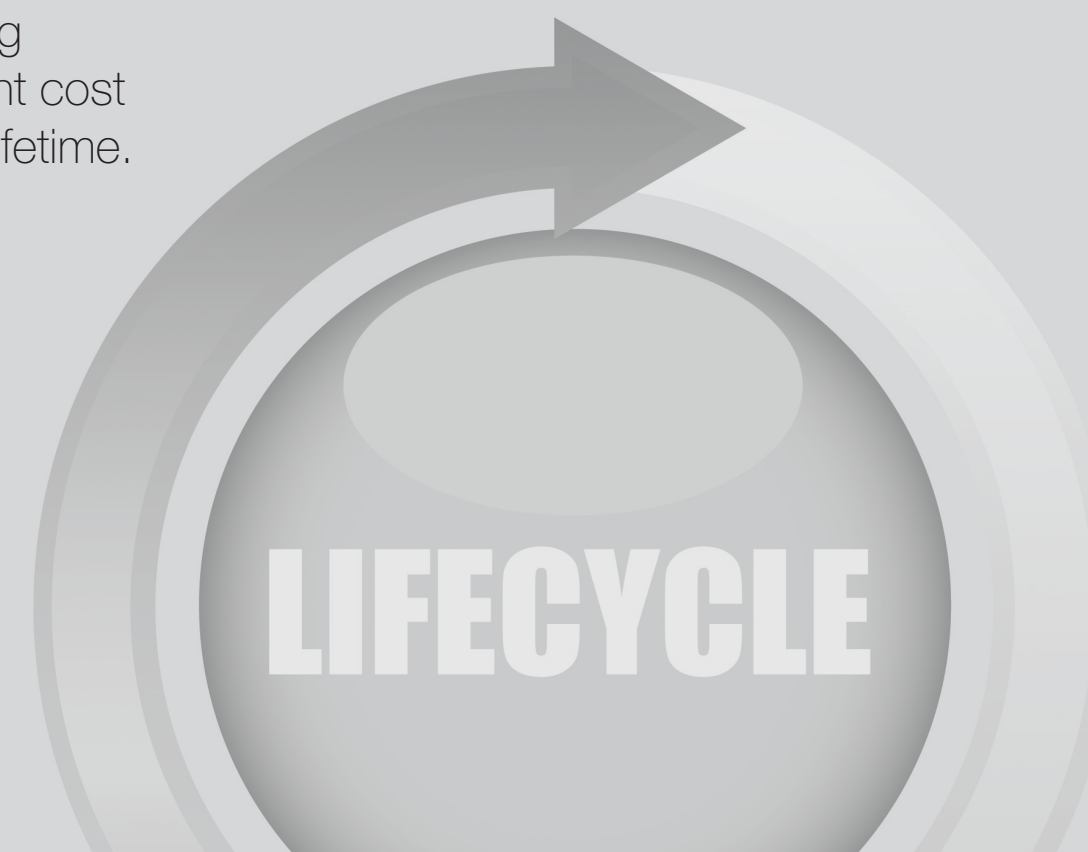




NX INFRASTRUCTURE LIFE CYCLE COST ANALYSIS



Life Cycle Cost Analysis (LCCA) is a method of analyzing infrastructure investment cost options over a design lifetime.



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Life Cycle Costs Analysis (LCCA) is a method of analyzing infrastructure investment cost options over a design lifetime and includes the initial construction cost and the costs of downstream repairs adjusted back to a present value using a real discount rate (which accounts for both the nominal interest rate less the inflation rate).



The US Federal Highway Way Administration advocates the use of life cycle cost analysis in bridge design and material selection. For bridges, life cycle costs are computed from the time at which corrosion of the rebar starts to where patching and overlay of the deck surface is no longer viable, so that replacement of the deck is required.

