	16.3

Source: [8] Statistics Canada, special tabulation, Investment and Capital Stock Division

Bridges and overpasses accounted for eight percent of total public assets in 2007 (\$23.9 billion). Unlike roads however, investments in bridges have been below the level required to hold their age constant. Hence, the average age of bridges rose by 3.2 years from 21.3 in 1985 to 24.5 in 2007 [6, 8].

2.1 Quebec

The biggest opportunity for bridge rehabilitation projects lies clearly in Quebec, where the numbers of structurally deficient bridges are the greatest in the reviewed region. Going forward the main activity will be in bridge rehabilitation, not new construction. Since 2008, significant spending on bridge rehabilitation is showing improvements in average bridge conditions. Quebec has about 9,000 bridges (provincial and municipal) under the responsibility of the Ministry of Transport – Quebec (MTQ), plus an additional almost 4,000 bridges in large municipalities (> 100,000 inhabitants) that are the responsibility of each city, for total of about 12,900 bridges [7, 16]. More than 70% of the bridges in Quebec were built between 1960 and 1980 [6, 7, 16].

Normally major repair work becomes necessary about 30 years after construction. The maintenance and required repair for Quebec’s bridges is considerable now. The current objective is to return 80 percent of all structures to “good status” (i.e. not structurally deficient, not requiring any foreseeable intervention/maintenance for the next 5 years) by the year 2022. In the fiscal year 2011-2012 over \$800 million was invested in Quebec’s structures, including municipal bridges. This significant investment, since 2007-2008, has resulted in 68.1 percent of all provincial bridges now in “good status”, which is 3.1 percent higher than the original target of 65%. The proportion of structurally acceptable provincial bridges has increased by more than 15 percent since its lowest point in 2007[7]. Figure 2 shows the status of provincial bridges in Quebec.

Figure 2: Percentage of structurally acceptable bridges in Quebec

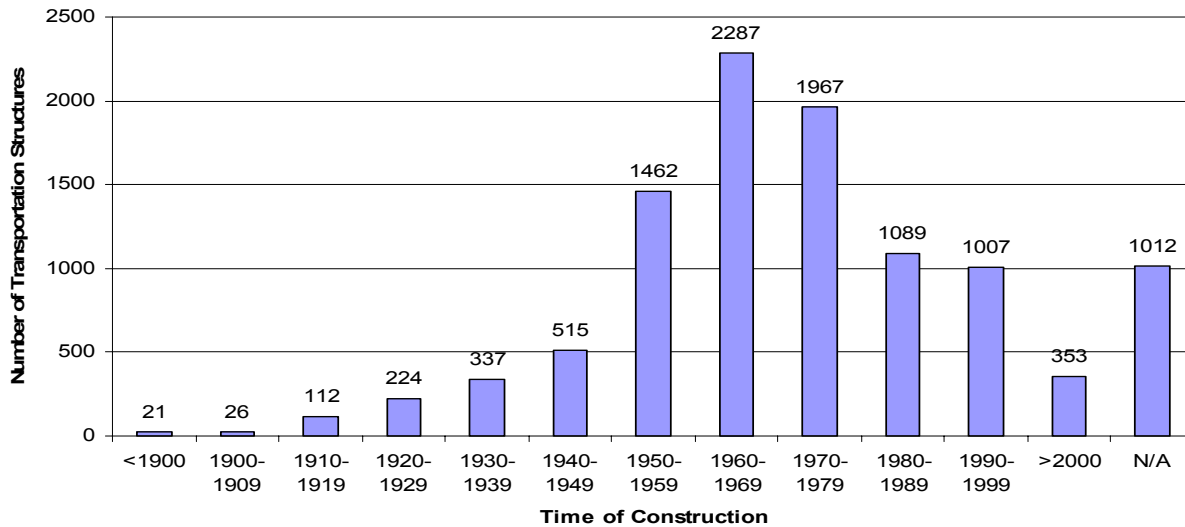


Source: Rapport annuel de gestion, 2011-2012, Ministère des Transports (Quebec), November 2012

Figure 2 shows that the percentage of structurally acceptable municipal bridges in Quebec have been in decline from 57 percent in 1999 to 39 percent in 2008 (when the MTQ took responsibility for municipal bridges in cities with less than 100,000 inhabitants) and now rising

again to 49 percent in 2011. The number of provincial bridges in good condition has been rising again since 2007. Clearly there has been progress after a significant decline in the earlier part of the decade, but there is considerable work to be done. Figure 3 shows the bridge ages for Quebec [6].

Figure 3: Quebec bridge inventory by age



Source: Hammad, et. al. [6]

The objective of the MTQ is to bring 80 percent of all bridges up to standard by 2022. This may be the biggest opportunity for aluminium if the MTQ approves the use of aluminium decks in its bridge rehabilitation program. In 2011-2012 Quebec spent more than \$800 million for structural improvements, mainly for bridges.

