

REG | THE ROAD EFFICIENCY GROUP

BEST PRACTICE AMP WORKING GROUP

Case Study

Bridge Management Frameworks - Managing Risk & Ensuring Value for Money

Initiative number 2013_05

13 December 2013

Version No	Date	Item Affected	Description of Change
1	13/12/13		Document presented to REG BPAMP Group
2	15/05/14		Final

Executive Summary

This case study will interest those seeking to better understand critical bridge vulnerabilities on their network and those looking to make better value bridge investments on low volume transport systems through improved, and less subjective, multi-criteria based assessments and analytical methods.

The case study covers enhancements to two key elements of bridge asset management that have greatly assisted Hastings District Council (HDC) in delivering an optimised outcome but does not attempt to cover all aspects of successful and effective bridge asset management.

The aspects of bridge asset management that are covered are: [1] condition, risk and maintenance assessments to inform understanding of vulnerabilities and cost; and [2] asset criticality assessment to inform prioritisation and service level discussions. The case study describes how knowledge at an individual bridge level has been translated into an overall network understanding that is necessary for good asset management and budget optimisation and is useful for discussions with senior decision makers.

The HDC network has approximately 260 bridges on a 1,600km road network criss-crossing the Heretaunga Plains and radiating out into outer-rural zones in a series of spokes from the central hub. Horticulture and forestry are significant activities in the region that have led to the demand for and introduction of numerous High Productivity Motor Vehicle (HPMV) routes on the local road network. In seeking to support and encourage enablers for improved economic productivity in the region, HDC has made stringent efforts to better understand the significance, condition and vulnerabilities of the bridge stock to ensure that responsible, pragmatic and quick management decisions could be made.

Additionally, significant storm events in recent times have had a noticeably detrimental effect on this asset group. These events have damaged and washed out bridges, resulting in high cost repairs, lengthy disruptions and some rural communities being denied road access until temporary access could be restored. High on HDC's priorities was to be able to quantify and monitor the storm vulnerability of the bridge stock to enable discussion regarding risk appetite and subsequent implementation of targeted preventative maintenance strategies to reduce the risk and consequences of damage.

Part A of the case study explains how through a number of small cost neutral adjustments to the practice of bridge inspections Hastings District Council has been able to achieve significantly improved understanding of risks, vulnerabilities, priority maintenance and cost of outstanding maintenance on the bridge network. This knowledge and understanding has allowed them to communicate effectively with

stakeholders and decision makers to secure appropriate funding and implement proactive strategies for managing the issues on the network.

Part B describes innovative and useful applied research to develop and implement a network assessment model to evaluate and rank the criticality of the bridges on the Hastings network. The research demonstrated the usefulness of an iterative spatial model which used accessibility analysis techniques that were a little 'left of norm', but better informed the decision making processes using multi-criteria performance measures. The model is used to calculate the journey time between land parcels and address points (origins) and the State Highway Network (destination) to evaluate the contribution of each bridge to the productivity of the region and the lifelines resilience of the network. Outputs include the relative importance of lifeline bridges and the relative importance of other bridges from a heavy commercial vehicle transport perspective. This newer way of assessing the criticality of bridges as part of a comprehensive transport network is proving useful for developing strengthening and posting strategies in a climate of tightening fiscal budgets. This will result in better investment decisions for the economic performance of the region and therefore more efficient outcomes, and ease the processing of funding applications due to the transparent investment methodology.

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Appendices

1 Introduction

1.1 Project Outline

Project Name:	
Project Location:	HASTINGS DISTRICT
Project Objectives:	
Length:	
Traffic Volume:	
Supplier(s):	Asset Management: Internal Bridge Inspections: MWH Bridge Evaluations: Opus, GHD, GDC & MWH Accessibility Modelling: Abley Transportation Peer Reviewers: MWH & Abley Transportation
Project Stage:	
Value: (cost savings)	
Scope of Work:	
Environment:	
Constraints:	
Project commenced:	Jan 2009
Key Issues:	Understanding and support from investment partner (NZTA)

1.2 Project Team

Name	Organisation / Role	Contact Details (Email and Telephone)
Matthew Rodwell	Asset Manager, HDC	06 871 5000
Jag Pannu	Transportation Manager, HDC	06 871 5000
Craig Thew	Group Manager Asset Management, HDC	06 871 5000
John Reynolds	Peer Review, NZTA	

2 Case study

2.1 Introduction

In 2009 Hastings District Council (HDC/Council) initiated a review of its bridge management strategy. The review focussed on understanding the performance, threats, demand and value for money issues surrounding this high value, critical asset group.

The review was triggered by Council's decision to bring asset management functions back in-house. To assist transfer of institutional knowledge and ensure that Council held in-depth understanding of the management approach, it was undertaken by Council staff with assistance from our key service provider (MWH).

This case study provides a summary of two key elements of the project that have resulted in immediate programme reductions of over \$5m and hopefully significant future maintenance cost savings through better understanding of and reaction to risk. It explains how the use of a structured and risk based framework for developing the strategy has enabled this to happen, and challenges asset managers to consider the assessment of risk as the principle foundation for developing an effective asset management strategy rather than as an activity in the process.

2.2 Background

When Council brought asset management functions in house in 2008/09, the bridges were managed using the NZ Bridge Manual, Highway Structures Inspection Policy, and the Inspection Manual for Highway Structures as the reference standards. There was a bridge management system, an accurate asset inventory, statement of service levels, a programme of 2 and 6 yearly general and detailed inspections, a maintenance programme, an assessment of renewal needs including a 10 year renewal programme, properly managed use restrictions and an up to date valuation.

It was generally stated that bridges & culverts on the network broadly provided a good level of service, and were in a sound condition based on the following:

- Regular engineering inspections were undertaken of all structures.
- Historic and outstanding maintenance was relatively small, and generally only included lower priority works:
- The average bridge age was less than half the expected average bridge life.
- 25yr forecast bridge replacements were very low.



Despite the above however, there was no continuous learning cycle in place and more specific intelligence and key information relating to governance and management of the bridge stock could not be answered or quantified:

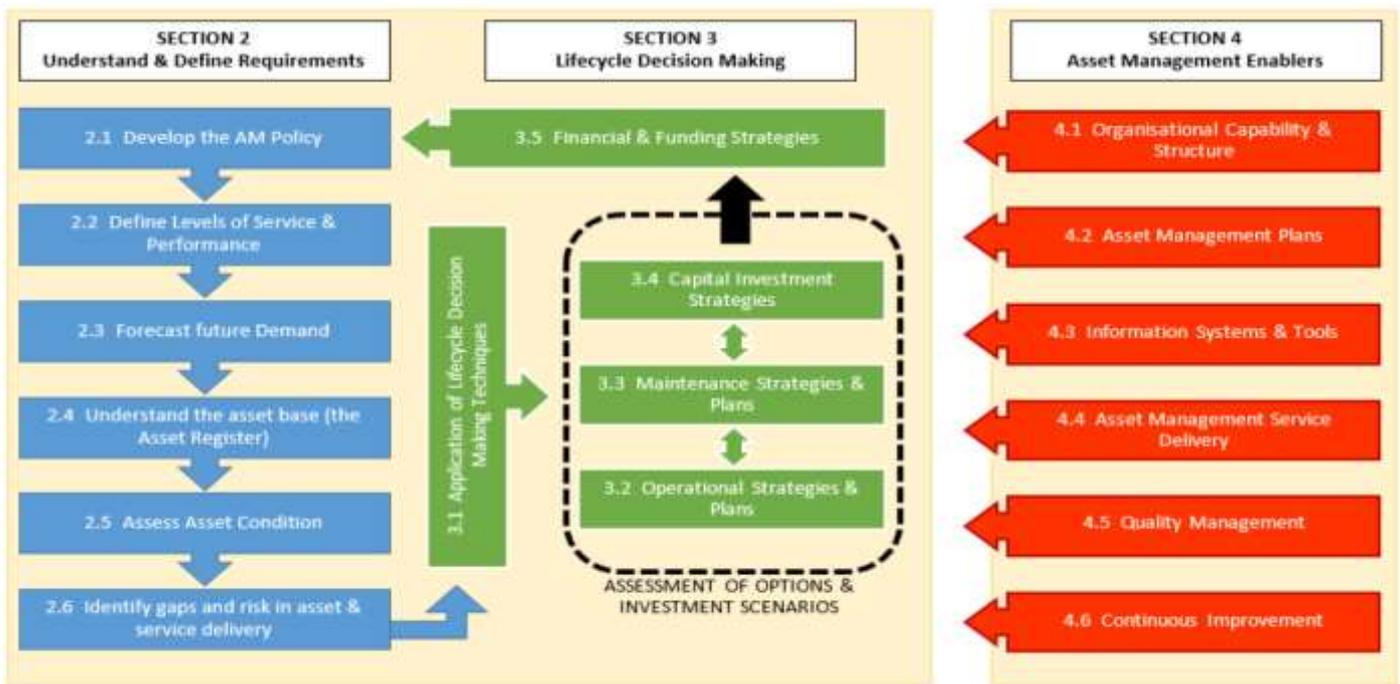
2.3 Case Study Objectives

This case study focuses on elements 1, 2 & 8 above and shows how Hastings District Council has changed its bridge management approach to identify, mitigate and monitor critical vulnerabilities on the bridge network to ensure that it is safe and delivers value for money. The case study is presented in two related parts showing firstly the approach at an operational level (**managing the bridge asset**) and secondly at a strategic level (**managing the transport outcomes**).