In bridge infrastructure economics, a major cause of bridge maintenance costs relates to deck deterioration arising from corrosion of the rebar selected, which creates stresses in the concrete, because the volume of the corrosion product (rust) is greater than that of the steel from which it is formed. When this occurs, local cracking, delamination and spalling of the concrete will be visible to the naked eye and eventually potholes will be formed on the bridge deck. When about 10% of the deck area has been patched, ride quality deteriorates sufficiently so that more serious and expensive rehabilitation (typically, installation of an overlay) must be

undertaken to extend the life of the bridge. Eventually, if the design life is not reached, the deck and overlay deteriorate to such a degree that replacement of the deck is required.

Wiss, Janney, Elstner Associates, Inc. (WJE) have recently applied a sophisticated computer model to assess the service lives and associated life cycle costs for a bridge deck constructed using (1) black bar, (2) MMFX-II rebar, (3) epoxy coated rebar (ECR), (4) solid Type 304 stainless steel rebar, (5) NX Type 316L clad stainless rebar (NX-SCR™), and (6) solid Type 316L stainless steel rebar. The analysis is based on 100 years design life and considers the differing levels of corrosion resistance inherent with each of these alternative reinforcing bars. The model assumes severe chloride contamination of the bridge deck surface, using a surface chloride concentration of 26 lb/yd³ (based on measurements of 9 bridges in Iowa and Virginia in 2001 and 2002).

The major conclusions from the WJE study were:

- The initiation of corrosion and rate of damage accumulation are slowed for bars having higher chloride thresholds: when the threshold approaches the surface concentration, very durable performance is predicted.
- NX-SCR™ provides the lowest annualized life cycle costs for real discount rates up to 4% p.a. depending on the life assumed for overlays installed when 10% damage has occurred.
- Even with favorable assumptions about their corrosion resistance, black bar, MMFX-II rebar, epoxy coated rebar (ECR), and solid Type 304 stainless steel rebar do not achieve 100 years life without costly bridge deck replacement and related disruption to traffic.

- NX-SCR™ and solid Type 316L stainless steel are expected to exceed 100 year life without deck replacement.
- The model considers only the direct costs of repairs. If consideration is given to user costs, e.g. the costs associated with the disruption of traffic to the State economy, the relative position of NX-SCR™ improves further.
- The model conservatively considers that the ends of NX-SCR™ are not capped, resulting in localized corrosion performance similar to black bar, but shows that this has only a minimal effect on the predicted life compared with solid Type 316L stainless steel rebar. In practice and according to the AASHTO specification for stainless clad rebar, NX-SCR™ rebar is shipped and installed with end-caps.
- The first three materials are expected to suffer from corrosion damage at lower chloride concentrations ranging from 1.5 to 12 lb/yd, whereas NX-SCR™ and solid Type 316 stainless steel are expected to remain corrosion free at, and possibly beyond, chloride concentrations of 15 lb/yd, and then only to corrode slowly above this level.
- The lifetimes predicted by the model for black bar and for ECR are in agreement with experience. There is only limited in-service performance data for the stainless steels or NX-SCR™ for comparison.

Type of rebar	Corrosion resistance	Handling	Service life	FHWA required bridge life	Current mkt price index	Life cycle cost ranking
NX-SCR™ ⁽¹⁾	very high	very good	>100 yrs	yes	280	1
	• stainless clad rebar • does not corrode in concrete structures • lowest total life cycle cost of CRR alternatives					
Solid stainless steel rebar (316) ⁽¹⁾	very high	very good	>100 yrs	yes	380	2
	• various producers • does not corrode in concrete structures					
Epoxy coated rebar	low	very poor	20-40 yrs	no	100	3
	• traditional US market standard • limited corrosion resistance • coating can be easily damaged and product cannot be fabricated on site					
MMFX rebar	low	very good	15-40 yrs	no	140	4
	• micro-composite steel (i.e low carbon, chromium alloy) • high strength, moderate corrosion resistance					
Galvanized rebar	medium	medium	20-40 yrs	no	110	not available
	• coated with a proactive layer of zinc • better bond to the cement (compared to ECR) and less fragile coating					