PCA
America's Cement Manufacturers™

MARKET INTELLIGENCE

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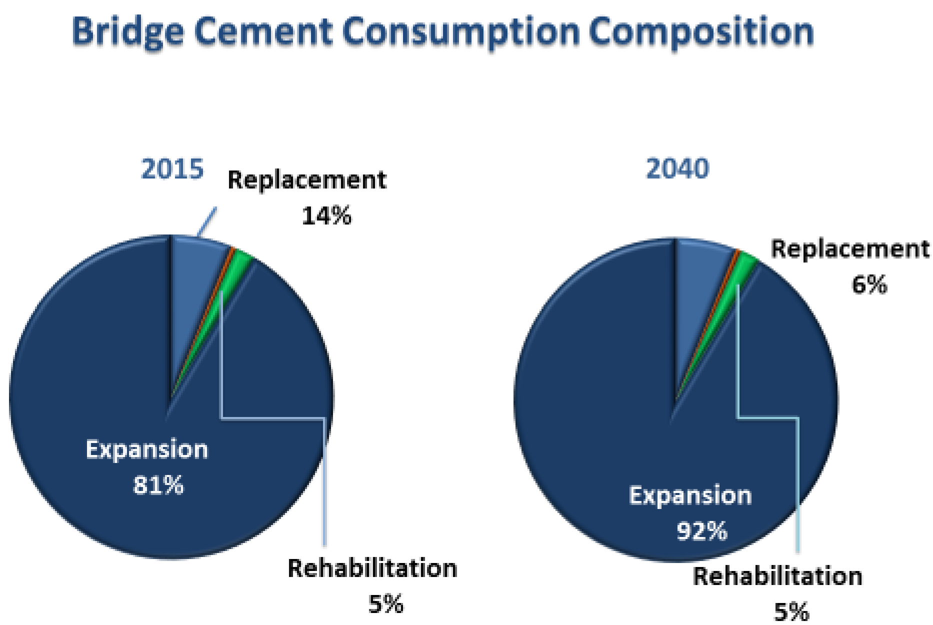
Bridge Market Assessment

PCA's market Intelligence Group is engaged in a comprehensive research project that estimates long-term opportunities for cement consumption. The study provides a 25 year outlook and evaluates both vertical (buildings) and horizontal (non-buildings) markets. The study not only estimates growth in construction activity based on economic, demographic, and structural issues, such as technology changes that are likely to impact demand, but it also measures building material market share trends in each construction segment. The project will identify the areas of greatest to least opportunity. Alternatively, the project will identify areas of greatest opportunity to least.

This report focuses on the United States' bridge market. Two key forces determine bridge construction activity. They include expansion in the number and size of bridges, and maintenance of existing bridges.

Profile of the United States' Bridge Market

Bridges are a critical part of the nation's infrastructure. Because they are an important ingredient in the United States' logistical system, their condition can impact overall economic growth. There are more than 610,000 bridges in the United States, small and large, representing 369 million square meters in area. Most bridges are concrete. Concrete's principal competitor is steel bridges. The market share of annual cement consumption has grown from 52% in 2000 to 57% in 2015.



Annual cement consumption for bridges has grown from 3.6 million tons in 2000 to 6.7 million tons in 2015. In terms of the bridge market's importance to the entire U.S. cement industry, it now accounts for 7.5% of the total United States cement market – up from 3.7% in 2000. Roughly 81% of bridge cement consumption is attributed to expansion, 14% to bridge replacement, and 5% to bridge rehabilitation.

Bridges in the United States service nearly 2.0 billion vehicles crossing each day, or more than 730 billion crossings annually. According to the Federal Highway Administration's National Bridge Inventory database, slightly more than 22,000 bridges are rated in poor condition and another 177,000 bridges are rated as being in "fair" condition. Some of those listed in fair condition could reflect problems. According to the American Society of Civil Engineers (ASCE), nearly 57,000 bridges nationwide are structurally deficient and in need of repair or rehabilitation – reflecting 9.3% of all bridges.