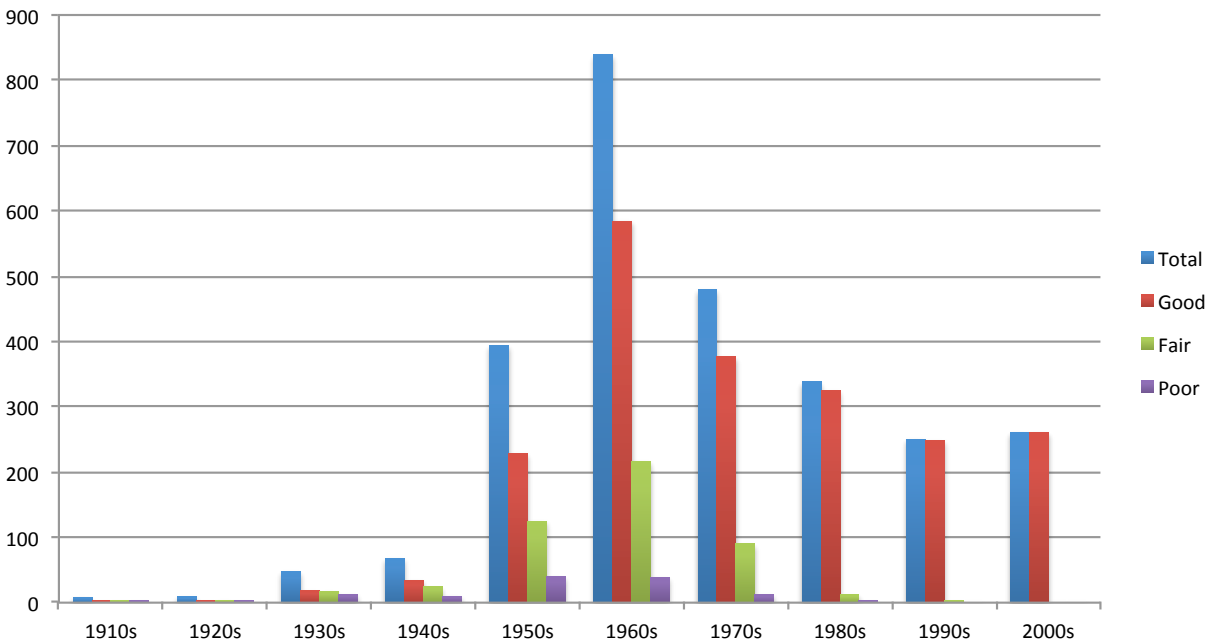
The Saint-Ambroise bridge in the Saguenay is scheduled for rehabilitation with an aluminium bridge deck in summer 2013 (which may be delayed until a viable supplier source can be identified) as a demonstration project. If it is a success, aluminium bridge decks might be considered for the replacement/rehabilitation of a large number of similar bridges in the province. A second aluminium bridge deck project for a longer bridge is possible short term if the first project is completed as planned, on schedule and within budget. The MTQ publishes the status of all their bridges as well as all planned rehabilitation projects for the following two years on their public website. [7]

2.2 Ontario

The majority of the bridges in Ontario were built between the 1950s and 1980s, similar to Quebec and many US States. Figure 4 shows the bridge inventory by age for Ontario. Bridges and overpasses in Ontario are benefiting from large investments in recent years. The average age of bridges and overpasses in Ontario reached an all-time low of 21.8 years in 1993. Thereafter, limited investments raised the average age to a record high of 24.5 years in 2004. The trend has reversed somewhat, as the 2007 average age was 24.1 years. Yet, Ontario ranked third among provinces in terms of having the oldest bridge infrastructure in 2007, after Quebec and Nova Scotia. Bridges and overpasses in Ontario accounted for 7% its public infrastructure stock in

2007 [20]. Approximately 22 percent of Ontario’s bridges are structurally deficient. At this time the Ontario Ministry of Transport has no plans for the use of aluminium in bridge construction or for bridge decks, however MOT Ontario has expressed interest in the progress Quebec makes with its initial aluminium bridge project before committing to a similar trial for an aluminium bridge in Ontario. The Burlington Canal Lift Bridge entry to Hamilton Harbour, ON, as well as the Strauss Bridge in Hamilton, ON, (both owned by the Federal Public Works and Government Services) is scheduled for rehabilitation in the near future, latest by 2018. The existing open steel grid deck will be replaced with an alternative bridge deck material and aluminium is one of the potential choices under consideration. Since this is an historical bridge without breakdown lanes snow removal is the biggest hurdle for a solid surface aluminium deck to overcome. [21].

Figure 4: Ontario bridge inventory by age



Source: MTO [20]

2.3 New Brunswick

New Brunswick has over 200 bridges of which 61 are covered bridges. Bridges in New Brunswick represent 19% of total public assets. Their bridges and overpasses are somewhat younger than those in other provinces, with an average of 21.2 years in 2007, over three years less than the national average. The value of the gross stock invested in bridges and overpasses accounted for 19% of total public assets, well above the national average of eight percent. This relatively high share (as well as low average of years) was due to the allocation of the New Brunswick investment in the construction of the Confederation Bridge linking New Brunswick with Prince Edward Island [22]. New Brunswick has about 15 to 20 percent structurally deficient bridges. The provincial government will invest approximately \$55 million for bridge rehabilitation and repair in 2013/14. Provincial bridge engineers have expressed interest to learn more about aluminium use in bridge construction.

3 Current Situation in the United States

The United States Federal Highway Administration (FHWA) is the central agency for funding state and federal highway and infrastructure programs, including bridge construction and rehabilitation, in the United States. 80 percent of all state highway projects are funded through the FHWA which has a vested interest in maintaining high standards and the containment of costs. FHWA also maintains the US bridge inventory including the status of the 607,000 bridges in its database [23].

FHWA has programs in place to encourage state Departments of Transportation to understand how new technology can be used to build federally funded bridges faster, smarter and more cost effectively. Accelerated Bridge Construction (ABC) is one FHWA program that has been widely accepted by the majority of state DOTs. It focuses on the use of pre-engineered bridge elements and structures (PBES), or factory built components which can be shipped directly to the bridge construction site for installation. Aluminium bridge decks are an excellent example of a PBES component. Also since approximately half of the US bridges are short spans (<30 m long) they are structures that can be factory fabricated for transport over the road to the bridge site. Aluminium bridge decks are light enough to make factory fabricated structures a viable alternative to conventional construction methods.

In this study, the emphasis was on states in the US Northeast. In the US Northeast, Pennsylvania's bridges are in the worst condition. Indeed, Pennsylvania has the highest percentage of structurally deficient bridges in the United States at 22 percent. The US average is about 12 percent, so Pennsylvania weights the Northeast to be worse than the US average. All of the other states surveyed are at or below the US national average.

3.1 Connecticut

Approximately nine percent of Connecticut's bridges are structurally deficient [24]. Connecticut will continue to replace/rehabilitates 25-30 bridges per year for the foreseeable future. The State DOT engineers experimented with lightweight, fibre-reinforced composite (FRC) deck panels for the rehabilitation of historic steel bridges, however the composite panels failed in service within five years and all were replaced with reinforced concrete. The state engineers told us they prefer using traditional materials, mainly reinforced concrete for new bridges and repairs, however aluminium deck panels would be an attractive alternative because of the substantial weight savings offered. Because of their bad experience with the FRC decks the Connecticut DOT would need to see evidence of the successful performance of aluminium deck panels in another state or province before making any commitment to an aluminium solution [25].

