Enabling better bridge management by understanding risk

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Abstract:

Bridge and culvert management is transitioning from a maintenance management approach to an asset management approach. Both approaches are underpinned by Level 2 inspections. While technical aspects of bridge condition rating are described in bridge inspection manuals published by various jurisdictions, there is currently significant variability in the way that such inspections are undertaken. In this paper, accreditation of both bridge inspectors and agency business processes are proposed. The intention is that this paper form the basis for discussion, and if appropriate, the development of accreditation processes to improve bridge inspection, and consequently bridge management outcomes. Regardless of the status of transition from maintenance management to asset management for a particular organisation, improved assurance of Level 2 inspection data can enhance organisational outcomes.

Keywords: Risk Management, Bridge Inspection, Accreditation

1. Introduction

Bridge management business processes have not changed significantly in most jurisdiction since the last decade of the 20th century. The disciplines of risk management and asset management have changed significantly in the intervening period. Consequently, there is a need to transform business processes associated with bridge inspection and management. Regardless of an organisation’s transitional journey, improved assurance in relation to bridge inspection is beneficial. This paper provides a review of both risk management (in an asset management context), and bridge inspection, before proposing systematic improvement for bridge inspection, with the objective of fostering engagement and discussion.
2. Background

2.1 Bridge maintenance prioritisation and risk

Review of international bridge management revealed that most international jurisdictions prioritise maintenance investment via prioritisation scores. This typically entails programmed inspections, and collation of structure condition data obtained from these inspections to develop a maintenance prioritisation score. As an example, the Queensland Department of Transport and Main Roads (TMR) uses an algorithm known as WhichBridge (Johannessen et al, 2019), and these scores are often used as a proxy for risk quantification (with inspections acting as risk detectors). WhichBridge pre-date more recent risk philosophies such as that set out in AS-NZS ISO 31000 (2009). More recently there have been examples where revised methodologies for bridge risk/prioritisation have been developed using risk concepts founded on AS-NZS ISO 31000 (2009), and these are now operational (Telfer, 2018). Preliminary indications are positive from these emerging developments.

McCarten (2018) asserts that bridge risk management methodologies require revision. He notes that analytical tools are used by bridge managers to develop maintenance, rehabilitation and replacement programs based on inventory, inspection and monitoring data. Decision making in bridge management is often based on cost-benefit analysis, which is informed by data from the analytical tools, but this usually does not provide a high level of transparency for the risk management decisions made (McCarten 2018). A credibility gap arises when decisions made based on these processes do not match up with the expectations of the community or the legal risk requirements in the case of a catastrophic event occurring.

McCarten (2018) states that bridge risk management planning needs to consider the following key elements:

- what can happen, how and why – by identifying the range of hazardous effects and the associated range of impacts on the structure response
- the possible consequences (in terms of impacts on objectives) and the factors influencing them
- the likelihood of the consequences and understanding what may affect the likelihood
- the effectiveness of controls in modifying the consequences or their likelihood
- the acceptability of the risk or the need for mitigation.

This approach is consistent with AS-NZS ISO 31000 (2009), and McCarten (2018) asserts that by following this process and developing processes consistent with accepted risk management standards, asset managers can better prevent catastrophic events from occurring and be better placed to respond to such an event should it occur.

2.2 Maintenance Management to Asset Management Transition

Bridge managers are transitioning from a maintenance management focus to an asset management focus, as illustrated by the respective frameworks in Figure 1 and Figure 2. Decision making is central to both frameworks, and Level 2 bridge inspection is a key activity supporting bridge management in both frameworks, but the way in which data is used, and the organisational culture and expectations regarding data vary significantly as each organisation transitions. Regardless of an organisations
progress in transitioning from maintenance management to asset management improvements in condition data collection are still beneficial to decision (business) processes.

Figure 1 Typical bridge maintenance management framework

Figure 2 Typical bridge asset management framework
3. Best practice risk management of assets

Mining legislation has driven risk management focus for over 25 years, and current mining practice is consistent with AS-NZS ISO 31000 (2009). Development of this methodology in the mining sector was driven in the past 15 years by the reality that mining houses had reached a point where more investment to reduce risk was resulting in unacceptable performance losses. A focus was therefore put on the balancing and optimisation of cost, risk and performance (fundamental to modern asset management decision making). This was achieved by ensuring clear links between operational risk and financial performance to ensure that systems are operating at full potential and available funding is being used as effectively as possible. Key to this was the development of in-depth management of risk and control measures, and continual review and improvement of controls (Quartile One, 2019). Key elements if this approach include (Quartile One, 2019):