Slightly more than 80% of all structurally deficient bridges are between 39 and 94 years old – with the mean age nearly 68 years. As population and the number of drivers on the road increases, so will total vehicle miles travelled and bridge crossings. The combination of increased crossings and rising vehicle weights suggest an acceleration in bridge stress during the years ahead. This, coupled with the fact that older bridges had fewer crossings and lighter vehicle weights during the course of their lives, suggests more bridges will reach structurally deficient status earlier in their lives under similar bridge rehabilitation spending as in the past.

Either by adding lanes or building new bridges, the total square meters of bridges in the United States has been growing at an annual rate of nearly 3.9 million square meters during the past 10 years. Unfortunately, even this level of new bridge construction and expansion has not kept pace with the demographic growth.

This shortfall in bridge expansion is reflected in two key congestion measures:

- **Bridges per licenses driver.** There were 3.1 bridges per 1,000 licensed drivers in 2000 and 2.3 bridges per 1,000 licensed drivers in 2015 – reflecting a 9.6% decline.

- **Bridges per vehicle miles travelled.** Perhaps more importantly, there were 23.3 bridges per 100 million vehicle miles travelled in 2000 and 20.5 bridges per 100 million vehicle miles travelled in 2015 – reflecting an 11.9% decline.

Bridges play an important part in the road system and at least some of the overall road congestion in the United States can be attributed to bridge congestion. According to the Urban Mobility report, traffic congestion on United States' roadways in 2015 accounted for an average commuting delay of 43 hours per driver annually – up 16% since 2000. In the same study, fuel wasted in traffic jams annually rose by 1 billion gallons during the same time frame, and accounting for time lost cost the American economy $170 billion dollars – a 49% increase over the last 15 years and equaling roughly 1% of total United States GDP. These metrics may reflect an important viewpoint if advocacy resources target bridges.

Methodology for Estimating Cement Consumption by Bridges

Growth projections for cement consumption associated with bridge construction activity over the next 25 years is anchored in three key assessments including: (1) bridge expansion activity, (2) movements in concrete's market share versus competing materials, and (3) bridge rehabilitation, replacement, and repair activity.

Each of these assessments are addressed in the following pages. The final estimates rest on the shoulders of assumptions and assessments made to the factors of bridge usage and expansion activity such as number of licensed drivers, vehicle miles travelled and bridge crossing estimates. Small changes in any of the assumptions and assessments can result in significant changes in projections and thereby long-run potentials during a 25-year horizon.

To this end, PCA offers a baseline projection (most likely scenario), a high-growth projection (a scenario reflecting optimistic assumptions and assessments), and a low-growth (a scenario reflecting pessimistic assumptions and assessments).

Bridge Expansion and Assumptions

Cement consumption associated with bridge expansion is based on assessments made regarding congestion levels and is not based on spending assumptions. Not only is this approach consistently used across other horizontal markets (roadways, airports, etc.), but it rests upon the idea that the level of urgency to spend is directly linked to the level of congestion. Urgency to spend, in turn, dictates funding levels and expansion efforts.

Demographic changes are expected to be powerful influencers in the amount of future bridge expansions. PCA defines "expansion" as adding to the existing levels of bridge square meters. This can be achieved by adding an entirely new bridge or by widening an existing bridge (Functionally Obsolete). PCA does not make a cement intensity distinction between the two forms of expansion. Demographic changes that are expected to occur during the next 25 years play an important role in determining bridge congestion levels.

Consider the following:

- Baseline population is expected to grow by 59 million persons – representing a 17.4% increase to 380 million persons by 2040 (High-growth scenario: 20.4%/390 million; Low-growth scenario: 14.3%/370 million).

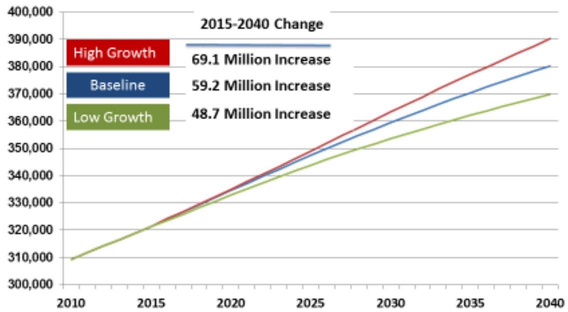
- As population grows, the number of licensed drivers will also increase. Licensed drivers is expected to grow by nearly 40 million drivers under the baseline scenario, 46 million drivers under the high-growth scenario, and 32 million drivers under the low-growth scenario. The percentage growth rates generally reflect the growth rates for total population.