For the purposes of this case study, value for money being defined as:

<i>At an operational level:</i>	<i>Delivering maintenance that is:</i> <ul style="list-style-type: none"> • <i>The most cost effective (long term) treatment of the fault</i> • <i>Targeted at the faults which deliver the best overall outcome for the network within the available budget</i> • <i>Prioritised to address the most critical and vulnerable elements first</i>
<i>At a strategic level:</i>	<i>Optimal performance of the network, achieving the specified level of access and mobility for the least long term cost</i>

The following figures show the IIMM generic asset management cycle and the activity components of amended bridge management framework used by HDC (the primary areas covered by this case study are highlighted):



	SERVICE FUNCTION & LEVELS	MANAGEMENT FRAMEWORK COMPONENTS	RISK AREAS
STRATEGIC	<p>Primary tier service function: connect a local transport network across obstacles to give access to (produce to market)</p> <p>Primary tier service level: efficiency of access (journey time, reliability and resilience to disruption)</p>	<p>Regional lifelines plan</p> <p>Strategic Network Plans (e.g. HPMV & 50 Max)</p> <p>Accessibility modelling</p> <p>Demand management plan</p>	<p>Value for money, economic productivity</p>
TACTICAL	<p>Management tier service function: Network performance trends, Cost optimisation, Coroner proof management approach</p> <p>Management tier service level: target investment levels, backlog, achieved lives, improvement plan</p>	<p>Detailed Structural assessment programme</p> <p>Prioritised improvement, strengthening and renewal programmes</p> <p>Knowledge consolidation plan (capture & centralise institutional knowledge)</p> <p>Global network maintenance & management strategies (e.g. painting, low level structures)</p> <p>Network scour, strength & seismic screening</p> <p>Procurement strategy</p>	<p>Bridge network vulnerabilities (current & long term), catastrophic failure, business risk (funding & cost, media / public opinion, resources), quality</p>
OPERATIONAL	<p>Secondary tier service function: adequately providing for the demand on the structure by users</p> <p>Secondary tier service level: load and volume capacity, safety</p>	<p>Structured learning reviews of unplanned disruption</p> <p>Special inspections (as required)</p> <p>Prioritised Maintenance programmes</p> <p>Individual management plans for significant or unusual / complex structures</p> <p>Network corridor patrols (frequency varies depending on route hierarchy)</p> <p>Load mitigation: postings, overweight & HPMV permit management</p> <p>Programmed Bridge Inspections</p> <p>Prioritised Pre and post event inspections</p> <p>Global bridge maintenance Resource Consent</p>	<p>Individual structure vulnerabilities such as material failures (cracking, fatigue, rot, corrosion etc); damaged, missing, loose or worn elements; and immediate threats around the bridge such as trees & unstable slopes</p>

Part A

2.4 The Case for Change

Bridges operate in a dynamic environment in which they deteriorate and occasionally fail. New Zealand has few high profile bridge failures and there is very high public expectation that bridges are safe (low tolerance for preventable failures). To effectively manage critical vulnerabilities you need to understand and monitor them and to deliver value for money you need to understand the objective of the service you are delivering and the impact of change. These need to be understood by the asset manager so that he can budget appropriately and communicate effectively with stakeholders.

The problem definition in Hastings is summarised by the following:

- Bringing maintenance functions in-house had fractured the supply chain creating disconnect between the Bridge Inspection Engineer and the maintenance activity. This unintentionally resulted in no one taking overall responsibility for the structural safety of the bridges, adding risk to our business.
- A lack of overall RCA understanding of key vulnerabilities at a bridge level meant that we could not manage threats effectively or monitor change.
- Inefficient business practices meant that there was long time-lag between fault identification and action. This increased the risk of high priority faults not being promptly addressed and meant that it was difficult to tell what work had and had not been completed when programmes were prepared.
- Lack of robust cost estimation at completion of inspections meant that it was difficult to effectively plan and programme work
- Poor recording and communication of scope or intent of identified maintenance activities meant additional site visits were necessary to plan the work and risked unintended maintenance outcomes leading to sub-optimal use of limited maintenance funds
- New Zealand's geographic location and its place in the global economy means that our transport networks must provide the least possible constraint on the rural production economy to ensure that every possible support is given to our businesses. Coupled with a changing climate and fiscal belt tightening, managing & minimising unplanned disruption to the network is becoming more and more important.

- Despite a recognised management approach and sound overall condition of the network we were still getting failures. There have been 10 full or partial bridge failures on the HDC network in the last four years at a direct cost of over \$1M. Although there is reasonable public tolerance for failures resulting from natural events, responding to these failures comes at significant cost both in repairs and disruption. A closer look at the recent failures shows that the majority are preventable if we can embed a structured approach to assessing and acting on vulnerabilities and learning from our experiences into our routine inspection and maintenance practices. Although we might not like to admit it, these are the facts that must be faced on real life networks by asset managers. A summary of these failures and the lessons learnt is shown in the following figure:

BRIDGE	PHOTO	DESCRIPTION	PREVENTABLE CAUSE/LEARNING
Havelock Bridge		<p>High winds caused a large tree to fall on and damage the railing and clip-on pedestrian walkway. Required replacement of railings and sections of the clip-on structure. Resulted in prolonged closure of the most heavily trafficked structure on the Hastings network while initial damage inspections were carried out and again during replacement of damaged sections of the clip-on structure.</p>	<p>The tree was on private property and had not been identified as a potential threat. Key learning from this event is to ensure that sections consider the wider environment when assessing maintenance need and hazards for a bridge. Additional priority must be assigned around structures with less robust primary structural elements such as light clip-on structures and trusses.</p>
Valley Road		<p>Bridge failure requiring full replacement. Undermining of western abutment led to sudden abutment settlement and deck failure due to "locked-in" nature of the structure.</p>	<p>The type of foundations which were typical of older structures (marginal span bridges with fairly shallow spread foundations) was found to be a particular risk factor in this failure. However, a lack of records has reduced our risk tolerance for scour influences across the bridge stock resulting in a tactical framework of zero tolerance for trees in the watercourse around structures.</p> <p>The value of temporary mobile bridge structures in quickly opening routes to traffic after an incident. HDC needs to maintain stock (3 currently).</p>
Junction Culvert		<p>Partial collapse of a large multi-plate corrugated steel culvert (3m dia.) as a result of a catastrophic hinge forming along the longitudinal bolted joint connection due to corrosion at the water line. Corrosion was extremely rapid since the last detailed inspection in 2009 when cores at the waterline showed relatively intact base metal yet inspection of the failure showed only corrosion product remaining. Actual collapse formed large hole in the centre of the road and was caused by a coincidence of rapid draw-down in water level & a heavy vehicle load.</p>	<p>It is preferable to prevent corrosion than to rely on the presence of sacrificial metal. Where galvanic protection has been lost, inspection cycles should increase as structure may be vulnerable to rapid corrosion from subtle changes in water quality arising from outside influences such as changing land use.</p>
Waimarama Bridge		<p>Bank erosion behind eastern abutment during high flows. Inadequate vegetation control and waterway maintenance (siltation) and poor bank protection in vulnerable areas (outside of a bend in the river upstream of the structure) led to loss of bridge approach during high flows.</p> <p>A combination of river siltation large amounts of growing and dead vegetation in the waterway led to dams forming and breaking, sending sudden, large high velocity flows down the river causing the waterway to change course.</p>	<p>Changing Regional Council waterway management policies and structures have led to heightened risk that had not been identified or responded to. This plus Valley Road failure highlight the importance the identifying and removing obstacles in the water course that may redirect flow or cause eddies near the structure in certain flow conditions. HDC have adopted a zero tolerance policy and identified issues are assigned maintenance priority 1. There is a need to establish protocols for identifying and managing risk with the Regional Council.</p>
Harper's Culvert		<p>During high flows the river overtopped the structure, removing the seal and washing away pipe bedding material.</p>	<p>Poor design detailing of the headwall and edge of seal across the culvert allowed water to lift the timber edging detail and flow under the seal, peeling it off. Once seal was gone, whole culvert structure became vulnerable to buoyancy and scour. In areas where water velocities are high during flood, headwalls and seal edge details need to be concrete or some other material that will not all high velocity flow to penetrate.</p>

BRIDGE	PHOTO	DESCRIPTION	PREVENTABLE CAUSE/LEARNING
Maraetotara		Vehicle lost control on the bridge and side-rails failed to contain vehicle on the roadway. High severity injury crash and bridge closed for considerable period. This is the top lifelines structure in the district.	Failure to identify risk which could have led to proactive replacement of the old non-compliant railing system failed to provide adequate containment. This is an elevated risk bridge site on exit to high speed corner with a moderate history of loss of control on adjacent sections of the road which had not been identified. HDC has initiated a road context safety risk assessment for each bridge to understand risk within the overall prioritised network safety programme
Makahu		Two separate incidences of vehicles being washed off low-level structure during high flows.	Low level structure designed for over-topping but inadequate warning and driver advice in place. Risk not adequately assessed at this site which gives access to popular holiday area and is used by visitors unfamiliar with conditions. No maintenance procedure to monitor and close low-lever structures during storms and heavy rainfall. HDC has developed and implemented a strategy for managing risk at low-level crossings.
Darkeys Spur Bridge		Surface slip from a steep slope above the road partially buried the bridge damaging one abutment and railings resulting in road closure while slip was cleared and bridge repaired.	Poor management of water on private land at the top of a cutting above the road led to high uncontrolled flows down the surface causing the slip. Better identification and assessment of the risks around a structure needed, including those originating on private land out of sight of the bridge.
Moka Moka Bridge		Bank erosion has led to loss of support to western abutment sitting on the edge of a steep sided gully. Precautionary closure and installation of temporary structure spanning danger zone.	Original structure span too short leaving minimal redundancy. Lack of adequate bank protection has failed to prevent reduction in already minimal factor of safety. Identified during site risk assessment following implementation of learning's from Valley Road failure and is example of proactive risk assessment which has prevented costly failure.

2.5 What we Changed

Through a number of small adjustments to the practice of bridge inspections in Hastings at no increase in management cost, we have been able to achieve a far better understanding of risks and vulnerabilities and implement proactive strategies for managing them.

The basis for the change was to ensure a thorough understanding across the supply chain of the overall framework within which each element was operating (making decisions) and enable effective communication of issues, risk & priorities bottom upwards & top downwards.

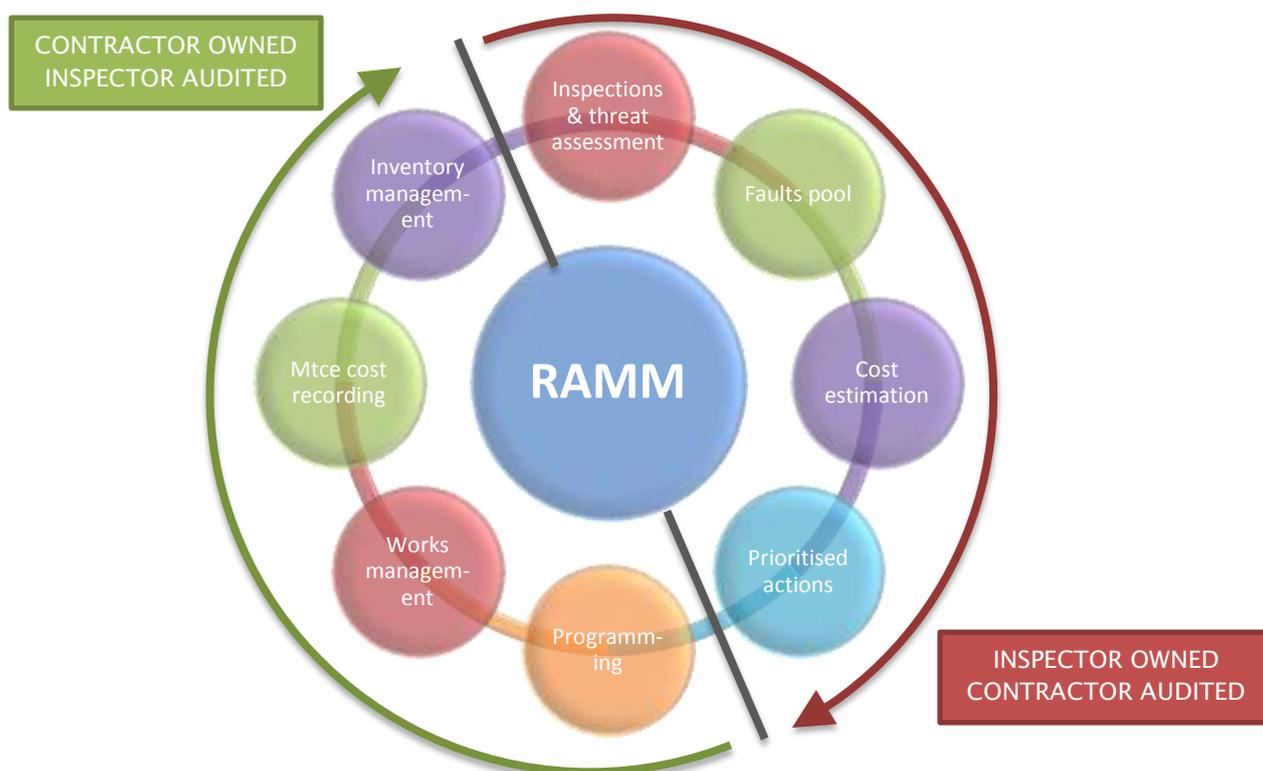
The preferred way forward was to:

1. Integrate bridge maintenance management into a more hierarchical asset management framework:

Source: Management of Highway Structures - A Code of Practice (UK Roads Liaison Group)



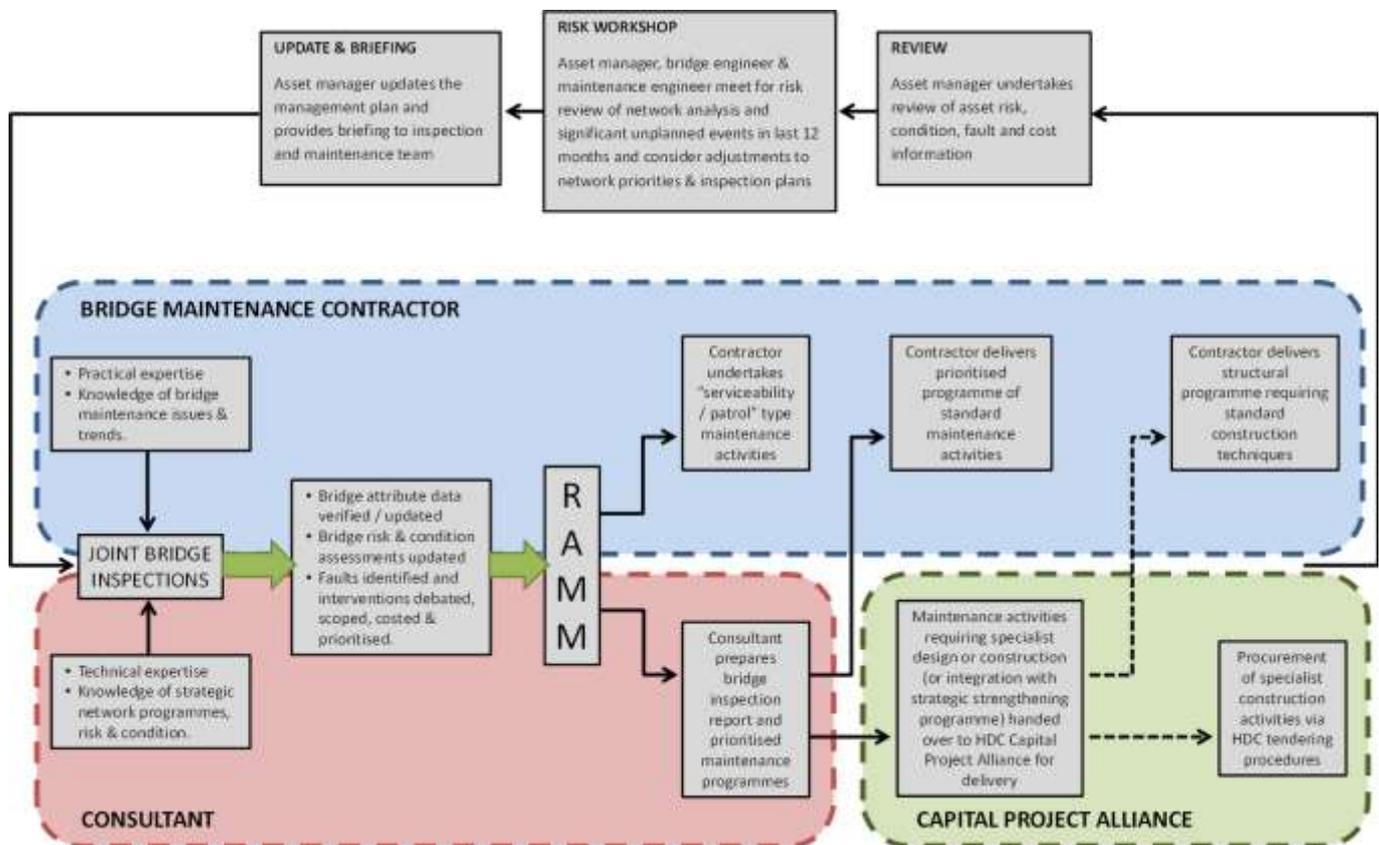
2. Consolidate the inspection, cost estimation, prioritisation and programming procedure and direct the full inspection and maintenance delivery lifecycle through RAMM (includes consolidation of all data storage and the full information management lifecycle into RAMM)



3. Appoint a single network bridge maintenance contractor
4. Introduce a formal threat assessment into the programmed inspections
5. Close the annual inspection and maintenance loop to create a continuous learning cycle and expand annual reporting to include network overviews and trend monitoring

The key elements within the approach are:

1. An annual risk workshop to review maintenance achievements and learnings from significant unplanned events
2. An integrated (consultant & contractor) inspection and maintenance team to ensure connectivity between inspection & data collection activities and the physical works programmes. This is shown diagrammatically in the following figure:



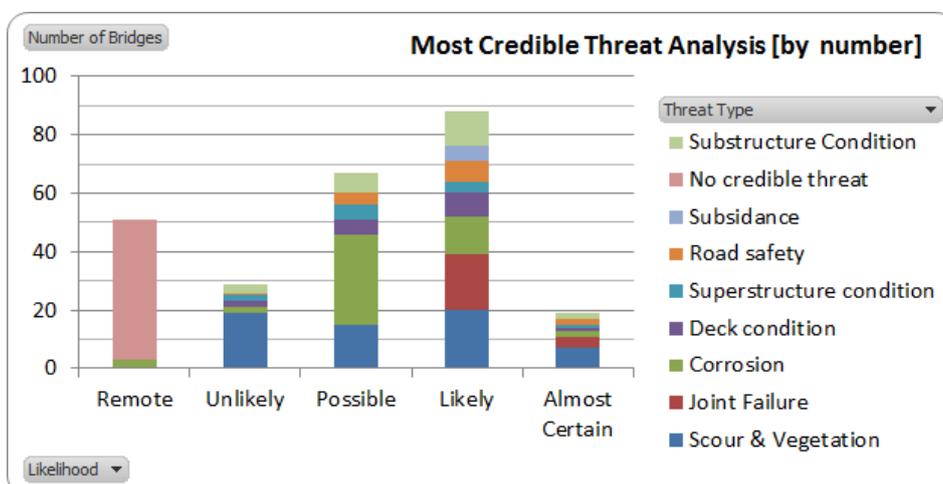
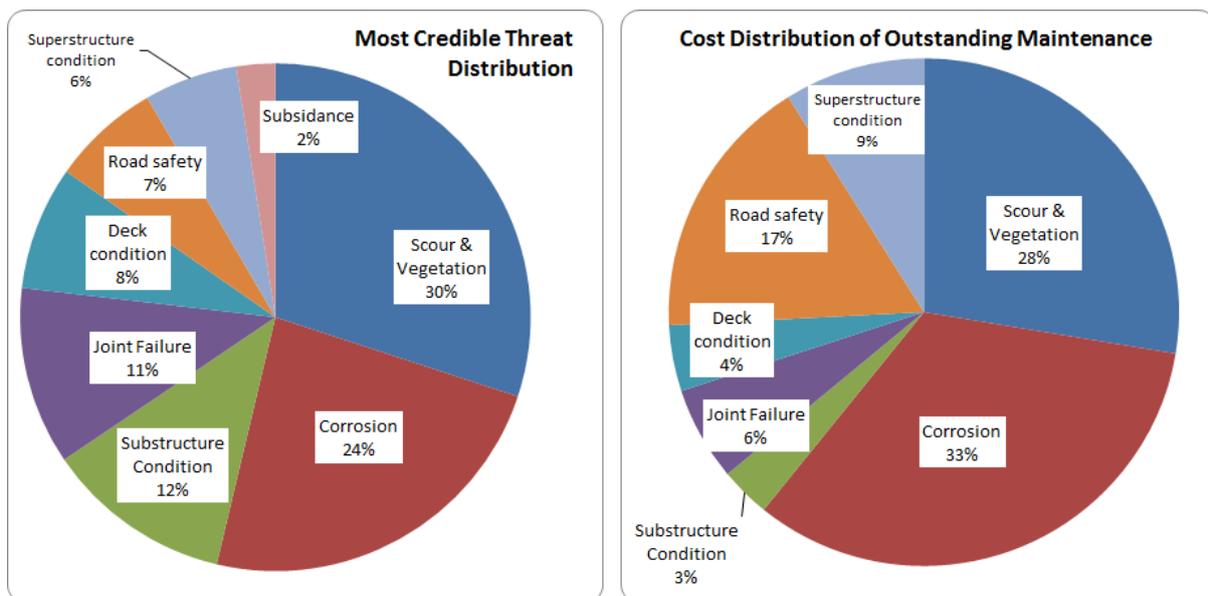
3. Recording of all faults, costs & priorities as dispatches in RAMM Contractor to facilitate briefing of work and network analysis
4. An assessment against a minimum threshold consequence [serious injury or costs >\$100k or 20% of the value of the structure] of the most credible threat opinion and assessment of likelihood is undertaken each time a structure is inspected (Likelihood meaning the likelihood of the threshold consequence occurring within 6 years [2 planning cycles]):