- Risk appetite policy: clearly defines the level of risk that the organisation is prepared to accept.
- Risk register: this allows threats, hazards and associated risks to be captured and documented.
- Risk matrix: allows risks to be rated based on consequence and likelihood. Matrix should be easy to use and understandable by all staff.
- Risk owners: the individual or entity who is responsible for the management of a certain risk. They must be clearly identified, and the risk owner must be comprehensively involved in the risk management process.
- Risk controls: human actions, devices, or combined systems which work to identify, prevent or mitigate the occurrence of an unwanted event. Each identified risk may have one or several associated controls.
  - Critical controls: controls linked to the prevention of fatalities or associated with previous incidents which require additional verification to ensure they are operating as required.
  - Inherent risk is the risk that is present before existing controls are considered, while residual risk is the risk present after consideration of existing controls.
  - The effectiveness of controls determines the actual effective reduction in inherent risk associated with any hazard and unwanted event, ensuring that the residual risk is an accurate reflection of the situation.
- Continual review of risks and control effectiveness: this must occur at all levels of an organisation. Critical controls must be continually verified to ensure that they are operating and reducing risk as expected.
- Bow tie diagrams: provide a clear representation of the threats, consequences, controls and the hazards associated with the occurrence of an unwanted risk event.

The key components of a bow tie diagram are shown in Figure 3. On the far left are threats which have the potential to lead to the occurrence of an unwanted event. Between the threats and the occurrence of the event are arresting controls which aim to reduce the likelihood of the event occurring. Once an unwanted event occurs, mitigation controls are relied upon to reduce the severity of the consequences, which are on the far right of the diagram. Bow tie diagrams:
— provide a clear visualisation of the relationship between technical ‘bottom-up’ threats, and outcomes which relate to the ‘top-down’ corporate risk categories.
— support the review of control effectiveness.

Figure 3 Bow tie diagram template

Figure 4 Risk management planning and implementation process

Risk management must be entrenched at all levels of an organisation if it is to be effective. At the level of CEO and board, there must be oversight to ensure that critical controls are acting as expected and that the level of risk that the company is exposed to is consistent with the desired balance between risk, cost and performance. At the level of general management, critical control verification takes place which entails monitoring to ensure that controls have been implemented and are acting as expected as well as continual improvement tasks. Following the chain of responsibility downwards, frontline managers are responsible for ensuring that critical controls are in place and operating as expected before and during the execution of all tasks. Frontline workers must be aware of critical controls and understand their purpose. The risk management planning and implementation process as a whole is illustrated in Figure 4. It can be seen that feedback loops are required. If this above approach to risk is implemented for bridge management, then inspections will be one of the key risk controls, and control effectiveness would be heavily influenced by the reliability of bridge inspections and the associated data.

4. Level 2 Bridge Inspections: Current state

Bridge inspection is a key tool informing bridge management (Lake, et al, 2012). Most jurisdictions in Australia have implemented an approach to bridge inspection that can be summarised as:

1. Level 1 – Regular (yearly) operational inspection
2. Level 2 – Periodic (2 to 7 year) systematic component condition rating
3. Level 3 – Event driven technical investigation targeted at specific concerns, often triggered by Level 2 or Level 1 inspections.

ARRB has been active for almost 10 years in delivering Level 1 and 2 training workshops in many jurisdictions in Australia including, Queensland, New South Wales, Victoria, Tasmania, and commercially deliver projects for agencies at all 3 levels. Recent correspondence between ARRB and IPWEA suggests concern that Level 2 bridge inspection outcomes exhibit variability and inconsistency, creating difficulties when decisions are to be framed based on Level 2 inspection reports. This is consistent with ARRBs observations as both a bridge inspection training agency, and commercial service provider. The following general observations can be made regarding Level 2 bridge inspection practice in Australia:

1. Market prices often varying significantly for the same scope (up to a factor of 3)
2. The scope of services requested by agencies is quite variable
3. Issues with inspection data reliability & interpretation are relatively common
4. Business rules associated with incorporating bridge condition inspection data into the asset data base vary significantly between agencies
5. Benchmark Level 2 bridge inspection costs have halved over past 10 years.

A key source of variability is that humans undertake visual inspection of bridges. In a major research project undertaken by the Federal Highways Administration (FHWA) at the turn of the last century, a range of bridge inspections were undertaken, involving 49 inspectors undertaking the same inspection tasks on the same bridges. Key outcomes of that research were (Phares et al, 2001):
1. Bridge inspection results are subjective but have an impact on safety and maintenance of a bridge.
2. Bridge conditions rating differs between inspectors and from reference ratings.
3. Rating consistency is better for major elements (girders etc) compared with secondary elements (barriers, joints etc).
4. Inspector attributes influencing inspection rating include:
   a. Fear of traffic/heights
   b. Eyesight
   c. Extent of formal training
   d. Perception about maintenance, accessibility, complexity
5. Most inspectors reliably detect general defects (e.g., weathered paint), but there is much more variability associated with the detection of critical/local defects (e.g., fatigue cracks).
6. Inspection accuracy correlates with time, focus and comfort level (experience) of the inspector.