- As the number of licensed drivers increase, the number of vehicles on the road is also expected to increase. According to PCA baseline estimates, vehicles on the road are expected to increase by nearly 53 million vehicles. Under the high-growth scenario, vehicles on the road increase by 61 million vehicles and only 44 million under the low-growth scenario.

- With more drivers and vehicles on the road, total annual vehicle miles travelled (VMT) is expected to increase by 600 billion miles by 2040 under the baseline scenario. According to the high-growth scenario, VMT increases by 1.7 trillion miles and is held basically constant at existing levels of roughly 3.0 trillion miles annually under the low-growth scenario.

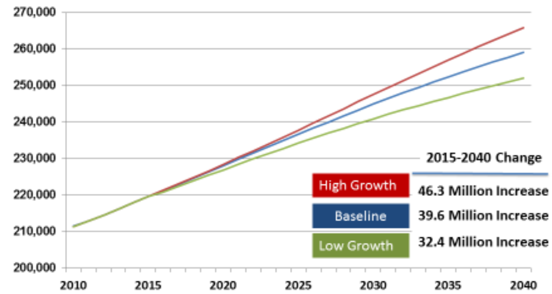
Based on these demographics, step-wise assessments lead to estimates regarding bridge crossings – and hence, annual bridge usage. Bridge crossing estimates are critical in formulating bridge congestion estimates and therefore bridge expansion calculations. Unfortunately, a consistent historical series of annual bridge crossings for the entire United States does not exist. Some data, however, exists on specific bridges and specifically structurally deficient bridges. According to ASCE, 187 ***million*** bridge crossings on structurally deficient bridges occurred ***daily*** in 2015. These bridges represent 9.3% of all bridges. While wrought with potential biases, this implies that 67.5 ***billion*** crossings on structurally deficient bridges occurred ***annually*** in 2015. Since this figure represents less than 10% of the total number of bridges, PCA estimates total bridge crossings at more than 730 billion crossings annually. Similar estimates were made with other years' sparse data to cross-check our estimates.

POPULATION
THOUSANDS OF PERSONS



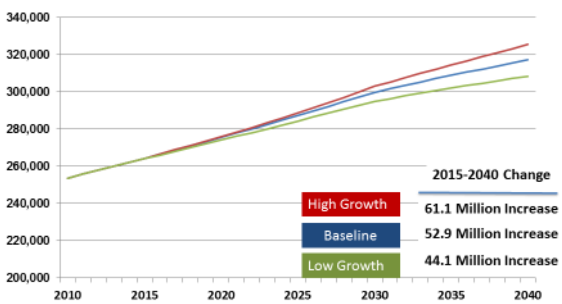
Source: Bureau of Census, Moody's & PCA estimates

LICENSED DRIVERS
THOUSANDS OF PERSONS



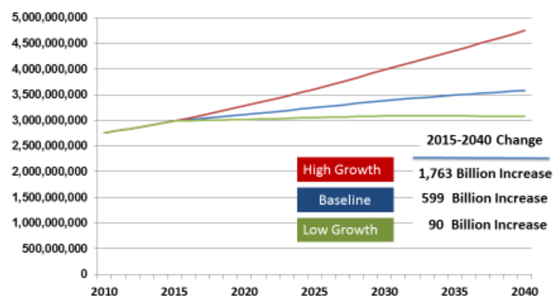
Source: Department of Transportation & PCA estimates

VEHICLES ON THE ROAD
THOUSANDS OF VEHICLES



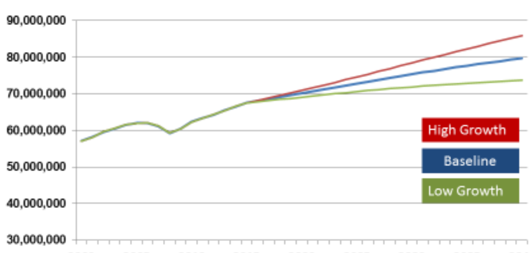
Source: Department of Transportation & PCA estimates

