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TRANSPORTATION

Aging Highway Bridges

Canada has developed a decision-support system for managing the risks associated with aging highway bridges.

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Both owners and users of bridges expect them to have a service life of 50 to 100 years, with only routine maintenance. But demands on most of our bridges have been increasing annually because of growing traffic volumes, higher loads, and harsher environments. These conditions, coupled with the inadequate funding allocated for maintenance, have led to the accelerated aging and extensive deterioration of these critical structures.

Over 40% of the bridges across Canada are over 40 years old and a significant percentage of them are structurally or functionally deficient, which means they require costly rehabilitation and replacement. The consequences of a bridge failure can vary from a minor disruption of traffic to catastrophic collapse with injuries and loss of life and. Therefore, rigorous approaches are needed for predicting performance and assessing the failure risk.

Owners [i.e. Municipalities and transportation authorities] need decision-support tools to help them ensure that the risk of failure is kept at an acceptably low level throughout the life cycle of each bridge. An effective bridge management plan should provide the owners with a priority list of bridge projects that should be scheduled for detailed inspection, maintenance, rehabilitation and renewal for each year within a specified period or life cycle.

The priority lists need to be generated using rigorous models for predicting performance and assessing risk. The selection of cost-effective maintenance options requires reliable estimates of all costs to be incurred during the life cycle of a bridge, which in turn require reliable predictions of the service life for all maintenance and rehabilitation options.

To help owners and engineers address these challenges, researchers at the National Research Council Institute for Research in Construction (NRC-IRC) have developed innovative approaches for the life cycle management of highway bridges.

Specifically, they have developed models for predicting deterioration, assessing risk, and optimizing maintenance -- with a particular emphasis on concrete bridge decks. The latter are directly exposed to traffic and the damaging effects of the de-icing salts that are applied to roads during winter, and which result in corrosion-induced deterioration. It is estimated that about one third to one half of the projected bridge rehabilitation costs in North America are allocated to bridge decks.

Qualitative and quantitative models developed

Two classes of models have been developed at NRC-IRC for the performance prediction of bridge components, systems and networks. These models are based on a stochastic modeling of bridge performance that accounts for its time-dependence and uncertainty.

The class-1 models are based on qualitative stochastic cumulative damage models, which are used to provide estimates of the life cycle performance of a bridge or a network of bridges, as well as long-term estimates of maintenance funding needs. These models are simple to use and can be developed from relatively limited historical data, considering the impacts of key parameters that affect bridge deterioration (e.g. environmental conditions, structural system type, traffic loading). Using the prediction capabilities of this model, the condition of a bridge (or a network) is rated using qualitative performance indicators obtained from a visual inspection and non-destructive evaluation.

The class-2 models are quantitative stochastic performance prediction models, which are used for high-risk and safety-critical bridge components, as well as for the detailed and final analysis of a given bridge. These models will enable a quantitative assessment of the safety and serviceability of a bridge and will provide a more accurate assessment of the risk of failure and life cycle cost.

Risk of failure used as criterion

Knowing the failure risk level of aging bridges (e.g. fatalities and injuries, major traffic disruption, high rehabilitation and/or user costs), enables owners to prioritize bridges for maintenance and rehabilitation. The risk of failure of a bridge is defined as the consequences of its failure weighted by its likelihood of failure. The use of the risk of failure as a criterion for making maintenance decisions will enable owners to maximize public safety and the reliability of its bridges.

Lifecycle costs for different designs determined

The life cycle cost analysis technique is an economic evaluation method that compares the total costs incurred throughout the life cycle of a bridge for different design alternatives. These costs are classified into two categories: (i) owners' costs, which include the costs of design, construction, inspection, maintenance, repair, rehabilitation and replacement; and (ii) user costs, which include travel delay costs, accident costs, vehicle operating costs, environmental costs, etc. Since various costs are incurred at different points in time, they are converted to present values using an appropriate discount rate.

The incorporation of such tools into a management system will help bridge owners improve the performance of its bridges, extend their service life and keep the failure risk at acceptable levels. For further information, go to http://irc.nrc-cnrc.gc.ca/ui/cs/lifecycle_e.html

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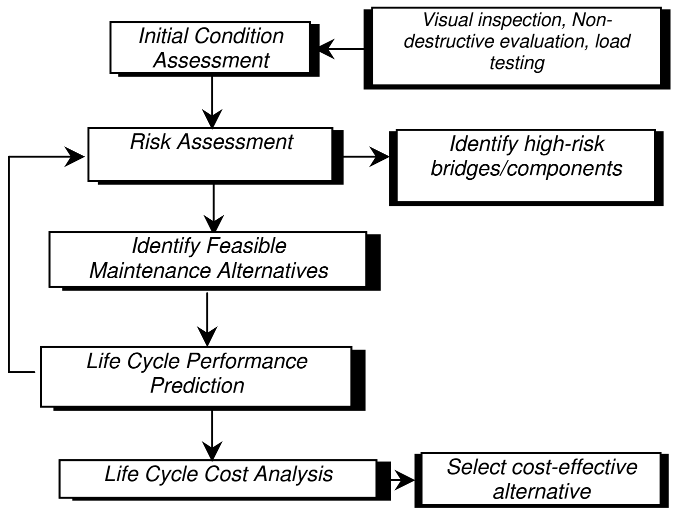

Integration of decision support tools for life cycle bridge management