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New Zealand Transport Agency 'Data Driven Structures Asset Management' Framework

Dewi Todd-Jones, NZ Transport Agency Waka Kotahi

Abstract

NZTA has identified that redevelopment of its structures asset management framework is required to support the proactive management of existing state highway structures, and provide an evidence-based approach for funding which will address the risk profile of the asset base. In particular, there are three principal issues driving the need for change, these are:

- Digital uptake - Accelerating digital uptake is a core part of NZTA's priorities.
- Funding – There are numerous factors putting significant strain on funding, and so an effort to make sure that money is being invested wisely is paramount.
- Risk - The current NZTA inspection process only collects data on specific defects on a given element and does not give an idea of deterioration of other elements, or the asset as a whole.

The proposed 'Data Driven Structures Asset Management' framework is therefore a fully digital collection of processes that will capture risk in a comprehensive manner, assess risk in a consistent manner, and forecast maintenance and renewals costs in an accurate manner. These processes are:

- Element Based Condition Assessment Process
- Centralised Database and Risk Algorithms
- Refined Funding Request Process
- Optimised Intervention Forecasting
- Structures Asset Management Online Portal

Once established, the proposed framework will be heavily reliant on the accurate and consistent collection of structural condition data to be able to precisely track the performance of the asset base. Therefore, to make sure that 'data integrity' is always maintained, an 'Inspection Progression Pathway' will be instigated alongside the production of a suite of new technical documents, training courses and auditing procedures to make sure 'competency, certification and auditing' processes are embedded and maintained.

This paper describes the context, purpose, and outcomes of the proposed framework that represents a complete revolution of almost every aspect of how structures asset management will be performed in New Zealand in the future.

Keywords: structures asset management, data driven, auditing, data integrity, intervention forecasting

1. Introduction

NZ Transport Agency Waka Kotahi (NZTA) has identified that an evolution of its structures asset management framework is required to support the proactive management of its existing asset base and to provide an evidence-based approach for funding. The new approach will address the risk profile of the asset base and present a long-term strategy. It is therefore proposed that a ‘Data Driven Structures Asset Management’ (DDSAM) process be developed and implemented within the next 3 years.

2. Reasons for change

There are three principal issues driving the need for change. The first is the need to be more digitally focused, as accelerating digital uptake is a core part of NZTA’s strategic priorities.

To that end, the newly developed ‘NZTA Structures Maintenance Policy’ states the following digital structures asset management principle - *“Be data driven so that decisions are informed by quality data whenever possible. To achieve this, data on the condition of an asset is collected in a proactive manner using all available technology, and mechanisms and tools are put in place to enable quality data to be analysed, and then made available whenever decisions are made”*

The second key driver is funding. Currently, there are numerous factors putting significant strain on funding, and so an effort to make sure that money is being spent accurately has become paramount. In particular:

- **Increased demand on the network**: There are ever increasing demands on NZTA’s structures asset base due to population growth and increases in vehicle loading,
- **Natural hazard awareness**: Over the last couple of decades, there has been improved understanding and increased awareness of the vulnerability of structures in relation to the various natural hazards that New Zealand is subject to,
- **Ageing asset base:** The asset base is also getting older (as a country, a significant proportion of New Zealand’s current structures asset base was built either during the inter-war period or post war period, and as such we have two upcoming ‘bow waves’ of bridges reaching 100-years-old in the coming decades)
- **Inflationary cost increases:** There are cost inflation pressures, which have increased the cost of bridge maintenance and renewals considerably in the last several years.

Finally, there is risk. Several key issues have been identified with regards to the way NZTA currently deals with structures risk at a national level:

- **Inconsistent risk assessment:** Variability exists across consultants, regions, and even inspectors within regions, leading to inconsistent risk ratings for similar defects.
- **Limited condition data:** The existing NZTA inspection process focusses only on documenting defects rather than on capturing overall asset condition trends.
- **Short-term forecasting reliance:** Maintenance and renewal forecasts are largely based on engineering judgment, which complicates long-term planning for funding cycles.
- **Lack of data integration:** Existing records are often siloed, making it difficult to analyse long-term performance trends or compare data across regions.
- **Subjectivity in funding prioritisation:** Without an objective, quantitative method to compare different funding requests, decision-making is susceptible to bias or ad-hoc justifications.