Two key sources of variability in inspection outcomes are therefore inconsistent market practice and inconsistent inspector preparation, and these inspection outcomes provide a key input into the management of risk under both management paradigms as follows:

1. Maintenance management – Inspections are risk “detectors”
2. Asset management – Inspections are a key risk controls

While bridge management is transitioning (Section 2.2) towards data driven decision making, this process is still in its infancy (Johnson et al, 2018), but regardless of the transition status, improved inspections are likely to lead to improved management of risk. In addition, best value does not necessarily result from current inspection processes, resulting in poorer outcomes for the agencies owning bridge assets.

5. Level 2 Bridge Inspections: Proposed improvements
ARRB has been collaborating with IPWEA to develop improvements in the consistency of Level 2 bridge condition inspections, on the basis that systematic improvements would appear to be relatively simple and cost effective, and are likely to deliver value to agencies managing bridges. In addition, it is possible that the proposed processes with also assist service providers.

The proposal is for IPWEA to develop accreditation processes for both individual inspectors and agencies as summaries in Table 1. The proposal for basic inspector accreditation are essentially intended as a response to address the issues identified by the FHWA (Phares et al, 2001). The advanced inspector accreditation is intended to support the basic accreditation with both a community of practice and provide a sound basis for inclusive continual improvement.

The basic business process accreditation is intended to provide a common basis for data to be scoped and incorporated into an agency. Note that these items all need to be included in the inspection scope of services provided to the market when tenders are issued. It is ARRBs experience that organisations that routinely include these items into the scope of services seem to gain
significantly more value for their investment in bridge condition inspection than those organisations that do not, and generally, the incremental cost of including these activities is minor.

The advanced business process accreditation is intended to support organisations that are pursuing alignment with ISO55001. This accreditation does not attempt to address ISO55001 accreditation, however it is intended to be supportive of same. It recognises that data collection and verification is central to ISO55001. It is proposed that the scope of advance business accreditation is limited to data collection, verification and integration, and that this would complement other potential ISO55001 activities in an agency.

Table 1. Bridge Management current state assessment

<table>
<thead>
<tr>
<th>Category</th>
<th>Inspector</th>
<th>Business Process</th>
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<tbody>
<tr>
<td>Basic</td>
<td>Competent Inspector</td>
<td>Competent business process</td>
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<tr>
<td></td>
<td>-Current medical certificate – eyes and ears</td>
<td>-Alignment kick-off meeting</td>
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<tr>
<td></td>
<td>-Satisfactorily completed recognised training course</td>
<td>-Inspector accreditation prescription</td>
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<tr>
<td></td>
<td>-Linked into a community of practice</td>
<td>-Action register generation</td>
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<td></td>
<td>-Sample of work audited on an annual basis</td>
<td>-Exceptions reviewed and tracked</td>
</tr>
<tr>
<td>Advanced</td>
<td>Senior Inspector</td>
<td>ISO55001 data integration</td>
</tr>
<tr>
<td></td>
<td>In addition to the above...</td>
<td>In addition to the above...</td>
</tr>
<tr>
<td></td>
<td>-Manager of inspection programs</td>
<td>-Inspection documentation consistent with ISO55001, particularly Sections 8 and 9.</td>
</tr>
<tr>
<td></td>
<td>-Current experience in the interpretation and use of inspection data</td>
<td>-Pilot inspections (alignment)</td>
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<tr>
<td></td>
<td>-Current experience in Level 3 investigations</td>
<td>-Data integration trial</td>
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<td></td>
<td></td>
<td>-Draft report (sample/pilot) &amp; final report</td>
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<td>-Asset group review workshop</td>
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6. Conclusions

The purpose of this paper is to propose systematic improvement to the manner in which Level 2 bridge condition inspections are undertaken and solicit feedback on same. Improved inspection outcomes should lead to improved management of risk, regardless of an agencies progress in transitioning from maintenance management to asset management.

It is proposed that IPWEA is the appropriate body oversee such an accreditation scheme, assuming there is broad support for such a scheme. The proposed approach would complement the inspection manuals that typically form the technical basis for Level 2 inspections. Preliminary accreditation framing is proposed in Table 1. Feedback in relation to the proposed approach is sought, and can be made via the authors of the paper, or via IPWEA.

Assuming there is support for accreditation consistent with Table 1 (or similar), the scope and cost of the scheme will require further development. It is anticipated that the cost of implementing such a scheme would not substantially impact the bridge inspection pricing, but would add significant value for stakeholders.

Acknowledgements

The support of the following is acknowledged and gratefully appreciated by the authors:

NACOE program – S49 Functional requirement for classification of bridge risk and maintenance/renewal priority project

David Wilson – TMR S49 project manager

Quartile One – S49 project collaborator

IPWEA, particularly Craig Moss for support and advice in relation to accreditation.

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