VEHICLES MILES TRAVELLED
THOUSANDS OF MILES TRAVELLED

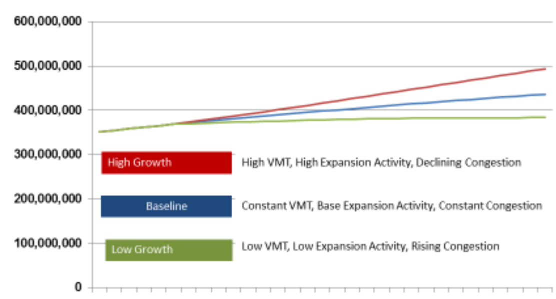


Source: Department of Transportation & PCA estimates

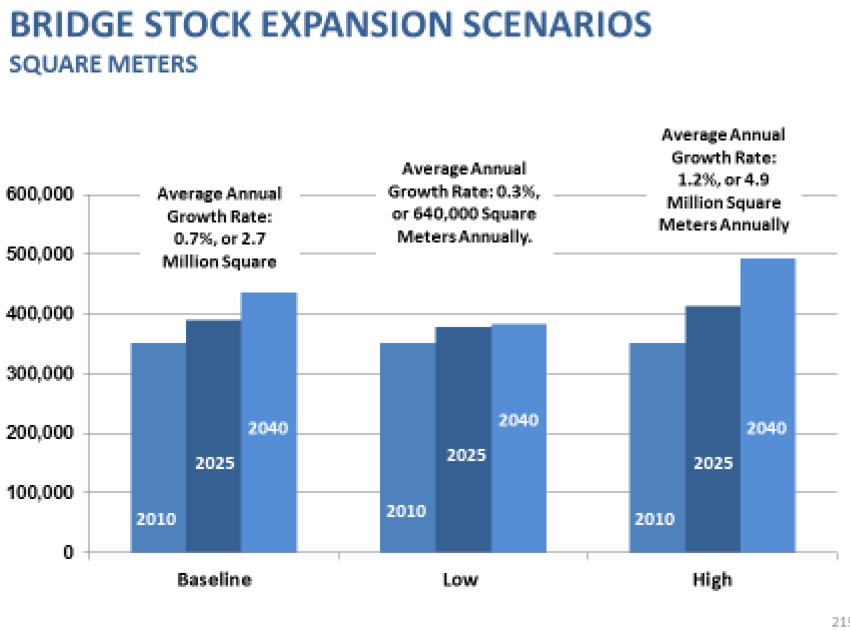
ESTIMATED ANNUAL BRIDGE CROSSINGS
NUMBER IN THOUSANDS, ANNUAL



TOTAL BRIDGE AREA IN SQUARE METERS



PCA assumes that the average annual bridge crossings is directly related to total VMT. This ratio is applied to historical VMT data to develop a history of bridge crossing data. Projected future VMT levels are estimated from expected future levels of population, licensed drivers, vehicles on the road, and average vehicle miles travelled per vehicle. Once VMT is projected, the bridge-to-VMT ratio is applied to estimate bridge crossings annually through 2040.



The baseline scenario assumes that existing congestion levels are held constant – neither deteriorating nor improving. The square meters of bridge area, according to this scenario, must rise at a rate exactly consistent with the bridge crossing growth rate during the 25-year forecast horizon. Bridge crossings are expected to rise from 733 billion in 2015 to nearly 867 billion in 2040. According to this methodology, an additional 66.7 million square meters of bridge area materializes by 2040 – reflecting an 18% increase. This translates into growth of roughly 0.7% annually or an average of 2.7 million square meter increase annually – compared to an average rate of 3.9 million square meters average annual expansion that materialized during 2006-2015.[1]

The high-growth scenario incorporates all supporting high-growth assumptions/assessments and assumes a 10% improvement in congestion levels against 2015 levels and measured against square meters of bridges per crossing. According to this scenario, an additional 123 million square meters of bridge area materializes by 2040 – reflecting a 33% increase. This translates into growth of roughly 1.2% annually or an average of 4.9 million square meter increase annually.

The low-growth scenario incorporates all supporting low-growth assumptions/assessments and assumes a 10% decline in congestion levels against 2015 levels and is measured against square meters of bridges per crossing. According to this scenario, an additional 15 million square meters of bridge area materializes by 2040 – reflecting a 4.2% increase. This translates into growth of roughly 0.3% annually or an average of 615 thousand square meter increase annually.