3. Discussion on the current process

Due to the above noted issues, there is currently no mechanism ensuring that funders have confidence in the appropriateness of funding requests, nor in their ability to address asset risk needs effectively. This issue can therefore be framed through three key questions that need to be answered by any proposed structures asset management system:

- What outcomes will be achieved with the requested funding?
- What specific risks arise if a lower funding level is approved?
- How confident are the funders in the supplied figures?

Without clear, data-driven responses to these questions, funding decisions are susceptible to continued subjectivity, regional inconsistencies, and potential misallocation of financial resources.

Addressing these issues therefore requires improvements in three core areas:

1. **Comprehensive risk assessment and data capture:** More granular, standardised data is required to assess risk and deterioration trends accurately through numerical condition rating.
2. **Consistent risk evaluation standards:** A structured framework is necessary to ensure that all funding requests are evaluated using centralised uniform criteria.
3. **Improved forecasting capabilities:** Predictive analytics should be integrated to facilitate proactive maintenance rather than reactive repairs.

4. Implementation Considerations

There are numerous studies that have been undertaken over the last 20 to 30 years that outline the limitations of using numerical condition ratings, derived from visual inspections, to assess the state of bridges and inform maintenance decisions (Moore et al. 2001[1], Lea and Middleton 2002[2], Bennetts et al. 2020[3]).These ratings have been criticised for being qualitative, inconsistent, and potentially biased, raising doubts about their reliability in representing actual bridge conditions, and therefore their ability to help predict future maintenance needs.

This problem has been attributed to a number of different issues. Lea and Middleton 2002[2] and Bennetts et al. 2023[4] note that a lack of consistent and up-to-date guidance documents contributes to inconsistencies in inspection practices across different maintenance areas. It is further noted by Moore et al. 2001[1], Vardenaga et al. 2024[5], that a lack of formal training and certification means inspectors are not necessarily well-trained and competent. Finally, the establishment of quality control/quality assurance measures such as auditing is not always undertaken which leads to errors (Stewart and Melchers 1989[6]; Devendorf and Lewis 2008[7]).

Feedback from Australian and New Zealand road agencies in Austroads Engineering Guideline to Bridge Asset Management 2021[8] highlights several further issues: condition ratings tend to remain static due to slow deterioration rates and maintenance efforts; critical maintenance needs are sometimes overlooked while other maintenance is carried out when it wasn't necessary; and there is no universally applicable target condition number for bridges.

Furthermore, deterioration modelling, used to predict future bridge conditions and costs, can have limitations due to their complexity, and hence there can be concerns over the reliability of outputs. In particular, models based on numerical condition ratings can be particularly problematic, as they can produce unreliable results due to inconsistent data (Srikanth and Arockiasamy 2020[9]).

To improve bridge asset management, the Austroads Engineering Guideline to Bridge Asset Management 2001[8] recommends using a more comprehensive approach that combines numerical ratings with specialised testing, financial data, and detailed engineering assessments. The document also notes that the inclusion of maintenance backlog data, independent audits, and forecasts for both bridge renewals and maintenance are also crucial for ensuring effective management.

Therefore, any proposed system must not rely solely on single-condition ratings, and instead adopt a broader, multi-faceted approach to bridge monitoring, forecasting and decision-making.

5. Proposed process

As noted previously, given the complexities involved, a singular solution is insufficient to answer all 3 of the proposed problem statement simultaneously. Instead, a small collection of processes is proposed to take account of the immediate risk, ongoing risk, and forecasting, and through an integrated process model, connect them through several feedback loops that act as checks and balances, thereby giving ongoing confidence that any one part of the process is operating adequately at any given moment.

The key elements are:

- **Element-Based Condition Assessment:** Expanding inspection forms to collect condition ratings for all structural elements.
- **Centralised Databases and Risk Algorithms:** NZTA managed databases will be developed to aggregate inspection data and apply algorithms to determine risk ratings. This will allow for more accurate, data-driven decision-making in funding requests.
- **Refined Funding Request Process:** Integrating real-time risk ratings into individual project funding requests will improve repair prioritisation. This will standardise the way risk is presented and ensure consistent funding justifications.
- **Optimised Intervention Forecasting:** Developing predictive deterioration models based on historical maintenance trends and key structural parameters. This will enhance long-term budget planning and optimise lifecycle costing for assets.
- **Structures Asset Management Online Portal:** Supplying a visual dashboard to help track risk levels over time across asset elements, structures, and networks. Decision-makers will have real-time access to risk trends, enabling more informed funding allocations.

The proposed framework intends to leverage as many existing procedures as possible in an effort to retain the best parts of the current process, as well as smooth the transition to the new system.

