Improving infrastructure-asset management through reasoning that is compatible with mental models of engineers

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Abstract. Infrastructure asset-management decision making is improved when there is accurate knowledge of real behaviour. Site inspection, sensing and judicious model-based data-interpretation improves knowledge of real behaviour. This knowledge may reveal previously unknown reserve capacity, especially when the critical limit state occurs under nominally elastic stresses (for example, deflection and fatigue). Good data-interpretation techniques need to be accurate, robust with respect to unknown aspects of uncertainty and understandable by practising engineers. This paper focuses principally on this third requirement. Since information related to structural behaviour may become available gradually over periods of several years, bridge engineers need to employ methods that are easy to understand while accommodating essential aspects such as model uncertainty. An interactive approach called error-domain model falsification is described in this paper. Several aspects of this approach make it more understandable to practising engineers compared with Bayesian model updating. A case study is used to illustrate important aspects.

1. Introduction

A recent report by the World Economic Forum (WEF, 2014) stated that infrastructure demand exceeds supply (existing structures plus new construction) by $1 trillion per year and this gap is increasing each year. It is not likely that over the long term it will be possible to reduce demand. It is equally unlikely that the rate of supply of new construction will be able to increase so much as to make up this difference. The only viable solution is to manage existing infrastructure more efficiently, including repair, retrofit and improvement, so that needs for complete replacement are minimized, thus creating the situation where most infrastructure elements last indefinitely.

Fortunately, there is usually reserve capacity in infrastructure at levels much above the codified safety and serviceability requirements. Adding reserve capacity during design is justifiable due to the high-risks involved, particularly within contexts of incomplete knowledge of conditions on constructions sites. The challenge is that once an infrastructure element, such as a bridge, has passed the construction stage, this reserve capacity is unknown. Also, behavior models used during design are usually so conservative that they provide poor support for estimating reserve capacity.

Measurement of behavior has much potential to improve asset management. Through identifying good behavior models, future management challenges - such as evaluating the effects of load increases, bridge widening, adding cycling lanes, vehicle damage and deterioration - are supported so that actions can be optimized. However, interpreting measurement data is hard since there is much uncertainty from many sources. While there are entire journals, yearly conferences and books that present results from research into structural health monitoring, for example (Catbas et al, 2013) , most provide proposals for damage detection; very few deal with the special context of infrastructure asset management where reserve capacity is of interest.

This paper describes a data-interpretation methodology called Error Domain Model Falsification (EDMF) that is intended to be used to interpret data taken from measurement of large infrastructure elements for the purposes of asset management. A case study of a bridge