3.2 Maine

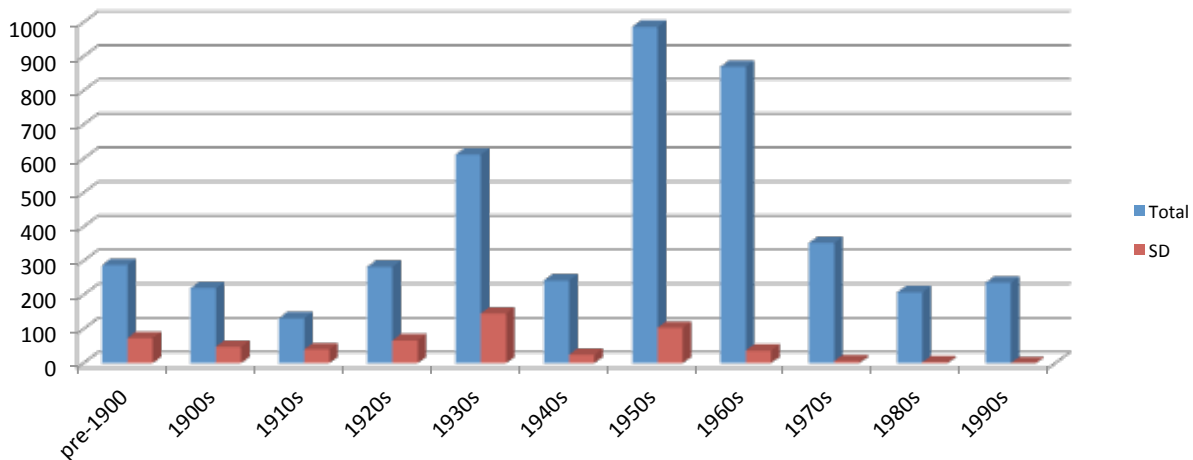
Maine is actively replacing their structurally deficient bridges with conventional materials and composites at a rate of 25 per year. Maine has about 3700 bridges with about 40% less than 20 feet. Approximately 12% are deemed structurally deficient [22]. Maine needs to replace or rehabilitate about 290 bridges by 2022. Maine is actively installing FRC and wood laminate bridge decks as demo bridges. The State DOT Bridge engineers (4) had no interest in discussing aluminium as an alternative. Maine has a leading research center at the University of Maine that is a center of excellence for structural composites and the State DOT has worked with them

actively on demonstration projects in composite bridges. The Maine DOT bridge engineers have taken leading roles for the AASHTO programs for composite bridges [26].

3.3 Massachusetts

Massachusetts is similar to the other northeastern US states with many older bridges. Of the 4,900 bridges in the state, over 80 percent were built prior to 1970. There were two major bridge building periods, during the Great Depression of the 1930s and post World War II to 1970. Figure 5 shows the bridge inventory by date of construction [27]. In 2005, MA had 550 structurally deficient bridges, but by 2015 that number is expected to decrease to about 300 due to a \$3.2 billion 8 year program to significantly upgrade the bridges. When this program is complete, Massachusetts will have rehabilitated or replaced approximately 300 bridges and reduced the number of structurally deficient bridges to about 350, bringing its number of structurally deficient bridges to about 7 percent of the total [28]. Currently Massachusetts has eight percent structurally deficient bridges.

Figure 5: Massachusetts bridge age



Source: <http://www.engineers.org/tec/file/Infrastructure%20Status%20Report%20on%20Bridges.pdf>, Infrastructure Status Report: Massachusetts, 2005

Massachusetts Department of Transportation also has the only friction stir welded aluminium bridge deck in the United States. It is a low use, single lane, factory-built demonstration bridge in Sandsfield, MA installed by Sapa in February 2012[29]. Massachusetts DOT has taken a wait and see attitude before committing to the further use of aluminium bridge decks because of construction delays and cost overruns on this demonstration project.

3.4 New Hampshire

New Hampshire has about 12 percent structurally deficient bridges [30]. It has a large number of steel truss bridges built in the 1920s and 1930s which are functionally obsolete because they can no longer handle the weight of today's truck traffic. New Hampshire DOT rejected FRC deck panel replacements because of the problems experienced in other states. Aluminium deck panels appear to be an attractive solution and one the state might consider if there was a credible supplier available to deal with. New Hampshire is experimenting with lightweight reinforced concrete but it only provides a 20 percent decrease in the dead load of the deck [31].

3.5 New York

With 17,000 bridges and an annual rehabilitation and replacement rate around 300 bridges per year, New York is still not keeping up with the rate at which their bridge inventory deteriorates into the structurally deficient category. Currently it has approximately 12 percent structurally deficient bridges [32]. Currently, New York DOT will only specify traditional steel and concrete for new bridges and bridge rehabilitation projects. New York had difficulty with FRC bridge decks installed before the life cycle was proven that required replacing all their FRC decks within five years. New York also invested in 3 bridges with aluminium beams and girders and a steel reinforced concrete decks. They went into service on Long Island in 1963/64. Two of the aluminium bridges were taken out of service in the 1980s with severe corrosion problems. State bridge engineers said they would need to see clear success with aluminium bridge decks elsewhere before considering the aluminium alternatives [33]. We have also been told the Port Authority of New York and New Jersey is considering the use of aluminium bridge decks on the entrance and exit ramps as part of the rehabilitation of the Lincoln Tunnel [13].

3.6 Pennsylvania

Pennsylvania is replacing about 300 bridges per year. Pennsylvania has about 32,000 bridges, 25,000 are state owned and 7,000 are owned by counties or municipalities. Approximately 22 percent of the bridges in the state are structurally deficient [34]. Pennsylvania needs to replace or rehabilitate about 8,000 bridges by 2033. They are increasing the rate of bridge repair to over 300 per year, but will need to increase it even more to reach their goal of parity with the national average of structurally deficient bridges. The State DOT Bridge engineers have little knowledge of aluminium in bridge construction and instead are using conventional and pre-stress concrete due to the low first cost option. Pennsylvania replaced an historical aluminium deck bridge in Pittsburgh about 10 years ago [35].