The first existing process that will be amended is the current inspection process. It is proposed that new digital inspection forms be developed that will capture the condition rating of each individual element of a structure via an element condition rating data entry app.

The centralised databases will then collect the element-based condition ratings into a centralised NZTA owned and operated platform. An algorithm, or set of algorithms, will also be developed to risk rate the elements, which will then be aggregated to give a risk rating for each structure.

The current funding request process will also be amended so that instead of risk being assessed for specifically identified maintenance projects based on the engineering judgement of external suppliers, the newly developed set of centralised databases and algorithms will be leveraged to give up-to-date risk ratings for the current structure, as well as the provisional new risk rating for a given repair option. This will be achieved by allowing the structures asset management engineers to provisionally amend the condition rating for a proposed element being repaired, which when combined with a risk rating algorithm will show a new risk level of the structure for the chosen repair option.

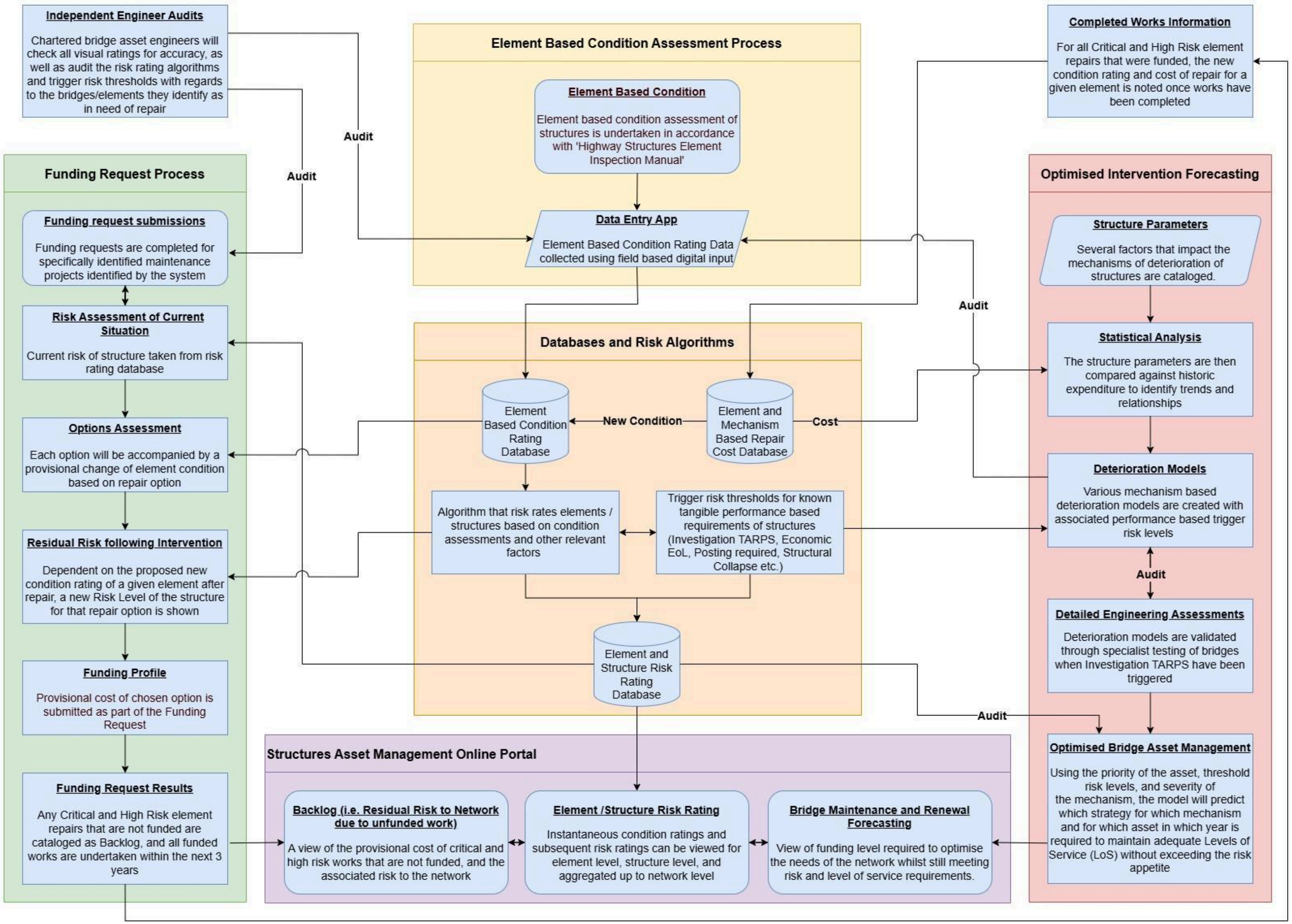
This will be used to make sure that the correct repair option is being adopted for a specific defect, and should it be necessary during times of constrained funding, it can be used in a moderation process to make sure that money is being spent on the most critical repairs at a network wide level. Any remaining works that are deemed High or Critical but are not undertaken will be considered ‘Backlog’, which is the immediate residual risk to the network due to unfunded High or Critical work.