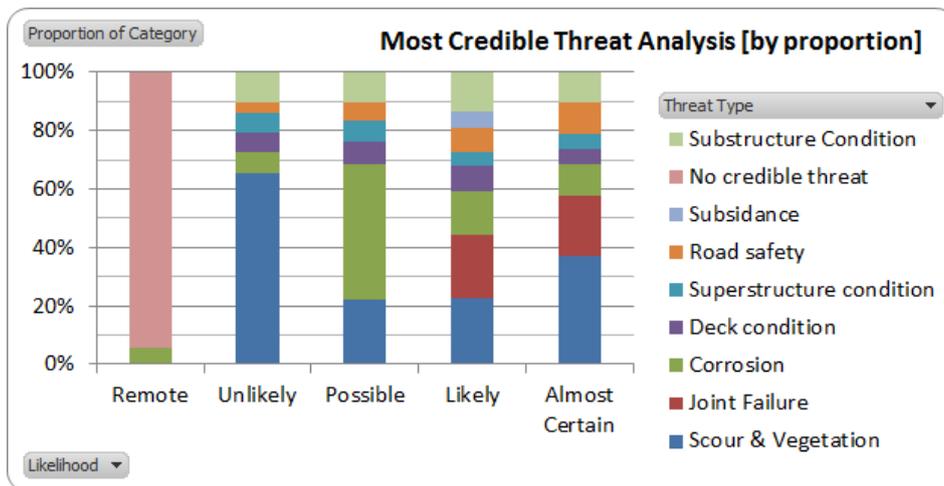
Likelihood	Description
Remote	May occur only in exceptional circumstances
Unlikely	Could occur only very occasionally (<5% of the time)
Possible	Might occur from time to time (<30% of the time)
Likely	Will probably occur (>30% of the time)
Almost Certain	Expected to occur (>75% of the time)

- “Serviceability / patrol” type maintenance activities (e.g. cleaning bridge end markers) are identified by the contractor during the inspections and managed as a separate activity. They are not included in the prioritised maintenance pool as they distract from structural maintenance record and can hide the real need and trends.
- Standardised maintenance fault coding to enable consistent data analysis (Client owned)

2.6 What we Found

Results from an analysis of the outstanding maintenance and on-site threat assessments are shown in the figures below:





The above figures show the dominance of the scour threat across all levels of likelihood and especially at the critical end. This corroborates the findings of the failure cause analysis and confirms the need to focus on waterway management. The results also show the prevalence of critical joint failure issues and a looming issue with corrosion protection systems.

The results have enabled us to take a number of informed management actions to mitigate critical vulnerabilities:

1. Zero tolerance on trees in waterway or locations that could fall on bridge
2. Prioritise preventative maintenance for scour protection
3. Secure a long term global resource consent for bridge management to allow prompt and active waterway management around structures
4. Expand the focus of bridge inspections to include the environment surrounding the bridge
5. Develop an optimised bridge painting strategy
6. Develop a long term joint management strategy
7. Develop of low-level crossing management plan (Appendix A)
8. Promote inspection of corrugated steel culvert structures to annually where galvanic protection has been lost

Although many of the risks facing bridge structures are intuitively managed through natural decision making of experienced engineers, we have found it necessary to provide some tactical prioritisation frameworks to manage overall network risk and resilience.

There is always a large proportion of non-urgent maintenance work identified from inspections. Maintaining a prioritised all-faults record in RAMM allowed this work to be tracked and further deterioration rates monitored to inform decisions on escalating priorities and timing of intervention.

2.7 Benefits of the Approach

A global network understanding of vulnerability and maintenance need enables asset managers to balance bridge risk management and resource allocation with other asset groups and asset management activities. This also facilitates more effective communication with senior decision makers.

The benefits of the framework presented are that it creates clear risk governance & management responsibilities and delivers value for money by ensuring:

1. Optimised inspection procedures & use of expertise - combining the bridge engineer and contractor on inspections ensures:
 - a. Good debate of options combining technical and practical expertise
 - b. Improved efficiency as all work is scoped and estimated in one visit without need for multiple trips to often remote areas
 - c. Improved cost estimation for programming
 - d. Reduced risk of poor communication between engineer & contractor in terms of treatment intent & scope, minimising rework and ensuring value for money
2. Regular, consistent collection of condition & risk data
3. Risks are mitigated through targeted & prioritised maintenance programmes that are integrated with long term strategies for a safe, responsive and sustainable bridge system.
4. Monitoring & clear communication of the operational threat profile
5. RAMM as the single repository of all up to date fault, cost, condition and risk information and is accessible to the whole team
6. Ability to quantify all outstanding maintenance and its priority at any point in time
7. Annual reporting on network condition and fault trends enabling asset management strategy improvements
8. Continuous improvement cycle to ensure proactive assessment of vulnerabilities and effective mitigation plan
9. Allows condition and risk states to be monitored and compared to funding expenditure
10. Reduction in unplanned cost and disruption? (too early to tell)

2.8 Discussion

The NZTA Bridge Inspection Policy is very clear that overall responsibility for the structural safety of structures is transferred to the bridge inspector:

4.2.1 ...*The Bridge Inspection Engineer shall:*

- i. maintain overall management and technical supervision of the structure inspection and maintenance programme for those highway structures scheduled by the NZ Transport Agency (NZTA) Project Manager;*
- ii. take responsibility for the technical competence of all personnel involved in inspections;*
- iii. take responsibility for the structural safety of all highway structures advised by the NZTA Project Manager;*
- iv. take responsibility for consulting with specialist staff when necessary; and*
- v. ensure that the schedule of highway structures and the inspection requirements are appropriate and comply with this policy.*

This ensures that the safety of bridges is managed by someone who understands the structures, hazards and performance requirements.

However, in reality overall governance responsibility lies with the RCA and the buck ultimately stops with him in the event of a failure. The RCA is also responsible for ensuring the overall transport network outcomes are achieved and the value for money is delivered in balance with competing network priorities.

When engaging a bridge inspection engineer, Bridge Asset Managers should therefore also ensure that the bridge inspection engineer:

1. will make them immediately aware of critical vulnerabilities (bridge specific & network wide) and satisfy them that appropriate mitigation is, or is not being taken
2. has a clear understanding of the expectation that the actions and recommendations of the Bridge Inspector are focussed on delivering best long term value for money across the network. *The value for money imperatives of linking inspection & maintenance activities with asset management planning across the network require that the asset manager ensures that the bridge inspection engineer has a thorough understanding of:*
 - i. historic issues and vulnerabilities with the bridge stock*
 - ii. the overall bridge management strategy & budgets*
 - iii. asset manager's appetite for different types of risk*

Part B

2.9 Problem Statement

In 2009 records indicated that 65 bridges on the Hastings network were potentially substandard (assessed at < 100% Class 1) and not posted with restrictions. The cost of strengthening all 65 bridges was estimated at \$6.3m and the network impact of posting the bridges could be significant.

The management imperative was to understand the real risk of a critical failure occurring at one of the “substandard” structures and to understand the real social and economic impacts of different strategies for managing the risk.

This part of the case study describes how the management problem has been investigated and managed using accessibility modelling to develop a strategy that has resulted in negligible impact on rates, road users and the regional economy.

2.10 Background

In January 2009 officers reported to Council that there was a key knowledge gap and risk around the structural capacity and demand being placed on the network’s bridges. They also reported that they did not have sufficient information about the structural capacity of the bridge stock or the level of risk around un-posted substandard structures to effectively manage the risks. Additional funds were requested and subsequently allocated to close the knowledge gap.

Understanding this risk was important because:

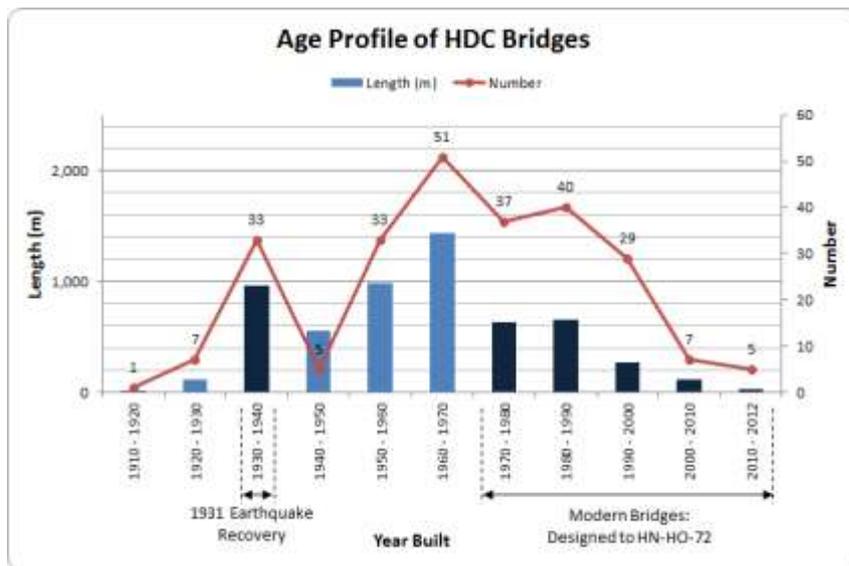
1. Economic productivity of rural Hastings is a key regional priority and the road network fulfils a vital role in achieving this. Posting and strengthening decisions could have significant impacts on the community
2. Strengthening is a significant cost item;
3. Bridges are an expensive and significant asset that provide a vital community service so optimised lifecycle management is important;
4. Increases in bridge loading were forecast from both VDM rule changes (HPMV) and medium term increased local timber extraction

To manage this risk, HDC undertook a series of projects to understand the structural capacity of the network and the criticality of individual and groups of structures to overall network performance. This understanding was key to clarifying bridge strengthening need and opportunities for a balanced posting and strengthening strategy.

2.11 Hastings Bridge Asset

The Hastings road network relies on a large number of bridges and structures. We're responsible for maintaining nearly 265 bridges and large culverts - on average a bridge every 6.4km. The bridges range from major, arterial lifeline and multi-span bridges to low-level, single-span, single-lane structures. They are mostly built of concrete and steel, although there are still a large number of timber decked structures on low volume rural roads.