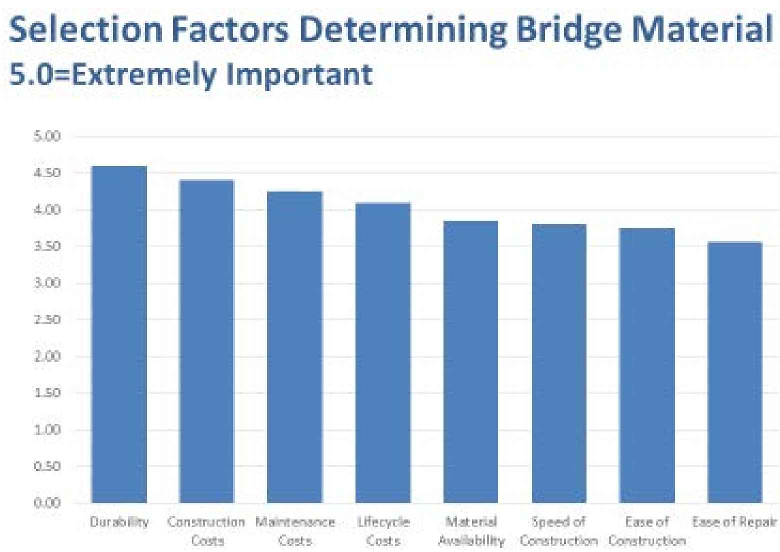
[1] The estimates provided in this report are based on the expectation of long run trends. The calculations make no provision for accelerated funding that may be associated with either the Trump Administration infrastructure program or other programs.

This scenario implies increased congestion and a heightened logistical drag to the economy. Theoretically, this drag could have macroeconomic impacts that would in turn impact bridge crossing estimates. PCA recognizes this point but does not include it in our assessment.

Based on the current average square meter area per bridge, and holding this level constant, this translates into more than 140,000 new bridges under the baseline scenario by 2040; 230,000 new bridges under the high-growth scenario; and only 55,000 new bridges under the low-growth scenario.

Market Share Assessments

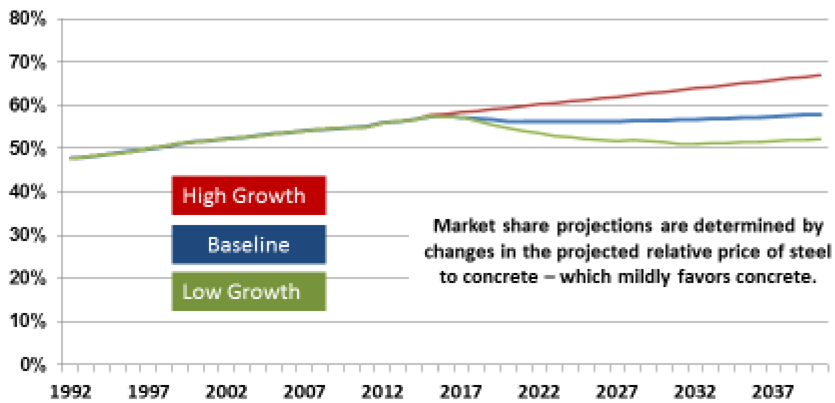
Concrete bridges currently represent nearly 58% of all bridges built. This reflects an increase from 52% in 2000. Durability and construction costs played a role in this market share improvement. The length of the bridge also play a role, with long bridges in excess of 150 feet favoring steel superstructures. While