3.7 Vermont

Vermont, like New Hampshire, is another small state having a large number of steel truss bridges, older than 70 years, which should be good candidates for aluminium deck panels. Vermont has approximately nine percent structurally deficient bridges. The State DOT engineers have tried fibre reinforced composite panels on one bridge rehabilitation project but never did another one. The state DOT has adopted Advanced Bridge Construction technology in the form of factory built reinforced and pre-tensioned concrete bridge sections that are trucked to the site and installed with a crane [36].

3.8 Florida

The State of Florida is the only state with a significant interest in aluminium bridge decking. Although Florida is outside the scope of this study, it has a vital importance for the future of aluminium bridges in North America and in general, as it is the first region in North America committed to aluminium. Florida is funding a significant research study on alternative bridge decking focusing on structural integrity, first cost, life expectancy and maintenance requirements. The outcome of the research effort undertaken by the State DOT on alternative bridge deck materials has led to a high degree of confidence for using aluminium in bridge decks. Aluminium has received the highest rating of the competing materials. Florida DOT is

looking at aluminium decking for their bascule bridges. They are likely to make a decision to do an aluminium deck in the next 12 to 24 months. Florida will likely replace 2 or 3 bridge decks within the next 3 years as demonstration projects. Florida is working with E. C. Driver (Consulting Engineers) on this project. The outcome of this program may move other states and Canadian provinces to consider the aluminium alternative [37, 38, 39, and 40].

4 Market Opportunities

The total number bridges in provinces of Eastern Canada and the North Eastern US states included in this analysis is approximately 86,500, almost 20 percent of which are classified as structurally deficient. The typical time for a bridge to go from first being placed into this category and it being considered unsafe and need of immediate closing is between 10 and 30 years, depending upon the bridge type, the traffic volumes, the materials of construction and the condition of the foundation. Typically it is approximately 20 years. In addition, each year additional bridges are added to the structurally deficient category as the bridges age. For the purposes of our analysis the bridge statistics used came from the state DOTs public websites, or when the state data was not published, it came from discussions held with state bridge engineers regarding their rehabilitation programs. Our best estimates based on expected condition and rate of deterioration, are shown in Table 2.

Table 2: Bridge condition inventory and estimated rehabilitation and replacements in the study area

State / Province	Total Bridges	Total Structurally Deficient	Estimated Annual Replacements/ Rehabs
QC	12,900	approx. 40%*	200 to 300
ON	2,700	22%	50 to 150
NB	200	15 to 20%	5 to 10
CT	5,300	9%	20 to 30
MA	4,900	8%	25 to 30
ME	3,700	12%	30 to 35
NH	3,800	12%	30 to 40
NY	17,000	12%	250 to 300
PA	32,000	22%	350 to 500
VT	4,000	9%	40 to 50
TOTAL	About 86,500	Almost 20%	1,000 to 1,400 p.a.

*) Data was only available for provincial and municipal bridges under MTQ responsibility, not for bridges under the responsibility of large cities (>100,000 inhabitants) in Quebec.

Note: Nova Scotia, PEI, Newfoundland & Labrador, New Jersey and Rhode Island were not included in the analysis. Source: US FHWA, Provincial MOTs, State DOTs, Viami/TSG estimates

The estimates for bridge rehabilitation and replacement take into consideration the projected funding on bridge projects and the specific situation in each jurisdiction. There is some level of investment policy that considers goals of the National average, while other jurisdictions consider best in class. In some provinces and states investments in bridges have increased significantly in the last few years, but it is likely that bridge investment will have to increase well above the current investment rate just to maintain the present levels of structurally deficient bridges. The vast majority of the bridges built in the region were built between 1945 and 1975 and these bridges are entering the period where they will be most in need of significant repair. This will undoubtedly bring the region to doubling their bridge investments (in current dollars) over the next 30 years.

4.1 Opportunity by Jurisdiction

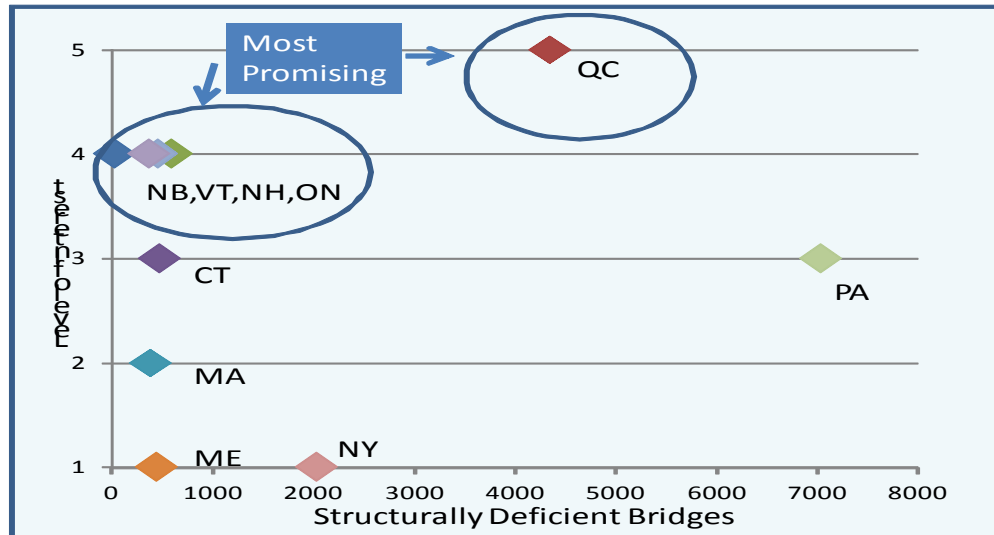
The bridges in Quebec and Pennsylvania are in the worst shape within the region and are in need of the greatest increase in funding. Our conservative estimate of bridge rehabilitations and replacements, especially in those two jurisdictions, is based on the current level of funding, which has been reduced by budget constraints in Quebec in 2013 and the years following. The funding levels are still well below the rate needed to substantially reduce the proportion of bridges in the structurally deficient category. Pennsylvania will likely just stay even in its situation, rather than bring it down to the levels of the other states in the region. Quebec has begun to make progress in reducing the level of structurally deficient bridges since 2008 with a significant fourfold increase in funding for bridge projects, before slowing again starting 2013.