With regards to the forecasting tool, a live ‘Mechanism Based Deterioration Modelling’ process will be developed. Mechanism-based modelling focusses on the known and observed mechanisms of deterioration through the analysis of several structural parameters that impact the deterioration of structures and compares them to historic expenditure.

Finally, a ‘Structures Asset Management Online Portal’ will be developed that will allow users to view up-to-date condition and risk ratings for element level, structure level, and aggregated up to network level of the structures. These risk ratings will also be tracked to see if the risk is increasing, decreasing or remaining stable over time.

The proposed framework is shown in Figure 1, which displays how each process is connected to each other. This model takes a holistic view of the various procedures and combines it into one ‘Data Driven Structures Asset Management Integrated Process Model’.

Figure 1 NZ Transport Agency Waka Kotahi Data driven structures asset management integrated process model



6. Challenges in Implementation

While the proposed enhancements offer significant benefits, they also present challenges that must be managed effectively with consideration of the existing processes, the transition to new practices, and the embedding of the new framework into the current bridge asset management industry.

In particular, with reference to the issues previously noted within the 'Implementation Considerations' section, and acknowledging that some of those issues are applicable to the current processes undertaken within New Zealand, there are a number of issues that are required to be addressed before the DDSAM framework can be successfully adopted.

The proposed issues are planned to be addressed via a suite of new processes, procedures, or documentation as set out in Table 1.

Table 1 New processes, procedures, or documentation required for DDSAM adoption

Issue No.	Issue	Proposed solution
1	**Variability in inspection results:** Visual inspections are prone to human errors due to natural human fallibility and performance influencing factors.	**Robust inspector audit procedure:** Implement a DDSAM-driven audit process with system-monitored variance checks alongside independent engineer audits.
2	**Inconsistent guidance:** There is a lack of consistent and up-to-date guidance documents, contributing to inconsistencies in inspection practices.	**New documentation:** Develop a "Highway Structures Element Inspection Manual" and "Highway Structures Operations and Maintenance Guide" to guide the industry.
3	**Outdated training courses:** Currently available training materials and courses reflect decades-old practices.	**New training courses:** Create updated training materials that cover defect identification and condition monitoring.
4	**Lack of target condition number:** There is no universally applicable target condition number for bridges.	**Trigger risk thresholds:** Establish clear risk limits tied to tangible performance metrics for specific road corridors.
5	**Lack of skilled inspectors:** Few choose to make bridge inspection a career, which leads to increased variability in the quality of inspections undertaken.	**Instigate career progression pathway:** Create new 'Structures Inspector' career pathway which will generate value within the profession.
6	**Inconsistent repairs:** Repairs lack standardisation which will limit the DDSAM's forecasting ability.	**Standardised repair guidance:** Develop a suite of standardised repair specifications for all common defects of primary structures construction materials.
7	**Change management:** Transitioning from existing practices to a more data-driven approach will require careful change management strategies.	**Ongoing consultations:** Partake in ongoing stakeholder engagement and capacity building before, during and after the release of the new framework.
8	**Potentially unreliable forecasting:** Models based on numerical condition ratings are potentially unreliable due to inconsistent condition rating data.	**Forecasting audit system:** Validate forecast data using detailed engineering assessments as well as track forecasts against actual risks mitigated by works.