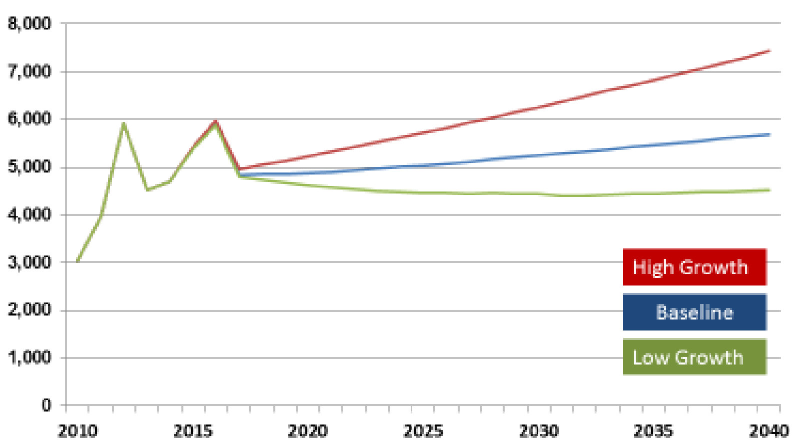
many factors can play a role in determining project bridge material selection, PCA has not included the potential of all these influences into its assessment. Instead, PCA focuses only on relative rated price changes as determining market share. PCA does not project cement or concrete prices due to anti-trust concerns. We assume, however, that concrete prices will rise at a rate equal to long-run inflation, or roughly 2% annually through the 25-year forecast horizon.

Changes in relative prices, and hence market share, depend on whether steel prices will rise at a rate faster or slower than inflation (Faster = concrete's relative price position improves. Slower = concrete's relative price position deteriorates.). PCA projects steel prices going forward. Our steel pricing model is rather simple and dependent on world economic growth conditions. China produces nearly 45% of the world's steel. This structural condition is likely to characterize the market throughout the forecast horizon. Weaker economic conditions in China and worldwide imply a more aggressive export push from China. According to this scenario, lower imported steel prices are met with comparable reductions by domestic producers. This scenario results in a weakening in concrete's competition position. Stronger worldwide economic conditions imply stronger price increases and favor a strengthening in concrete's competitive position.

CONCRETE SHARE OF THE BRIDGE EXPANSION MARKET
AREA IN SQUARE METERS



BRIDGE EXPANSION CEMENT CONSUMPTION
THOUSAND METRIC TONS



Based on long-term world GDP estimates by various agencies and consulting firms, the world economy is expected to grow at an average of slightly less than 3% annually during the near term. Thereafter, an annual rate of more than 3% annually is expected to characterize the long term. Under no scenario does long-term global economic growth retreat. While temporal disturbances are likely to materialize in the 25-year future, they are impossible to predict accurately and are not included in PCA's long-term estimate.

According to the baseline scenario, growth in concrete prices marginally exceed the growth from steel prices during the next five years. This translates into an initial market share flattening and eventually giving way to a marginal decline in concrete share – declining a full 100 basis points from current levels long-term global economic growth retreat. While temporal disturbances are likely to materialize in the 25-year future, they are impossible to predict accurately and are not included in PCA's long-term estimate. As longer term growth accelerates, modest gains in concrete market share are expected to materialize – recapturing lost share and pushing share close to 58% by 2040.

Cement Consumption: Bridge Expansion

Combining the projections for new bridge construction measure in square meters with market share projections translates into projected growth in concrete bridge construction measured in square meters. These projections for square meters of concrete bridge construction are then converted into metric tons of cement by use of a constant cement intensity. According to the baseline projection, cement consumption associated with bridge expansion increases at a rate of 0.8% annually, and averages 5.2 million metric tons annually during 2016-2040. Under the low-growth scenario, cement consumption associated with bridge expansion increases at a rate of roughly 0.3% annually, and averages 4.6 million metric tons annually. Under the high-growth scenario, cement consumption associated with bridge expansion increases at a rate of 1.7% annually, and averages 6.1 million metric tons annually.

Bridge Rehabilitation and Replacement Assumptions

Structurally deficient bridges form the basis of repair activity according to the PCA scenario. Bridge rehabilitation and replacement activity occurs once a significant level of deterioration occurs. The term 'structurally deficient' refers to highway bridges if the deck, superstructure, substructure, or culvert is rated in "poor" condition by the National Bridge Inspection (NBI) rating scale.