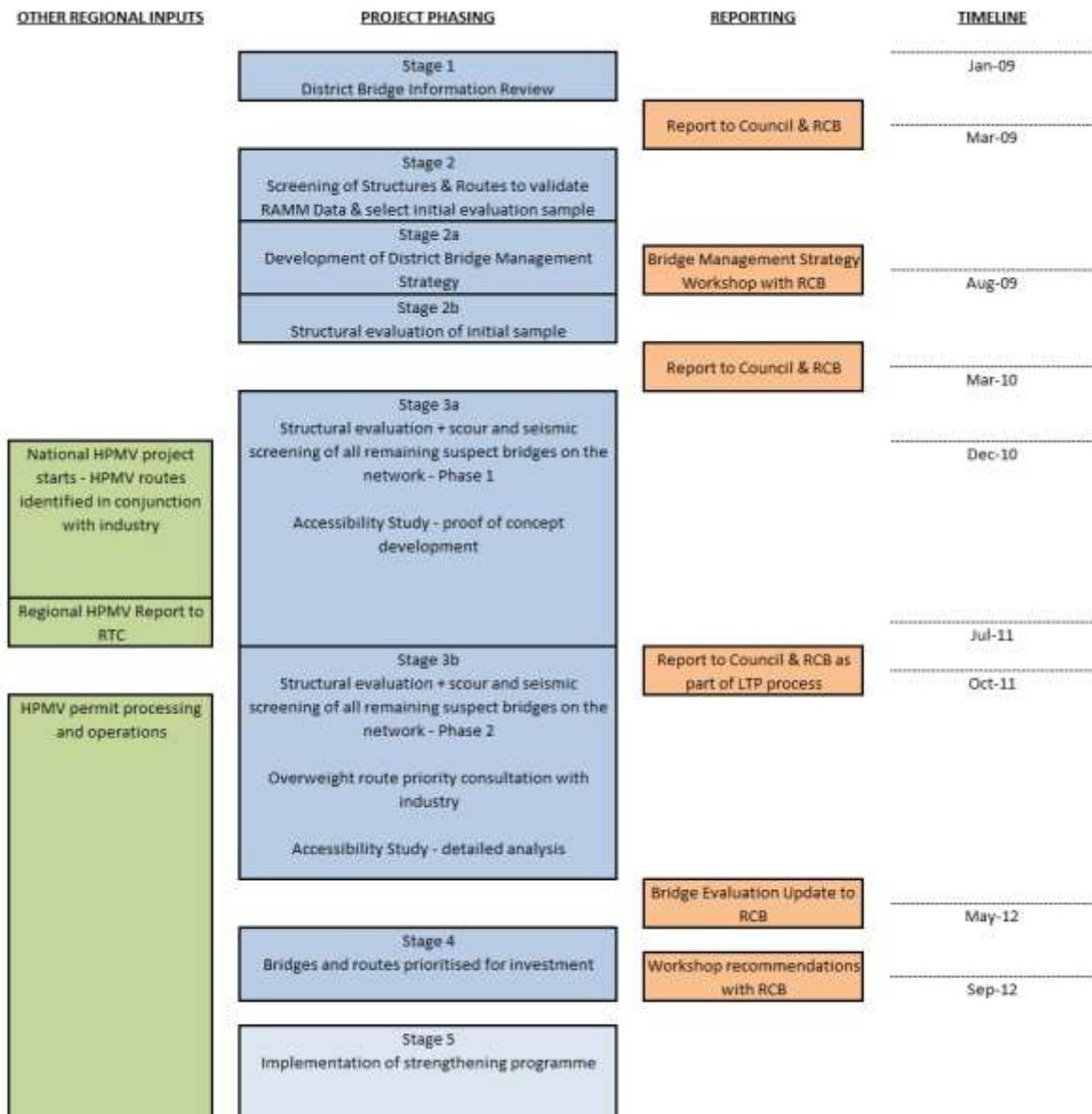
The Hastings bridge stock is aging with a large number of bridges entering the second half of their lifespan:



2.12 Evaluation Approach

The approach to developing an optimised bridge strengthening and management programme was based on a staged development model starting with initial data collection and risk validation and then moving on to bridge screening, detailed evaluation & risk assessment and finally action prioritisation and optimisation. Regular updates and consultation with Council has helped guide the process.

Early priorities for assessment were based on risk and ensuring a representative sample was taken across the network (network area, bridge type, length, age & use).



2.13 Network Analysis

HDC could not find an appropriate decision making framework that could be used for assessing bridges and their wider social, environmental and economic impacts. The Economic Evaluation Manual and Seismic Evaluation Manual SM110 are the primary formalised decision support processes for bridges in New Zealand; however they fail to recognise that bridges are nodes that support the interconnected function of a network. Therefore, improvements across a group of structures can get ranked piecemeal to meet isolated project needs instead of network benefit, risking sub-optimal network outcomes.

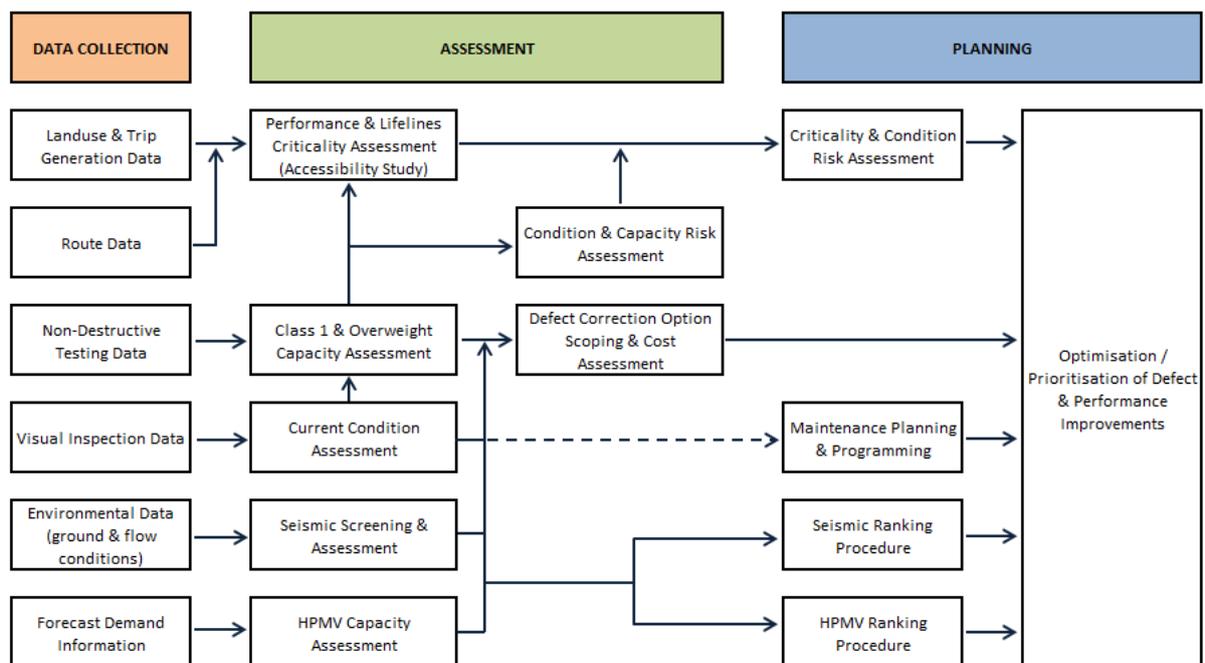
One of the complexities for a local road network is that the assessment of service level must be network focussed rather than individual asset or route focussed.

To address this HDC developed a network accessibility model with Abley Consultants to create performance metrics that correlate bridge maintenance management with district and regional economic outcomes.

Accessibility is the ease with which activities, either economic or social, can be reached or accessed by people. Accessibility modelling is typically used in multi-stage transportation models to model the level of access to essential services by different travel modes afforded to individual land parcels by the transport network. It has been applied to bridges by modelling the level of access (journey time and distance) to the state highway network given to land parcels by the local road network. In conjunction with land parcel intelligence (size, rateable value, land use etc.) this is assumed to simulate the contribution of the bridges to economic productivity.

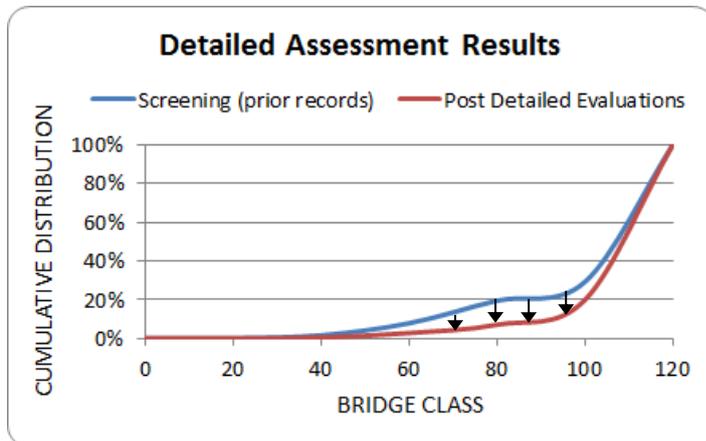
Under this model, performance is measured by both load capacity (restriction on travel) and the impact of any restriction, or combination of restrictions, on access between land parcels (production) and the state highway network (markets). This creates a link between bridges and the regional economy by joining operational need at a land parcel level with asset performance at a network level. Linked with other network investment priorities, this provides a basis for more proactively managing the aging district bridge stock.

The following figure gives an overview of how assessment information has been combined with accessibility performance measures to provide a transparent decision support process that generates defendable outcomes, and more importantly leads to improved network outcomes:

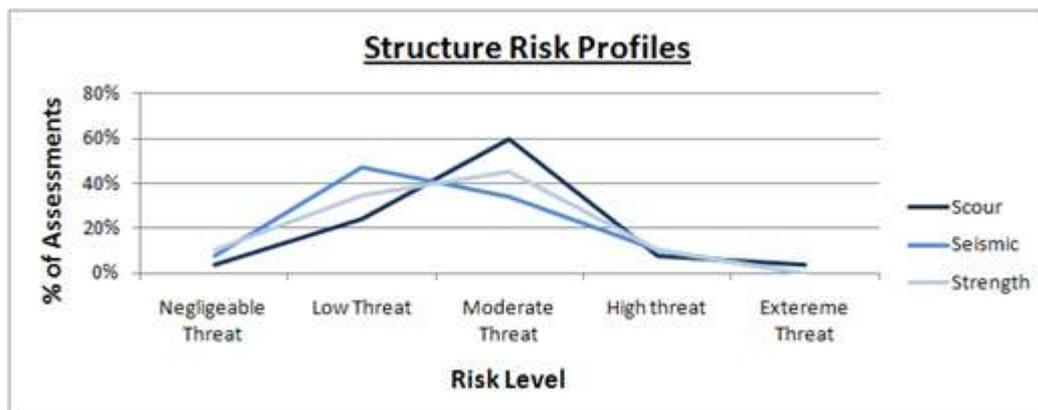


2.14 Structural Evaluations

Detailed structural assessments were carried out on the 65 potentially substandard structures plus a further 19 significant structures. A combination of advanced structural & seismic analysis and material testing of over 100 structures reduced the pool of sub-standard structures by about 35% to 41 (\$2.2m strengthening cost removed at an investigation cost of \$300k):



Detailed risk assessments were also carried out in conjunction with the structural assessments and confirmed the overall high level threat profile of the network:



2.15 Accessibility Modelling

Accessibility is the ease with which activities or destinations, either economic or social, can be reached or accessed by people, and for transport systems includes four interrelated components:

Land Use:	Transport System:
1. 'Demand' (productivity)	1. 'Capability'
2. 'Opportunity' (markets)	2. 'Mobility'

Accessibility modelling provides an integrated way of measuring changes in either system. Using a GIS platform, it considers the separation of origins and destinations, including barriers between origins and destinations such as bridges, and provides a means to measure changes to the overall performance of the

transportation network using factors such as journey time. The philosophy behind this project was based on travel from land parcels to certain destinations and the importance of specific bridges to achieving access to that destination.