Ontario and New York also have significant numbers of structurally deficient bridges and are the third and fourth most important jurisdiction in terms of overall bridge replacement market. The remaining jurisdictions all fall in the level of 20 to 50 bridges a year, while still significant, are small in comparison to these other, larger jurisdictions.

The other important factor for seeking to replace or rehabilitate a bridge with aluminium systems is the experience and knowledge the bridge engineers have of the benefits of working with aluminium. Interviews were conducted with bridge engineers at the MOTs/DOTs in each jurisdiction and with leading bridge consulting engineering firms to develop an understanding of their specific experience, knowledge, and level of interest, to use aluminium in bridges. In most cases, the bridge engineer was agnostic to the use of aluminium or was interested in learning more about the benefits. In a few jurisdictions, bridge engineers were disinterested because of prior negative experience with aluminium in bridges (New York State) or were focused on using another alternative material (Maine where major bridge deck rehabilitation projects use fibre reinforced composites). Because of these issues, we rank the jurisdictions as shown in Figure 6 below.

Based on interviews and scale of the problem, Quebec is the most promising jurisdiction. The next most promising jurisdictions are Ontario, New Hampshire, Vermont and New Brunswick. The least promising are Maine and New York.

Figure 6: Level of interest versus number of structurally deficient bridges



Source: Viami/TSG estimates based on interviews with bridge engineers

Quebec represents the largest short term potential (next 5 years) with at least one, and possibly two demonstration bridges under discussion. In addition, Quebec is very promising due to the overall condition of its bridges, the large number (almost 5,000) of “short” bridges, and having a rehabilitation rate of 200 to 300 bridges per year in the next two decades.

Ontario, together with the smaller states/provinces of New Brunswick, Vermont, and New Hampshire, will be the second potential early markets. The bridge engineers expressed interest in aluminium as bridge material and said that they will follow with their own first demonstration projects once Quebec and/or Florida prove success with their aluminium bridge deck projects. The time horizon for the completion of these province/state demonstration projects is five to ten years out. After successful demonstration in each province/state, aluminium could capture, under the right conditions and with strong industry support, some of the 1000 to 1400 bridges per year that will need rehabilitation in the coming decades.

New Hampshire DOT engineers believe there is some potential for aluminium decks but see the lack of suppliers as a hurdle. Vermont DOT had a bad experience with FRC deck replacements, and staff are concerned that aluminium may to have some similar problems especially issues with roadway joints and surfaces.

The other northeastern US states will require more time and more success stories from other states and provinces before adopting aluminium in their future bridge designs. Massachusetts DOT has mixed feelings about acquiring a second bridge based on the Sapa design due to the delays with the demonstration bridge and its higher cost compared with conventional bridge designs. This is due in large part to the limitations on fabrication available at the time and is an issue that should be addressed in any new venture. Pennsylvania DOT has no plans to do any aluminium bridge projects and has no strong proponents among their bridge engineering staff.

New York had bad experiences with failed Al bridges installed in the 1960's and recent failures of FRC decks on six bridges. Any new technology will have to be extensively proven elsewhere before being considered for future projects. Maine DOT has done several FRP bridge projects and is likely to continue in that direction. New York and Maine probably are the last adopters. Connecticut DOT engineers are indifferent to the use of aluminium, but would be interested in learning about successes it may have in other states or provinces.

4.2 Opportunity by bridge type

The market opportunity can be segmented by bridge types, each of which has different requirements:

- **Bridge Decks** – Bridge decks are the roadway support system. These are easily produced in factory fabricated modules that can be shipped to the bridge site for quick installation. The Sapa bridge installed in Sandfield, Massachusetts is an example of a factory built bridge deck. The benefits of factory built bridge decks include consistent fabrication, utilizing friction stir welding, improved quality control over field built decks and fast installation to reduce traffic delays. Bridge decks shipped to the site for installation can be used in most bridges.
- **Short Span Bridges (less than 30 meters)** - Deck and girders can be factory fabricated and the complete bridge shipped to the site. Approximately half of all bridges in North America are short span bridges and aluminium is suitable for use for these bridges.
- **Bridge Rehabilitation Projects** - Accelerated bridge construction favours factory fabricated deck sections. Since aluminium bridge decks and deck/girder systems are substantially lighter than concrete, there is an opportunity to utilize this as a lower cost alternative to demolition and re-construction of bridges that have reasonable foundations, abutments and piers.
- **Bascule (Lift & Rotating) Bridges** – These bridges are a small portion of the bridges in North America, estimated at about 1,000 [41], but are among the most costly to build and to maintain. Since many of these bridges are historic, the replacement of the bridge decks and other structural components with lightweight aluminium is appropriate as the alternative steel or concrete would require complete rebuild of the bridge, rather than less expensive and less disruptive rehabilitation. Florida is leading the effort to use aluminium in these types of bridges.
- **Major Highway or Railroad Bridges** – Long span and major structures (e.g. Champlain Bridge, QC, Tappan Zee Bridge, NY) are not appropriate at this time as the level of risk of using aluminium is considered too high by the bridge engineers interviewed. There is no technical reason why aluminium cannot be used in these bridges, but there is significant inertia among bridge authorities to utilize a new material in such high traffic bridges. In the case of railway bridges, the spans may be too great and the weight of the train may be too great for producing suitable extrusions.

4.3 Timeline of Opportunities

Quebec is the only province/state in the northeastern region covered by this study where the Ministry of Transport is currently strongly considering replacing a structurally deficient bridge

with an aluminium intensive replacement structure (steel beams supporting a FSW extruded aluminium deck). Quebec has the second highest number of structurally deficient bridges in the region, many of which would also be candidates for rehabilitation with aluminium decks. In the near term the early opportunities for the use of aluminium in bridge construction will be in the relatively small number of demonstration bridges the Ministry of Transport–Quebec (MTQ) will build to become comfortable with the technology prior to adopting aluminium in their mainstream bridge rehabilitation program – which the MTQ confirmed would not take 5 or more years after successful demonstration of the first projects.