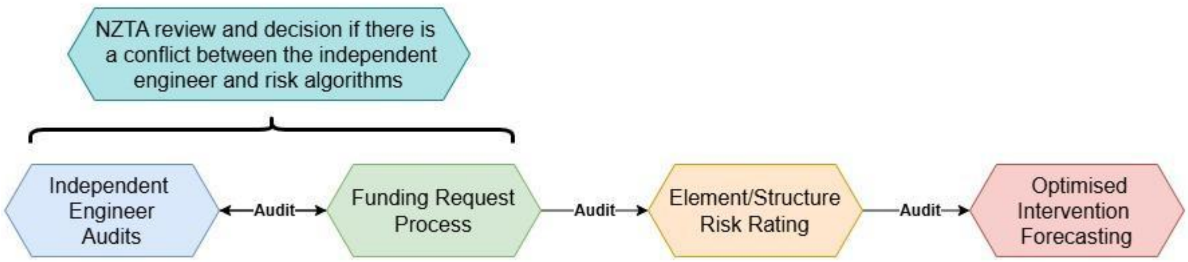
7. Data Integrity

Compromised data can lead to flawed decisions, and hence data integrity is a core requirement of any successful asset management system (International Infrastructure Management Manual 2020[10]). As such, the entire proposed DDSAM framework is built around robust audit procedures which will ensure confidence in the ongoing validity of the systems outputs.

In particular, the ‘Independent Engineer Audits’ are fundamental, as they represent a near continuous audit of the ‘Funding Request Process’ and associated ‘Databases and Risk Algorithms’. Should either process start to deliver incorrect outputs (i.e., putting forward low risk ratings for visibly obvious serious defects, or vice versa), then the Independent Engineer Audits which check the Funding Requests before submission will pick up these errors. If it is not clear that there is an issue, then NZTA structures asset engineers will investigate and determine whether the issue is with the algorithms, or with the risk profile of the Independent Engineer. Where errors in the algorithms are identified, issues can be located and fixed giving confidence that the accuracy of results shown in the ‘Structures Asset Management Online Portal’ for ‘Element/Structure Risk Rating’ are constantly improving.

The final stage of ensuring validity of the overall process involves comparing the ‘Optimised Intervention Forecasting’ against the ‘Element/Structure Risk Rating’ over time. As funding is made available based on keeping the structures within upper and lower bound risk thresholds, the element/structure risk rating of the same assets should begin to mirror the forecasted risk ratings. Should there be a divergence, then analysis can be undertaken to understand the deviation after which the forecasting tool can be corrected. The overall process is shown below.

Figure 2 Overarching DDSAM audit procedure



Through these processes, data integrity will be maintained by ensuring the accuracy, consistency, and completeness of data throughout its lifecycle, guaranteeing that information remains unaltered and reliable for its intended purpose, which will ultimately make it trustworthy for decision-makers.

8. Expected Benefits

Through the mitigation of issues identified above associated with structures asset management systems, and by integrating structured data collection, consistent risk evaluation, and predictive modelling into the proposed system, the resulting DDSAM framework is expected to bring several tangible benefits:

- **Greater Funding Confidence:** With robust data-driven justifications backed by strong auditing procedures, funding approvals will be based on objective, quantifiable evidence rather than subjective assessments.
- **Improved Asset Lifespan:** Proactive maintenance planning through deterioration modelling will extend the useful life of infrastructure assets, reducing long-term replacement costs.
- **Enhanced Risk Management:** Decision-makers will have clear insights into asset vulnerabilities, enabling more effective risk mitigation strategies.

- **Transparency and Accountability:** A structured, standardised process ensures that funding decisions are transparent, auditable, and defensible.
- **Optimised Resource Allocation:** Prioritisation based on risk and performance will ensure that limited funds are allocated to the most critical projects, improving overall network resilience.
- **Cost Savings:** By shifting from reactive maintenance to proactive planning, significant cost savings can be realised over time, reducing emergency repairs and extending asset life cycles.
- **Enhanced Stakeholder Confidence:** With more reliable data and clearer funding justifications, confidence among government agencies, policymakers, and the public will increase, supporting better long-term infrastructure planning.

9. Conclusion

The proposed DDSAM framework represents an active attempt to understand the issues that have previously impacted similar international structures asset management systems, and mitigate them through a range of processes, procedures and documentation so that the resulting system will improve transparency, efficiency, and long-term asset sustainability.

By adopting a more data-driven, standardised, and forward-looking approach, NZTA and its partners can ensure that New Zealand’s state highway structures receive the necessary funding to maintain their safety, functionality, and longevity. Furthermore, the improvements in risk assessment and forecasting methodologies will foster more efficient use of taxpayer funds, ensuring a more resilient and reliable transport network for future generations.

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Author contacts

Dewi Todd-Jones, NZ Transport Agency Waka Kotahi, Principal Asset Engineer Structures

dewi.todd-jones@nzta.govt.nz