Methodology

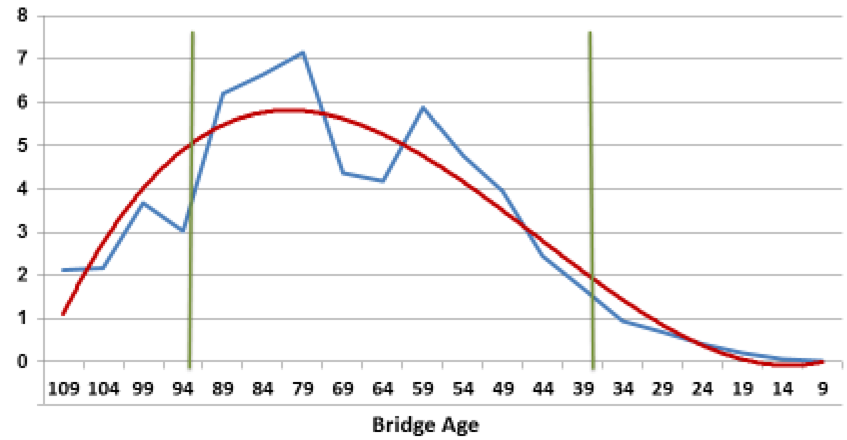
To estimate bridge rehabilitation and replacement activity, the pool of structurally deficient bridges must be estimated going into the future. According to the NBI, there are more than 610,000 bridges in the United States that total 369 million square meters in area. A number of bridges also exceed their expected lifespan of 50 years. The average age of an American bridge is **42 years.**

At first glance, it appears there is a correlation between bridge age and structurally deficient bridges. Slightly more than 80% of all structurally deficient bridges are between 39 and 94 years old – with the mean age nearly 68 years. While it is tempting to estimate the future pool of structurally deficient bridges by using an aging technique, PCA believes the correlation is actually reflective of crossings and usage – not age.

The combination of crossings and vehicle weights suggests the amount of stress endured by a bridge over its lifetime. This stress, or usage, is a better indicator than age because stress is likely to accelerate in the years ahead in the context of increased vehicle usage and heavier vehicles. This implies an accelerated movement of bridges into the structurally deficient status – as compared to an estimate based only on age.

AGE DISTRIBUTION OF STRUCTURALLY DEFICIENT BRIDGES

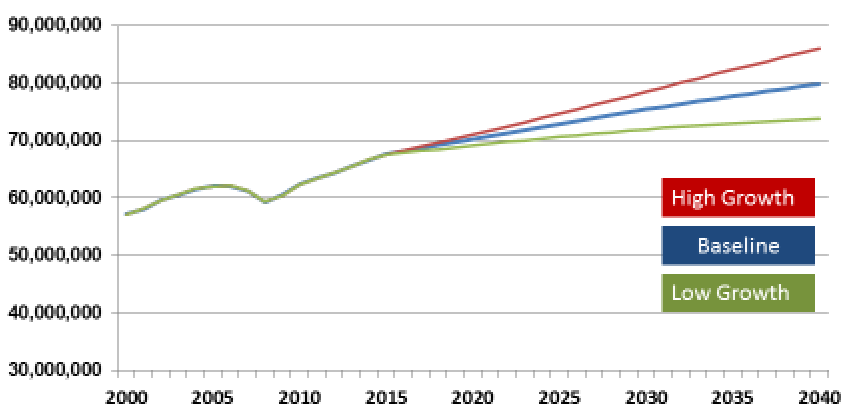
AGE % OF TOTAL



The age of bridges can be translated into average cumulative bridge crossings per age cohort by estimating total vehicle miles travelled (VMT) per year and constructing a historical bridge crossing data series. As bridge crossings accelerate, the pool of structurally deficient bridges, measured in square meters, accelerates unless met by even more rapid repair spending. The proportion of each age cohort that fall into the structurally deficient category can also be translated into bridge crossings.