The Saint-Ambroise bridge in the Saguenay-Lac-Saint-Jean region (ten meter short span) with an aluminium bridge deck is scheduled for conversion in summer 2013 from the current wood and steel design. It will be MTQ's first demonstration bridge for the use of aluminium, however the project may be delayed until a supplier for the friction stir welded aluminium deck can be identified. A second longer span demonstration bridge will follow relatively shortly the completion of the Saint-Ambroise bridge, assuming the first bridge is completed as planned, on schedule and within budget. This should be the start of greater use of aluminium in future bridge rehabilitation projects in the province. The MTQ wants then to gradually increase the size of the bridges that use aluminium decks to make sure the technology works before adopting it more generally. They will require some time following the completion of the two demonstration bridges to prove their satisfaction with its performance, both technical and economic, including the long-term total cost of ownership, before committing to go forward with other aluminium intensive bridges – but according to the MTQ this will not be 5 or more years, but rather less. The MTQ has several hundred relatively similar bridges in Quebec, plus about 130 bascule and truss bridges, all of which could be early candidates for similar updates with FSW extruded aluminium decks.

Rehabilitation of the aluminium structure of the historical Arvida bridge (built in 1950 with concrete deck) has also been scheduled by the MTQ. This shows their commitment to maintaining the connection to the historical use of aluminium in bridge construction in Quebec.

Ontario and New Brunswick are both interested in learning more about aluminium in bridges and would look to the experience the MTQ has with a demonstration bridge before considering the use of aluminium in their provinces. Both MOTs have told us they would start with a single bridge to learn about the process before any larger opportunities will arise. The Burlington Canal Lift Bridge entry to Hamilton Harbor, Ontario, owned by Public Works and Government Services is being considered for an aluminium bridge deck. Public Works and Government Services - Canada have commissioned a consultant's study to identify and assess alternative deck materials, including aluminium, for the replacement of the open steel grid deck before this bridge is scheduled for rehabilitation latest in 2018.

So in the near-term, three to ten years out, the main market opportunities in the region appear to be for the Quebec aluminium bridge demonstration projects, the Hamilton Harbour lift bridge and the entry/exit ramps for the Lincoln Tunnel connecting Northern New Jersey with New York City [15]. Followed by whatever ramp up MTQ decides upon, plus potential demonstration bridges in Ontario and Quebec. So probably only a small number of bridges, before the concept of the aluminium bridge is generally accepted and much larger production numbers kick in.

What comes after and when? Eastern Canada was not exposed to negative history of aluminium in bridges like the Northeastern US states, so there is no history of failed projects to be overcome. Also northern Quebec and Ontario could present a significant opportunity for new bridge construction where aluminium could offer its cold weather advantage.

5 Conclusions

5.1 Aluminium Bridge Decks – Potentially an Attractive Market Opportunity

Quebec could be well positioned to be the North American leader in aluminium bridge deck technology. Once the MTQ makes the commitment to build the demonstration bridge with a friction stir welded aluminium deck as a trial project and then, based on the performance of the trial bridge, identifies additional opportunities for using aluminium decks, the market will begin to open up. We have identified an emerging interest in Eastern Canada and the Northeastern United States for the use of aluminium in bridges. Within this region there are approximately 86,500 bridges, of which almost twenty percent are structurally deficient.

As shown in Table 2, the primary opportunity is in the annual replacement and rehabilitation of these structurally deficient bridges. Over the next several decades, we estimated that between 1,000 and 1,400 bridges per year will need rehabilitation or replacement. The majority of these bridges could be potential candidates for aluminium decks if costs and performance are confirmed in the MTQ trials.

A secondary market may exist in the construction of new bridges in northern Quebec and Ontario since aluminium maintains its structural properties in extreme cold and can be easily transported due to its light weight. There is continued expansion of development in the north in the two provinces, especially for the support of natural resource exploitation and other developments.

Quebec is a particularly attractive market since it has the highest percentage of structurally deficient bridges of all the markets studied and therefore opens up an attractive “home market” for Quebec manufacturers to supply. Quebec is also among the most experienced in the use of aluminium in structural applications through the program developed by the Aluminium Association of Canada, to train civil engineers in the use of aluminium for bridges and other structures. This combination of engineering skills and manufacturing capability sets the stage for Quebec manufacturers to export bridge decks to the adjacent provinces and states as their MOTs/DOTs adopt the aluminium solution based on the Quebec experience.

Currently, Quebec, and Florida are the only jurisdictions in North America where the MOTs/DOTs are considering the use of aluminium in bridge replacement/rehabilitation. None of the other bridge engineers interviewed for this study have any plans to include aluminium in future projects; however Ontario, New Brunswick and the smaller states would consider aluminium if they could see successful bridge projects in other jurisdictions.

Ontario and New Brunswick are interested in the potential for aluminium in their bridge replacement/rehabilitation program. Public Works and Government Services (Ontario Region) is considering the rehabilitation of the Burlington and Strauss, Ontario lift bridges with an alternative to its existing open steel grid deck. Aluminium is among the materials under consideration. Ontario and New Brunswick will look to the success of the Quebec aluminium bridge program before taking any action. Success of the Quebec aluminium bridge program will also be important for the Northeastern states of Vermont, New Hampshire and Connecticut, also interested in considering aluminium decks once the data is available from Quebec or Florida.

