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# Computational platform for the integrated life-cycle management of highway bridges

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ABSTRACT

Throughout their service life, highway bridges are subject to progressive deterioration in performance; an issue that may render the use of these facilities unsafe at some point in time. Over the last few decades, there has been successful research towards developing procedures for establishing the various vital elements required in the life-cycle management of civil infrastructure. It is noted, however, that frameworks for integrating these elements together are lacking. The objective of this paper is to present an integrated framework for the life-cycle management of highway bridges in the form of a detailed computational platform. The elements integrated into the framework include the advanced assessment of life-cycle performance, analysis of system and component performance interaction, advanced maintenance optimization, and updating the life-cycle performance by information obtained from structural health monitoring and controlled testing.



## 1. Introduction

Throughout their service life, highway bridges are subject to progressive deterioration in performance; an issue that may render the use of these facilities unsafe at some point in time. The importance of predicting the changes in performance is one thing, but being able to optimally maintain this performance satisfactorily may pose a challenge. Further yet, the agreement between the prediction and the true performance is a matter shaped by uncertainties in what information is available and how representative it is. These uncertainties should be constantly put to the test, properly handled, and reduced when possible.

Over the last few decades, there has been successful research towards developing procedures for establishing the various vital elements required in the life-cycle management of highway bridges [1]. These elements include the life-cycle performance measures, maintenance optimization formulations, and reduction of epistemic uncertainty by integrating information obtained from SHM and controlled testing among others.

A multitude of life-cycle performance measures are now available [2–4]. However, the selection of the proper measures has to be made by considering their ability to be integrated in the life-cycle management framework and interact properly with all its other relevant elements. For instance, the selected performance measure should facilitate a proper maintenance optimization solution. This requires the performance measure to accurately represent the intended structural quality, and not to pose a computational burden in solving the optimization problem.

Several maintenance optimization formulations have been developed during the last two decades. However, the advances in genetic algorithms (GA) in the last decade [5] have accelerated progress in developing complex multi-objective maintenance optimization formulations. A key reason for this outcome is that GAs are capable of analyzing the optimality of a population of solutions simultaneously at each iteration (called generation in GA terminology). This eventually provides a Pareto-optimal set per a GA optimization solution, as opposed to only one optimum solution per a conventional optimization solution. Another key reason for using GAs is that their operations can be conducted on the corresponding encodings of the design variables. This encoding can be binary, simulated-binary (for continuous real variables), and integer. In fact, the GA operations are robust and flexible enough to handle any desired logical encoding. This is a significant advantage for solving complex maintenance optimization problems. Introducing mixtures of innovative encodings, and the ability of GAs to handle them, has significantly improved the state of maintenance optimization process [6–14].

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