Cost-Benefit Criteria in Optimizing Maintenance Strategies

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Summary

The life extension of existing deteriorating structures requires maintenance interventions which allow partial or complete rehabilitation. However, such maintenance interventions have to be economically reasonable, that is, maintenance expenditures have to be outweighed by expected future benefits. For this purpose cost-benefit criteria are developed herein, which not only allow to specify optimal sequences of maintenance times and rehabilitation efforts, but which also allow to determine optimal lifetimes and acceptable failure rates. Numerical examples show, that deferring decisions with respect to maintenance not only results, in general, in higher losses, but also in no longer acceptable, that is, potentially hazardous structures.

Keywords: Rehabilitation; cost-benefit analysis; optimization; structural safety; maintenance.

1. Introduction

In recent years increasingly consideration has been given to the life extension of deteriorating structures. This is based on the simple fact that a growing percentage of civil infrastructure is threatened by obsolescence and that due to monetary reasons this can no longer be countered by simply re-building everything anew. Hence maintenance strategies are required which allow partial or complete structural rehabilitation. However, maintenance strategies have to be economically reasonable, that is, maintenance expenditures have to be outweighed by expected future benefits. If this is not the case, then indeed the structure is obsolete—at least in its current functional, economic, technical, or social configuration—and innovative alternatives have to be evaluated.

Thus, the overall objective of maintenance interventions is to find an optimal balance between recovering the profitability of structural operation over a designated time horizon and the maintenance expenditures spent—without compromising safety issues. This paper discusses optimum maintenance planning (optimal sequence of maintenance times and rehabilitation levels, as well as optimal lifetimes) by maximizing the expected net present benefit rate. The underlying formulation is as follows: (a) between maintenance interventions structural deterioration is modeled by a continuous-time Markov chain; (b) maintenance interventions can take place anytime throughout lifetime and comprise the rehabilitation of all deterioration states above a certain minimum level; and (c) maintenance interventions are optimized based on cost-benefit criteria, that is, by taking into account not only all life-cycle costs (construction, failure, inspection and state-dependent rehabilitation costs), but also (state- or time-dependent) benefit rates.

2. Modeling structural deterioration and failure

When optimizing maintenance interventions, it is mandatory to have a description of structural deterioration in terms of (directly or indirectly) observable damage or deterioration states, which can be related to specific structural performance conditions—including its effect on the load carrying capacity and the remaining lifetime—as well as rehabilitation actions [1,2]. Moreover, since

https://doi.org/10.2749/weimar.2007.0504