The Buy America Act and Buy American Act may be impediments to penetrating the US market for a Quebec based producer. However, under NAFTA and WTO requirements, there are options for Quebec based suppliers to participate in the US market. Under NAFTA, Canadian goods and suppliers are exempt from these requirements (Buy America, Buy American) if procurement is done directly by a listed U.S. federal department or agency and if the value of procurement exceeds NAFTA thresholds (currently US \$25,000 for goods, US \$77,494 for general services and US \$10,074,262 for construction services). For municipal purchases there are no provisions. For State agency purchases they should follow WTO guidelines; which means any purchase above \$7.7 million should be treated on an equal basis as US goods [42]. The key issue is whether the bridge deck is considered as a product (with low minimums) – or as a construction service (with high minimums). Defining a bridge deck as an engineered product would place it the category of “goods”, rather than having it included as a construction service will open it up to the widest possible opportunity. This may restrict Canadian engineering/construction firms from bidding for the complete design/build package, but may not exclude a Canadian supplier of a bridge deck. In addition, if no credible alternative supplier exists or there are a sufficient number of qualified suppliers, procurement rules may require international competition for US bridges. The State of Kentucky sourced two aluminium bridges from the Netherlands less than 10 years ago without triggering any Buy America issues[9].

5.2 Supply Chain Deficiencies

Quebec has a strong base of established engineering and manufacturing companies (fabricators) with the types of skills important for the design and manufacture of aluminium decks for the Quebec “home” market as well as for bridge markets in Eastern Canada and the Northeastern US. This study identified the gaps in the value chain, particularly for an extruder in the region with the capability to supply the large (13.5inch x 9 inch) Sapa type hollow extrusions required for manufacturing 8-inch bridge decking. Currently there are no extruders in Canada with 16-inch circle size, or larger presses, the minimum machine size required to extrude this material. One possible way to avoid this “gap” and to use existing extrusion capabilities in the province would be the development of a suitable 5” bridge deck (similar to the design used in Florida). Alternatively, the large extrusions and deck design know-how could be imported from Europe, with the smaller extrusions sourced in Quebec.

There is no industry “Champion” developing the market for aluminium bridges or bridge decks in the US or Canada since Sapa exited the aluminium bridge deck market in 2012. Sapa is still available to supply extrusions and has an agreement with H. F. Webster in conjunction with the

Rock Island Arsenal to friction stir weld Sapa extrusions into end products such as bridge decks, but are no longer prepared to take on the full systems responsibility for the deck design and performance[13]. All the provincial and state MOTs/ DOTs interviewed for this study told us that having a credible supplier for engineered aluminium decks to work with would be the key requirement for them to specify the aluminium deck option. The former head of the Sapa bridge division is trying to fill this void through an alliance in the US. At this time there is no apparent existing Quebec based manufacturer that would be a credible supplier of aluminium bridge decks who could immediately also act as the “champion” for the aluminium option and develop the market in Quebec and other jurisdictions. But there are several highly competent participants in the Quebec industry who could offer services and some fabrication, but not yet the full engineered deck. This will still take some time to develop this.

Other than the H. F. Webster/Rock Island Arsenal partnership, we have not been able to identify any aluminium fabricator in North America with a friction stir welding facility capable of welding the long aluminium extrusions required for bridge decks in a single pass using multiple welding heads. One or more Quebec aluminium fabricators will have to invest in developing friction stir welding capability before aluminium bridge decks can be manufactured locally. However having this friction stir welding capability in Quebec will open other manufacturing opportunities to the companies that made the investment in the FSW process. The existing FSW installation at the UQAC in Chicoutimi as well as their (and other Quebec organization’s) technology transfer programs would be highly beneficial for any Quebec based company looking at this opportunity[43].

Other technical challenges still remain, such as improving the properties of the aggregate/epoxy wear surface coating (particularly for cold weather locations) to extend its life beyond the ten to fifteen years claimed by Sapa for their aluminium bridge decks. Snow removal also presents a problem for the use of a closed deck on historic bascule bridges without breakdown lanes in Canada and the northeastern states covered by this study.

In summary, at this point in time there are still major gaps in the supply chain that affect the ability of Quebec companies to design, manufacture and sell aluminium bridge deck products in Quebec as well as to the other states and provinces covered by this study.

5.3 Bridge deck cost

Costs for bridge decks depend on many factors, including but not limited to the type, size and exact design of the bridge deck, distance to suppliers and the final site, location and associated costs for labour, energy, etc. of the fabricator, and the number of bridge decks produced at a time or in a given time frame. Bridge deck prices have been quoted by a Sapa contractor at approximately \$139 to \$149 per square foot ex-fabrication site for the 8-inch deck system. The price includes the complete factory produced deck system. Our analysis of the bridge deck system includes the cost of the metal, extrusions, the cost of fabrication of the deck system, the cost of the surface coating, cost of expansion joints and drainage devices. Our analysis of the costs associated in production of a bridge deck follows in Table 3 [44, 45, 46]. It shows that it should be possible to get into the same price range as Orthotropic Steel Decks (OSDs) [47].

Table 3: Costs for producing aluminium bridge decks

Cost Item	Cost (\$ per square foot of deck)	Source
Aluminum metal price	14.42	Platts Metals Week
Extrusion billet premium	2.38	Platts Metals Week
Extrusion conversion	19.60	RTA, Viami/TSG
Wear Surface	10.00 (7.00 -12.00)	SAPA Contractor
Fabrication (FSW)	16.00 (10.00 - 20.00)	ESAB
Drainage, Bolts, Expansion Joints	10.00 (8.00 - 15.00)	Viami/TSG
Engineering, Transportation, Tooling	20.00 (15.00 - 25.00)	Viami/TSG
Overhead & Profit	25.00 (10.00 - 35.00)	Viami/TSG
Cost to Site	117.40 (86.40 – 136.40)	

Note: All costs are in Canadian dollars assuming parity with US dollar. Installation cost not included.

Longer term we can assume this price to change and most likely go downwards, depending of course on many factors currently difficult to foresee or estimate:

- The Al metal price varies constantly and shows higher volatility than steel and certainly concrete. With a significant portion of the aluminium producers not making any profit at the current price it can be assumed that this price will rise, i.e., the current \$14.42 per square foot of deck will longer term probably rather increase to \$18 to 20 per square foot or more.
- The extrusion billet premium will depend on which alloy will be used, the potential of integrating recycling content, proximity of the casthouse to the extruder, volume sourced in the specified alloy and diameter, etc. As it is a small portion anyway it will likely not have a big impact on the total price, and no truly significant changes can be expected longer term for this item.
- Extrusion conversion: This could certainly decrease once the volume increases. Again, the price will depend on the selected alloy, exact shape, distance to the fabricator, etc. The potential reduction could compensate the longer term increase in the base metal price.
- Wear surface and fabrication: With increased experience it can be expected to be reduced. How much will depend on the volume, the exact setup, location, etc.
- Engineering, transportation, tooling: This is the biggest cost item and will be most affected by volume.
- Overhead and Profit: Will go down (in percentage and absolute value) with increasing volume and number of projects and suppliers.