This enabled us to:

1. Analyse individual structure criticality in the network context
2. Analyse the effect of imposing bridge restrictions. Effect is measured at a network cost level (user costs and road maintenance costs) and at a land parcel access (economic potential) level
3. Undertake a lifeline assessment to identify the importance and level of redundancy for each bridge in providing emergency access/egress to/from residential address points.

The methodology required the development of performance indicators for the bridges to identify performance goals. However, different indicators apply to different parts of the network so for analysis of the accessibility indicators, bridges were divided into two categories:

1. Where access alternatives exist – these are described as performance bridges as structure limitations affect performance of the network. Network benefit vs. improvement cost ratios (BCRs) are used as indicators for performance bridges.

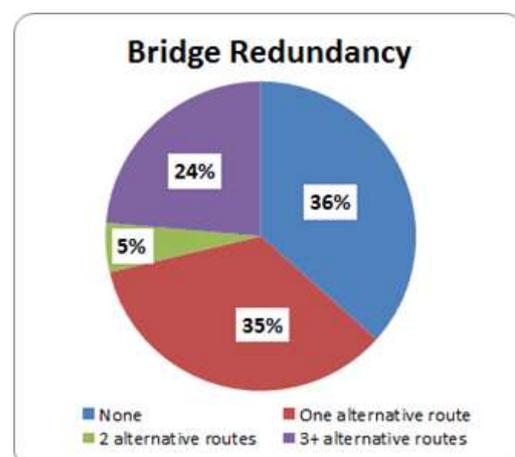
Note: within this category, bridge criticality is dependent on both the network performance contribution and level of redundancy (number of alternative routes available).

2. Where no access alternatives exist – these are described as lifeline bridges as structure limitations will isolate parts of the district. The performance indicator is the number of residential address points isolated.

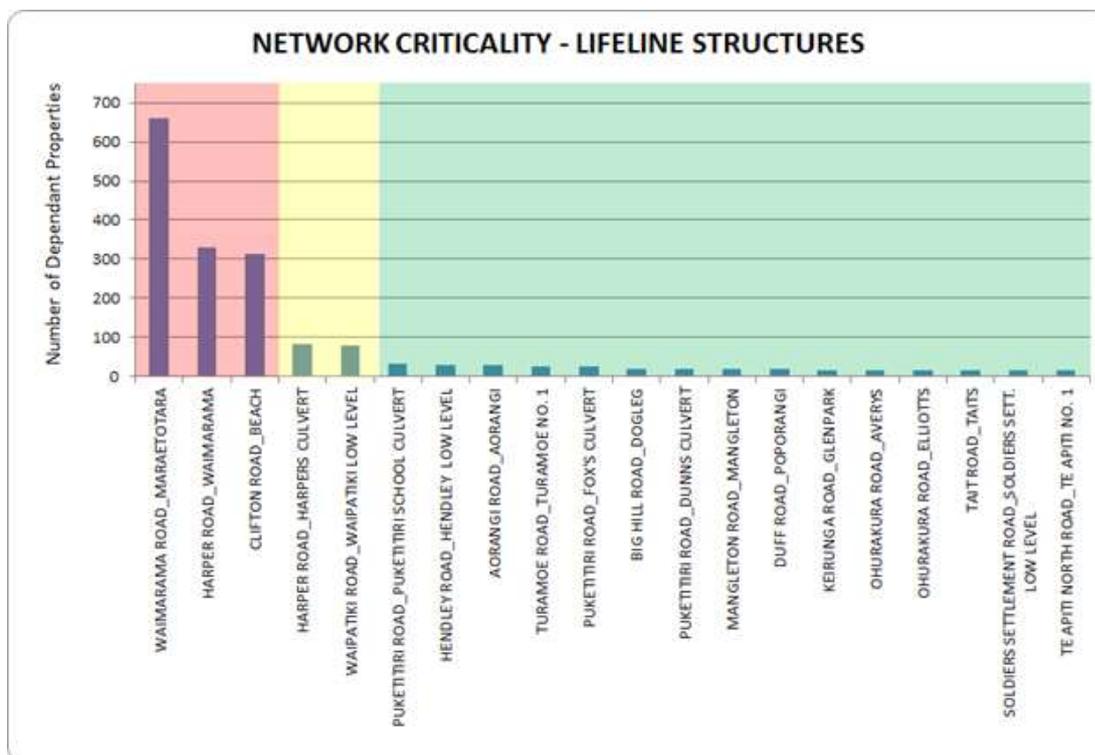
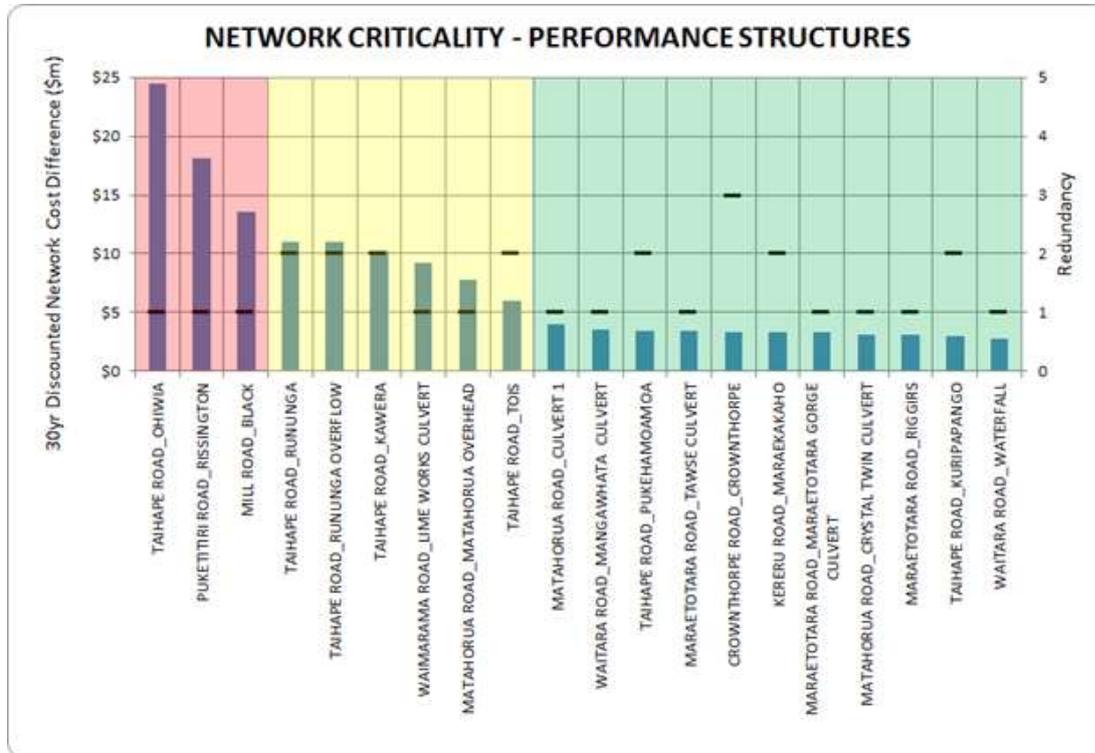
A more detailed explanation is provided in the Accessibility Modelling Report in Appendix B.

2.16 Criticality Assessment Outcomes

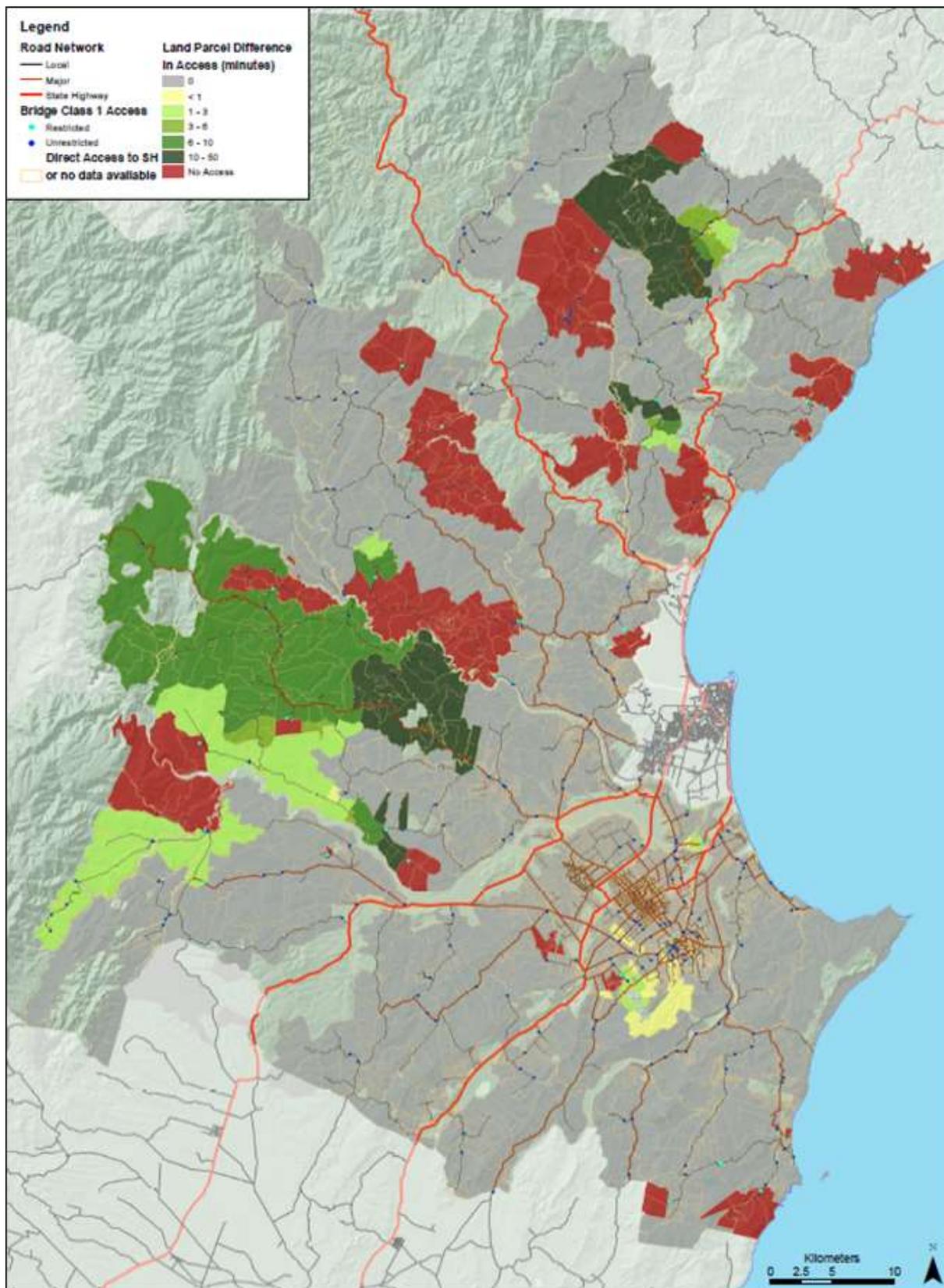
The figure below shows the level of bridge redundancy on the network as a whole. The “None” category relates to the “Lifelines” bridges while the remaining categories compose the “Performance” bridges.