ESTIMATED ANNUAL BRIDGE CROSSINGS

NUMBER IN THOUSANDS, ANNUAL



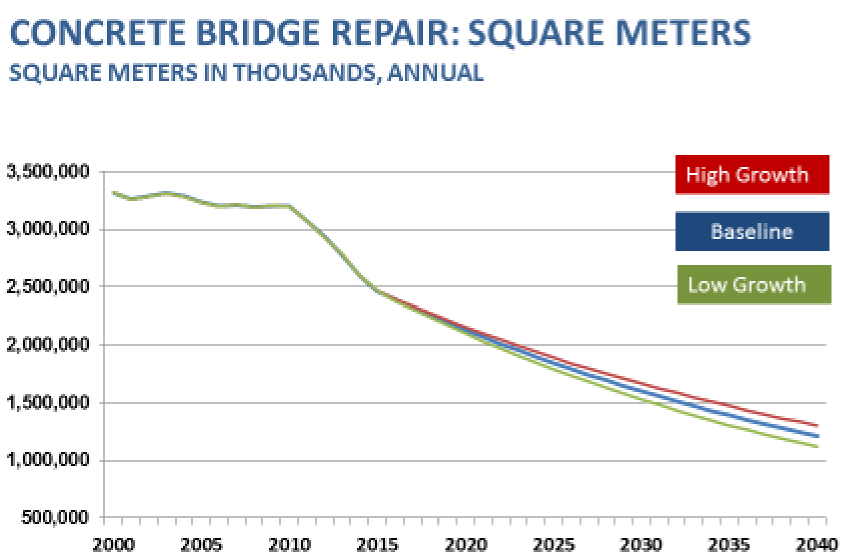
According to these calculations, more than 40% of all bridges with more than 125 million crossings during its life fall into the structurally deficient category. Similarly, 23% of all bridges with more than 110 to 125 million crossings, 12% with 100 to 109 million crossings contribute to the estimated pool of structurally deficient bridges. Below a level of 100 million lifetime crossings for a bridge the rate of contribution to the pool of structurally deficient bridges declines rapidly. PCA calculates the cumulative bridge crossings for all bridges and uses these replacement rates to determine the pool of structurally deficient bridges. Historical spending data on bridge replacement, major rehabilitation and minor rehabilitation is compared against the historical pool of structurally deficient bridges to serve as a proxy for repair activity.

Cement Consumption: Bridge Replacement & Repair

During the last 10 years, an average of slightly more than 2.9 million square meters of bridges were repaired. This repair activity averaged 1.5 million square meters of minor rehabilitation work (52%), 1.3 million square meters of bridge replacement activity (45%), and roughly 140,000 square meters of major rehabilitation activity (3%).

Bridge construction repair activity has been declining at an average rate of 5% annually during the past five years. This decline, at least partially, reflects the shrinking pool of structurally deficient bridges. The pool of structurally deficient bridges has declined from 32.5 million square meters in 2005 (accounting for 9.8% of all bridges) to 24.8 million square meters in 2015 (accounting for 6.7% of all bridges) – representing nearly a 23% decline. This decline reflects elevated bridge repair spending and concrete's gain in market share. As the composition of bridges favors concrete, and they are more durable, the rate of growth in the pool of structurally deficient bridges slows.

Total repair activity is expected to decline throughout the forecast horizon. The pool of structurally deficient bridges is expected to reach less than 19 million square meters by 2025 (4.7% of all bridges) and 12.1 million square meters by 2040 (2.8% of all bridges). With the shrinking pool of structurally deficient bridges, repair activity is expected to decline. During 2010-2016 repair and rehabilitation accounted for an average of 1,160,000 metric tons of cement consumption annually. During 2017-2040 this source of cement consumption is expected to average 991,000 metric tons annually.



The distribution of repair activity (replacement versus rehabilitation) is expected to reflect the average of the preceding 10 years. While minor rehabilitation construction accounts for 52% of bridge repair construction activity, it also carries the smallest cement intensity per square meter of construction activity. The low cement intensity more than offsets the amount of construction repair activity associated with minor bridge rehabilitation. As a result, minor bridge rehabilitation is expected to contribute only 20% of total bridge repair cement consumption. Replacement activity accounts for 45% of bridge repair construction activity and also carries a high cement intensity per square meter of construction activity. Replacement activity accounts for roughly 75% of cement consumption arising from bridge repair activity. Finally, major rehabilitation bridge replacement activity accounts for a small portion of bridge repair construction activity and cement consumption.

Total Bridge Cement Consumption

Total cement consumption attributed to bridge construction activities is expected to average 6.2 million metric tons annually during 2017-2040. This compares against a 2010-2016 average of 5.9 million metric tons. This reflects an average annual growth rate of 0.3% during 2017-2040. More aggressive growth in cement consumption (0.8% annually) attributed to bridge expansion is partially offset by declining activity attributed to repair and maintenance. This is reflected in the composition of cement consumption and gradually favors expansion construction activity. Cement consumption attributed to expansion construction activity accounted for 81.4% in 2015. By 2025 expansion construction activity is expected to account for 82.7% and by 2040 87.9%.