Therefore it seems appropriate to estimate a longer-term price to likely drop to about \$100 per square foot, but the exact value will depend on all the above described parameters. The main driver for this lower price will be market volume growth and consistent product requirements.

5.4 Overcoming the cost issues

The key unanswered question is if aluminium bridge decks are to be considered as an attractive alternative to reinforced concrete, and the provincial authorities continue to look at creating employment opportunities around the manufacture and fabrication of aluminium will there be a move to more aluminium bridges. Aluminium must become more cost competitive to attract more project opportunities.

First cost is an issue. Currently aluminium bridge decks have 1.5 to 2 times the cost of traditional steel and concrete alternatives, approximately the same level as Orthotropic Steel Decks. As outlined above more commercial experience with Friction Stir Welding and greater production volumes should reduce this first cost differential – but not substantially. Approximately \$100 per square foot of deck is our best estimate but Total Cost of Ownership (TCO) over the long term clearly favours aluminium over competitive materials.

In the case of bridge decks, factory fabrication and over road shipment directly to the site allows for just-in-time assembly, potentially saving days in the construction cycle and requiring lighter duty cranes and handling equipment for placement on the structure. FHWA in the US has documented that factory manufactured reinforced concrete bridge deck sections have better dimensional tolerances and last longer than cast in place decks. It is their observation that a factory manufactured aluminium deck should perform better over the long term than any cast in place reinforced concrete alternative.

However, since most bridge authorities do not consider TCO in the analysis of a bridge project.

- A coordinated marketing effort linking TCO with the technology and weight advantages of aluminium must be part of the selling process for aluminium bridge decks and other bridge components
- Comparisons are required with different bridge designs – not just traditional steel and concrete. This would include comparisons with new technologies like pre-tensioned, pre-cast concrete bridge sections that are factory built and shipped to the site. This is a typical example of a new technology that meets the standards of the FHWA “Every Day Counts” accelerated bridge construction program and has supporters in several state MOT’s.
- Simple tools to allow for TCO analysis on all bridge projects would enhance aluminium’s position versus other materials.

5.5 Summary

Most MOTs/DOTs in the region covered by this study are in the earliest stages of understanding the many advantages aluminium bridge decks offer in the rehabilitation of their inventory of

structurally deficient bridges. Florida and Quebec are currently the only jurisdictions in North America with active programs in place to install aluminium bridge decks for evaluation and to assess their performance over time. The market for aluminium bridge decks in North America is still in its infancy, and will remain so until such time as data on costs and performance becomes available from the demonstration projects in Quebec and Florida. Further aluminium bridge decks will then follow in both Quebec and Florida and, as the value proposition offered by aluminium becomes known, new demonstration bridges incorporating aluminium decks will begin to be considered in other states and provinces.

As one of the pioneers in the use of aluminium bridge decks in North America, Quebec is well positioned to become a market and technology leader as aluminium bridge decks are more widely used in Quebec and in other states and provinces. This represents a real opportunity for Quebec manufacturers to leverage their home market experience to supply aluminium bridge decks to adjacent provinces and states. We estimate that Quebec sourced aluminium bridge decks could be competitive in a 1000 KM range, which includes the states and provinces covered by this study. When this market begins to open up, the total potential annual market will be some percentage of the 1,000 – 1,400 bridges undergoing rehabilitation every year in the northeastern region.

Currently there is no Quebec/Canadian company positioned to market aluminium bridge decks as an engineered product to the MTQ in Quebec or to the MOTs/DOTs in adjacent states and provinces. The Aluminium Association of Canada has therefore a key role to play in working with Quebec manufacturers and engineers to come together to create a credible supplier base capable supplying aluminium bridge decks as an engineered product to serve this emerging market. Until such time as a strong Quebec company emerges to “champion” the aluminium bridge deck technology in the marketplace, AAC will also have to keep this effort alive both in Quebec as well as in the adjacent provinces and states.

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Glossary

Deck- The bridge deck contains extruded aluminium hollow sections, flanged to allow for welding. These extruded aluminium sections have been either welded or bolted in recent bridge projects.

Extrusions-The aluminium extrusions are produced from billet which is direct chill cast to the proper diameter for the extrusion press, homogenized and cut to certain length (logs). Billets are produced at casthouses of primary smelters, secondary smelters (recyclers) and at some extrusion plants with their own casthouse, especially those producing large extrusions where the volume of material throughput is large.

Wear Surface- The wear surface on bridge decks is the roadway surface. Typical surfaces include asphalt and concrete. For aluminium decks, urethane based epoxy resins with a mineral grit has been used.

Superstructure or girders – This is the main load bearing section that supports the deck and transfers the bridge load to the abutment/ wing wall, pier and footings. In most bridges it is steel girders. Aluminium girders have been used on bridges in the past. The girder is typically fabricated from aluminium plate and arc welded.

Pier – for longer spans, piers are used to support the bridge mid-span. Piers are typically steel reinforced concrete.

Abutment/wing wall – are the landing section of the bridge to the approach areas of the roadway. They are typically reinforced concrete; they typically are not steel as there is direct contact to the ground.

Footings/pilings – Footings are typically poured concrete. Pilings are typically steel. These form the basic foundation of the bridge structure. Pilings on older bridges could be treated wood logs.

Railings/guard rails – railings prevent the vehicles from driving off the bridge. Many bridges have used aluminium for railings due to the lighter weight and corrosion resistance. Concrete jersey barriers have also been used. Galvanized steel guard rails have also been used.

Truss - supporting lattice work added to create very tall beams that add rigidity to an existing beam greatly increasing its ability to dissipate the compression and tension