The following figures show the relative importance of individual structures in each category. The results show that there are few critical structures in each category and a large number of much lower criticality bridges with similar ranking. They also show that on the Hastings network, large complex, highly used structures that would naturally attract management attention are not always the critical structures in the network context.



By restricting HCV access across the 41 substandard bridges on the network, the following impacts are observed (per trip):



2.17 Strengthening Prioritisation Framework & Results

Two principal options existed for Managing Class 1 Access:

1. remedy all identified deficiencies; or
2. take a risk based approach balanced between strengthening and management of substandard structures.

Various options for assessing priority are available with the information available. For consistency with the overall risk based asset management approach used in Hastings however, the adopted prioritisation methodology combines risk of strength failure at an individual structure level with network criticality from the bridge accessibility work. This combination assists to inform both an appropriate response (e.g. strengthen or not) and priority of the response.

Weight restriction	Risk	Lifeline bridges	Performance bridges
<100% Class 1 bridges	Response as per the HDC transportation risk management framework (see below)	HCV Demand potential (24)	BCR (strengthening cost c.f. pavement maintenance and demand potential benefits) (16)

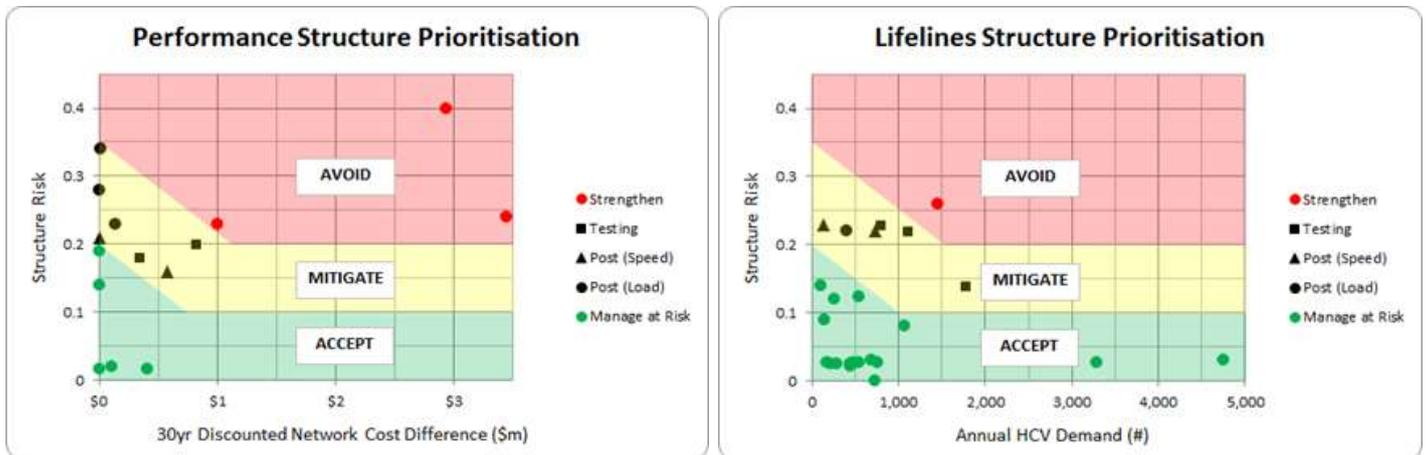
As lifeline bridges are critical to providing access to land parcels, where failure risk is comparable they should be prioritised before performance bridges.

HDC Transportation Risk Categories:

		CONSEQUENCES				
		No effect (0.1)	Minimal Effect (0.3)	Moderate Effect (0.5)	Significant Effect (0.8)	Disastrous (1.0)
LIKELIHOOD	Highly unlikely (0.1)	0.01 Negligible Threat ACCEPT PASSIVELY • Accept • Repair	0.03 Negligible Threat ACCEPT ACTIVELY OR TRANSFER • Accept • Repair	0.05 Negligible Threat ACCEPT PASSIVELY • Accept • Repair	0.08 Low Threat ACCEPT ACTIVELY • Enhance systems to minimise potential • Repair	0.1 Low Threat ACCEPT ACTIVELY • Monitor • Contingency & disaster plans
	Unlikely to happen (0.3)	0.03 Negligible Threat ACCEPT PASSIVELY • Accept • Repair	0.09 Low Threat ACCEPT ACTIVELY OR TRANSFER • Repair	0.15 Low Threat ACCEPT ACTIVELY • Monitor • Insure • Contingency Plans	0.24 Moderate Threat ACCEPT ACTIVELY • Enhance systems to minimise potential • Insure • Contingency plans	0.3 High Threat AVOID OR TRANSFER • Monitor • Insure • Contingency & disaster plans
	Could happen (0.5)	0.05 Negligible Threat ACCEPT PASSIVELY • Accept • Repair	0.15 Low Threat ACCEPT ACTIVELY • Enhance systems to minimise potential • Insure • Contingency plans	0.25 Moderate Threat ACCEPT ACTIVELY • Monitor • Insure • Contingency plans	0.4 High Threat AVOID OR TRANSFER • Enhance systems to minimise potential • Immediate action	0.5 High Threat AVOID • Contingency & disaster plans • Immediate action
	Will probably happen (0.8)	0.08 Low Threat ACCEPT ACTIVELY • Enhance systems to minimise potential • Repair	0.24 Moderate Threat ACCEPT ACTIVELY • Enhance systems to minimise potential • Insure • Contingency plans	0.4 High Threat AVOID OR TRANSFER • Enhance systems to minimise potential • Immediate action	0.64 Extreme Threat AVOID • Monitor • Insure • Contingency Plans • Immediate action	0.8 Extreme Threat AVOID • Immediate action • Cease activity
	Will happen (1.0)	0.1 Low Threat ACCEPT ACTIVELY • Enhance systems to minimise potential • Repair	0.3 High Threat ACCEPT ACTIVELY • Monitor • Insure • Contingency plans	0.5 High Threat AVOID • Contingency Plans • Immediate action	0.8 Extreme Threat AVOID • Immediate action • Cease activity	1.0 V. Extreme Threat AVOID • Immediate action • Cease activity

Following categorisation using the above approach, priority is further fine-tuned based on a number of other factors including HPMV priority and seismic attributes grading.

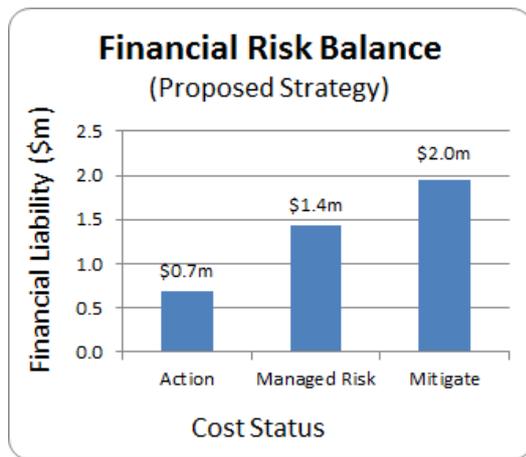
Results of the prioritisation analysis and the proposed response approach are as follows:



The above results in the following, the network impacts of which are shown in Appendix C:

1. Low risk structures being managed in a sub-standard state with no load restrictions. Bridges in this category will be generally in good condition with no sign that reduced capacity is having an effect on the bridge. These bridges will also have structural systems of high redundancy and ductile failure modes reducing the risk of failure or have low replacement cost & safety risk.
2. Structures with elevated risk receive a mitigation based approach (e.g. posting or more refined analysis prior to considering strengthening). Bridges in this category are likely to be in a poorer condition and operating closer to their performance envelope. Their structural systems may have less redundancy increasing the risk of failure. Failure modes will still be ductile.
3. Structures where condition indicates that they are operating very close to their performance limits, or there is a high consequence of failure, will be strengthened. These bridges are likely to play a pivotal role in the operation of the network and risk tolerance is low.

The financial risk balance of the above strategy is represented by the following figure and shows that the strategy has resulted in a commitment to \$0.7M of strengthening and \$3.4M of deferred strengthening being managed at risk. The cost to manage the risk and introduce annual inspections of these structures is about \$5,000. Even allowing for the risk of some strengthening need to be realised over time due to load related defects, this represents a significant value for money advantage over a full strengthening programme.



2.18 Managing Residual Risk

Managing substandard structures on the network requires the management of residual risk. This is largely being managed through annual special inspections to monitor for signs of overloading and load related distress. Routine surveillance inspections are also carried out by the maintenance contractor throughout the year to identify any obvious defect which may affect the safety of road users or anything else needing urgent attention.

2.19 Discussion

The Bridge Manual States:

7.4.3 Higher allowable stress levels for Class 1 posting and HPMV evaluation

In the evaluation of bridges for posting when subjected to Class 1 conforming vehicle loading, or for their capacity to sustain HPMV conforming vehicle loading, higher stress levels (i.e. lower load factors) may be justified where only a small number of bridges are restrictive on an important route. For this approach to be adopted, all of the following criteria shall be met:

- i. The bridge must be one of a small number of bridges restricting vehicles on an important route.*
- ii. The deterioration factors for the bridge shall be accurately assessed. This shall be confirmed by undertaking an initial inspection to assess the condition of the bridge.*
- iii. The engineer shall be satisfied that the structure has a ductile failure mode.*
- iv. The accuracy of the bridge structural data shall be confirmed (i.e. shear and moment capacities and eccentricity values must be confirmed).*
- v. The bridge shall be inspected at no more than six-monthly intervals to observe any structural deterioration.*
- vi. The engineer shall be satisfied that early replacement or strengthening is feasible.*

The decision to implement a specific inspection programme for a critical bridge to justify higher working stresses shall be discussed with the road controlling authority to ensure that the heavy motor vehicle or HPMV demand for a particular route

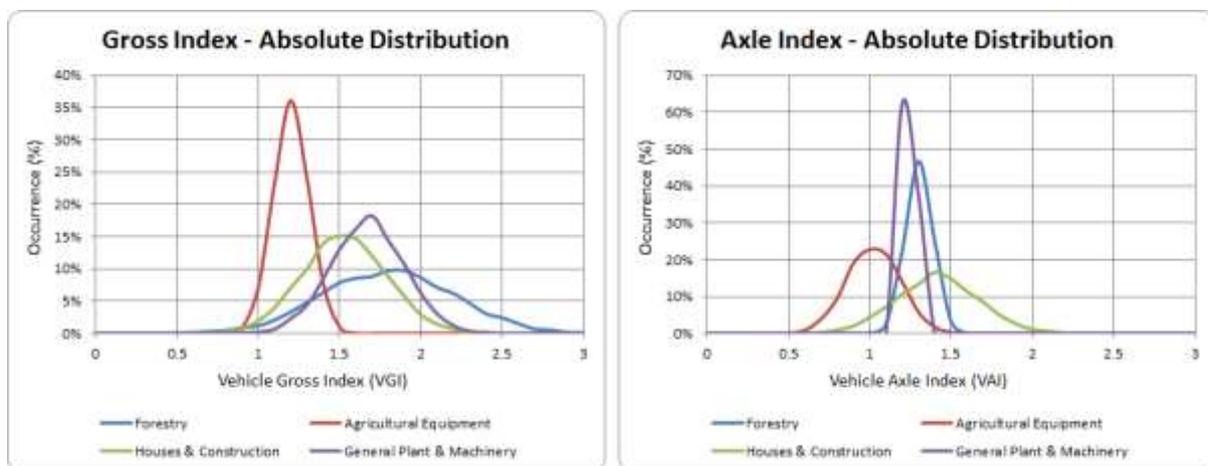
justifies the cost of regular inspections. This decision is only expected to be made for bridges with a high heavy motor vehicle or HPMV demand, that are one of only a few critical bridges on a route, that are in good condition, and where regular inspections would be relatively easy to undertake.

Accessibility modelling in Hastings has shown that on a low volume rural network, a large number of structures operate together to provide access to large areas of productive rural land that is critical to the region's economy. On a per trip basis, the cost of strengthening all bridges required to maintain open access for HCVs can be very high. The risk based analysis presented shows that managing a network of low risk structures at an elevated working stress level with regular monitoring inspections is a value for money strategy for supporting economic productivity and efficiency in the region.

Section 7.4.3 applies where only a small number of bridges are restrictive on an important route. HDC suggests that consideration be given to expanding this guidance to include "substandard" structures on low volume networks in productive rural areas.

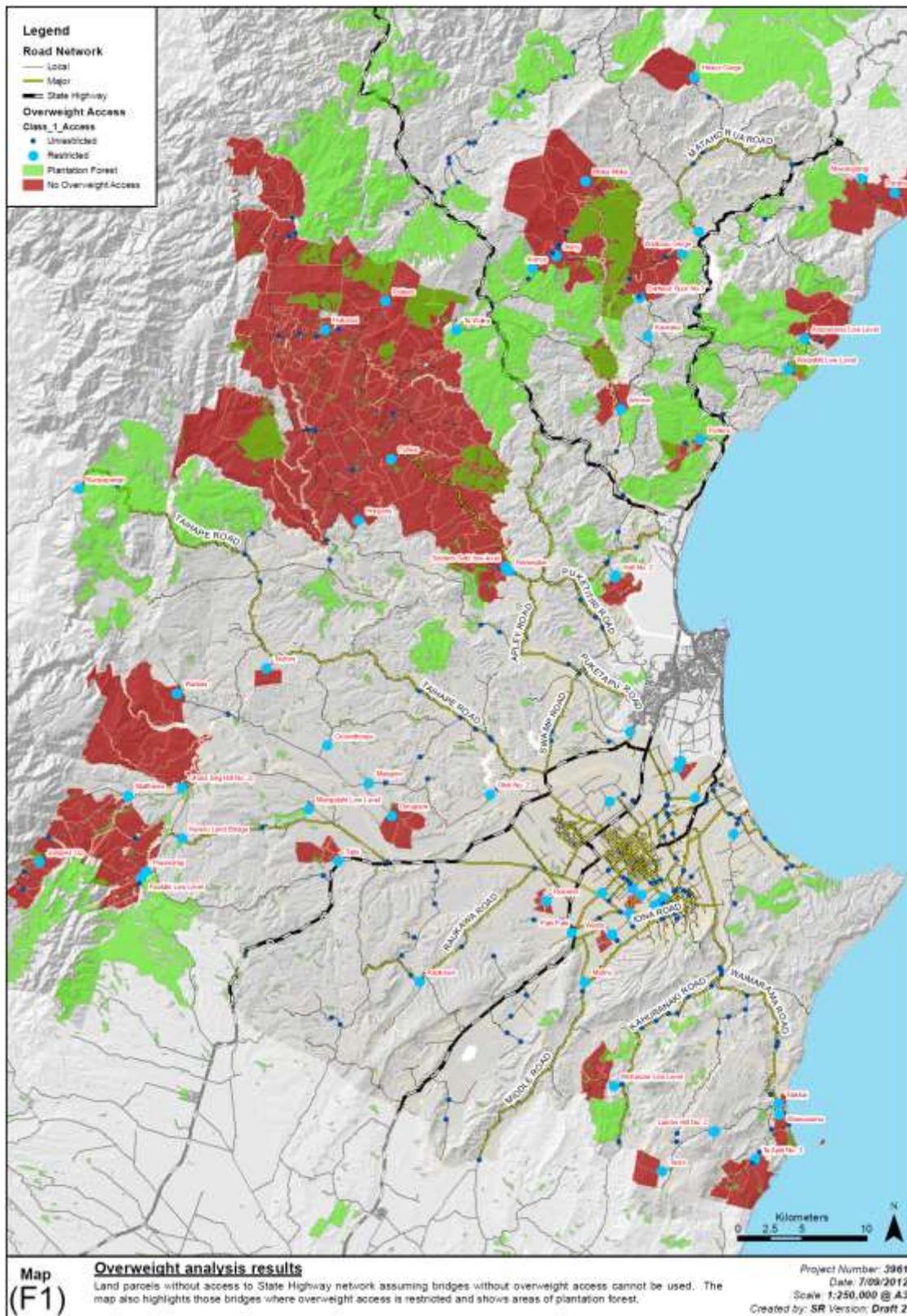
2.20 Further Opportunities

Accessibility analysis using land parcels also allowed us to determine variable level of service requirements for different overweight vehicles on different parts of the network based on land use. Evaluating historic overweight permit applications showed highly variable load demands for the different industrial sectors in the district:



By way of example, the following figure shows the current level of service for overweight forestry plant access based on 70% non exceedence probability with the primary plantation areas overlaid.

Red areas on the map would not be accessible in the scenario above so areas of forestry within the red zones could not be accessed by vehicles requiring overweight permits, effectively reducing economic productivity.



2.21 Future Enhancements

Further enhancements to the bridge accessibility methodology include (but are not limited to):

- Sensitivity testing to understand the sensitivity of the network risk to changes in base assumptions such as demand and land use.
- Use key freight destinations other than State Highways such as ports and distribution centres.
- Undertake economic evaluation incorporating crash risk in more detail rather than applying a uniform 'user cost' that incorporates crash risk.
- Extend the analysis to other network risk and reliability analysis such as areas vulnerable to closure from slips and flooding etc.
- Apply the analysis to future land uses.

2.22 Summary

This work focused on undertaking an accessibility analysis to measure the significance of the bridge assets (individually and collectively) within the Hastings District in terms of their criticality for servicing service the regional economy. The criticality of each bridge in the District was identified from both a lifelines and a heavy commercial vehicle transport efficiency perspective.

By using a novel application of accessibility analysis, the necessity of each bridge to provide land parcels (origins) with access to the State Highway network (destination) was determined analytically.

The accessibility maps of bridges provide a visualisation of areas within Hastings District that would have restricted accessibility by posting substandard structures at less than 100% Class 1 and are very useful for discussing strategies and options with stakeholders.

The adopted methodology has the following benefits:

- It is informative enabling decision makers to make better choices about prioritising maintenance schedules and upgrade plans for bridges as well as assisting with lifelines and emergency response decision making.
- The analysis process has also been for the most part automated, so it can be used to test various option scenarios and repeated periodically as changes to the road network, land parcel and bridge locations occur or to allow benefit and cost tests of potential improvements to be undertaken.
- The method is useful for analysing an inter-dependant network of roads and bridges rather than individual structures or routes.
- It removes subjectivity and is more transparent than the current approach to bridge asset management.

- the transparent investment methodology assists with producing better business cases for funding

Outcomes from the accessibility modelling when combined with individual bridge assessment and risk information enabled Council to prioritise bridge asset investment on the network and make informed decisions about the cost / risk balance of the strategy. This has reduced Council's capital bridge programme by over \$3m and will result in better investment decisions and more efficient long term outcomes.

The methodology has potential application to other local authorities and those involved with bridge asset management, including the NZ Transport Agency, particularly within a "One-Network" framework.

3 Recommendations

Specific Recommendations	Suggested Action to be Taken
<p>Cost effective management of low volume bridge networks relies on a flexible approach to risk management. This means accepting different management strategies for low risk structures</p>	<p>NZTA give consideration to expanding Section 7.4.3 of the Bridge Manual to include guidance on the management of low risk structures on low volume networks in productive rural areas.</p>
<p>An integrated bridge management system combining asset inventory and capacity data with risk, condition and defect/works management components enables efficient tactical oversight and management of performance and critical vulnerabilities.</p>	
<p>Combining consultant and contractor expertise on bridge inspections facilitates better communication and identification of optimised maintenance strategies.</p>	
<p>Assessment and recording of most credible bridge threats during routine inspections enables monitoring, management and reporting of overall levels of network risk exposure.</p>	
<p>Incorporate and annual learning review prior to each round of bridge inspections to inform the briefing and guide the setting of strategic priorities. This ensures continuous improvement.</p>	
<p>Identification of risk is the foundation on which a good asset management strategy is built and lowest cost, effective long term management of those risks is the objective of the strategy. Risk assessment should not be treated as an add-on or step in the process to validate or tweak a strategy.</p>	
<p>Asset managers need to be proactive in asserting their case in risk management and make their voices heard at senior management & governance level.</p>	
<p>Accessibility modelling is a cost effective tool for measuring network performance and integration with land use. It has useful potential as a wider analysis tool in conjunction with the current “One Network” management & investment focus for the NZ land transport network.</p>	
<p>Accessibility modelling provides a means of quantifying the assessment and hence introducing a higher level of scrutiny and transparent quantification for why certain bridges should be preferred for investment before others.</p>	<p>That the RIMS Group be asked to investigate the development of a strategic decision making framework for bridge investment decision making, considering the Accessibility Modelling as opportunity for optimising one-network outcomes</p>

Appendix A

Low level Crossing Risk Assessment: TR-03-13-919

Appendix B

Accessibility Modelling Detailed Report

Appendix C (Accessibility Mapping Outputs)

