Inspections to Manage Risks

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Inspections to Manage Risks

Highways Act 1980

- Background
- Highways Act
  - S41 Duty to Maintain Highways Maintainable at Public Expense
  - S91 Bridge Maintainable at Public Expense
  - S92 Reconstruction of Bridge Maintainable at Public Expense

- BD63 - Bridge Inspections
  - General Inspections – 2 yearly
  - Principal Inspections – 6 yearly
  - Special Inspections
  - BD79 – Management of Sub-Standard Structures

  (following structural assessment to BD21)

  Monitoring, Interim Measures

Inspections to Manage Risks

- BD63 Uniform inspection interval does not consider
  - New bridges with little existing damage
  - Environments or condition where deterioration is unlikely
  - Bridges & Bridge Types with long histories of good performance
  - Damage that has little effect on safety or serviceability

- The Challenge:

- Reduction in Revenue & TfL/LoBEG funding

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- How to manage highway structures risks with reduced budgets
- Tools available – Guides & BridgeStation

Interim Advice Note 171/12
Risk Based Principal Inspection Intervals

INTERIM ADVICE NOTE 171/12

Risk Based Principal Inspection Intervals

Interim Advice

Summary
This Interim Advice Note sets out the requirements and guidance for service providers using risk based inspection intervals.

Instructions for Use
This document is supplementary to BD63 and must be implemented in accordance with Clause 1.4 of the document.

Transport for London
Surface Transport

STREETS

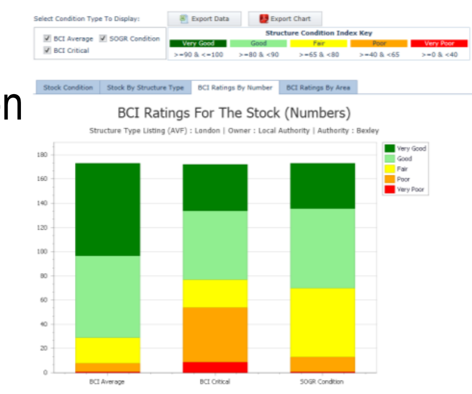
TfL Good Practice Guide

Risk Based Inspection of Highway Structures

December 2011

Inspections to Manage Risks

- Principles:
- Review of Bridge Stock
  - Condition, type/material, spans, obstacle crossed, strategic importance/consequence of failure/closure (including TM, political, commercial), age, vulnerability
- Desktop Study of available data & local knowledge – BridgeStation
- Fill gaps if necessary
- Prioritisation of Risks – focus where the money is best spent
- Methods:
  - IAN 171/12
  - TfL Good Practice Guide
  - Engineering Judgement - Less scientific but may be appropriate if engineer has sound knowledge of bridge stock and there are data gaps on BridgeStation



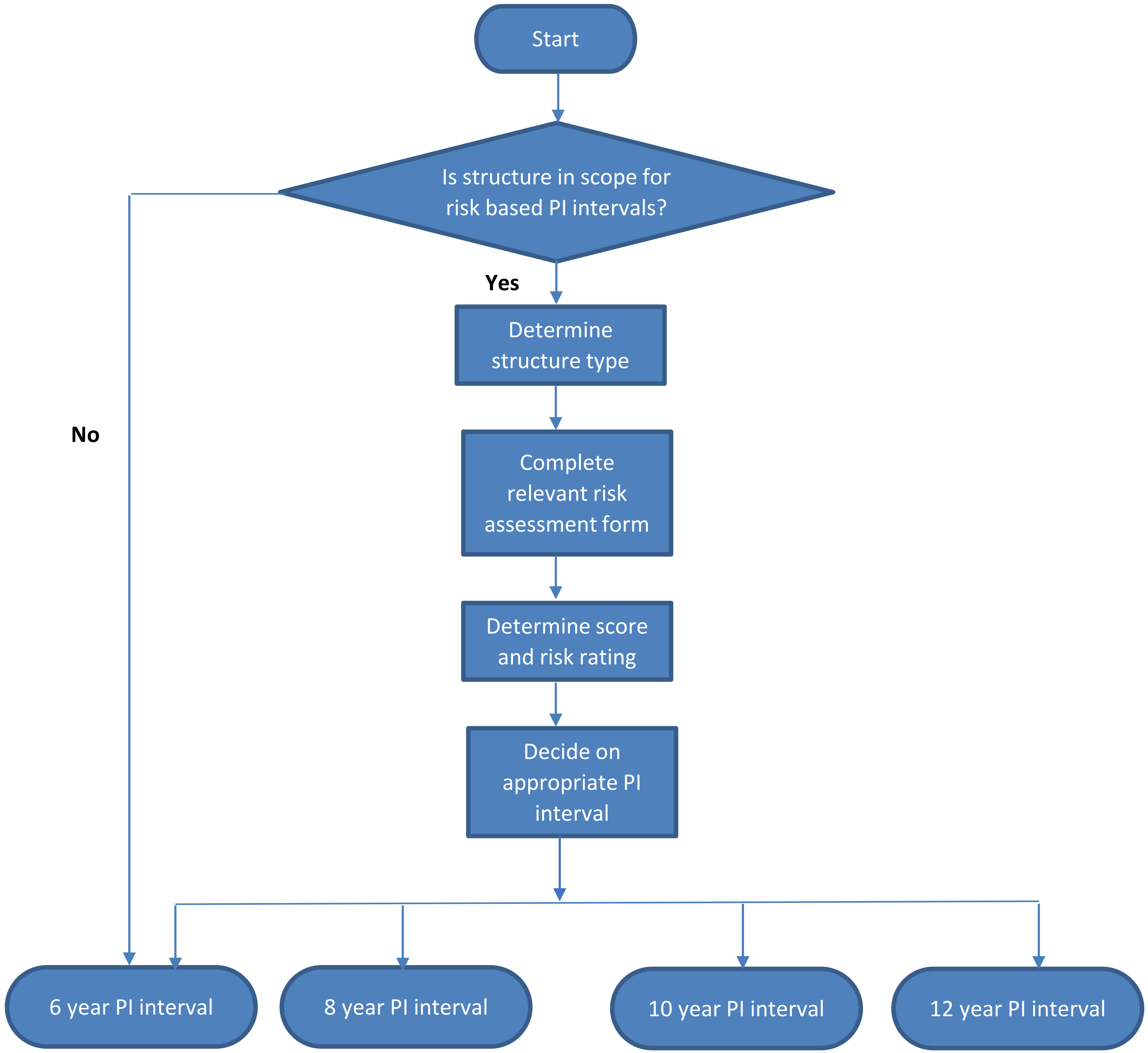


Figure 1 – Flow chart to show Risk Assessment Methodology

Table 1 – Risk Assessment Criteria

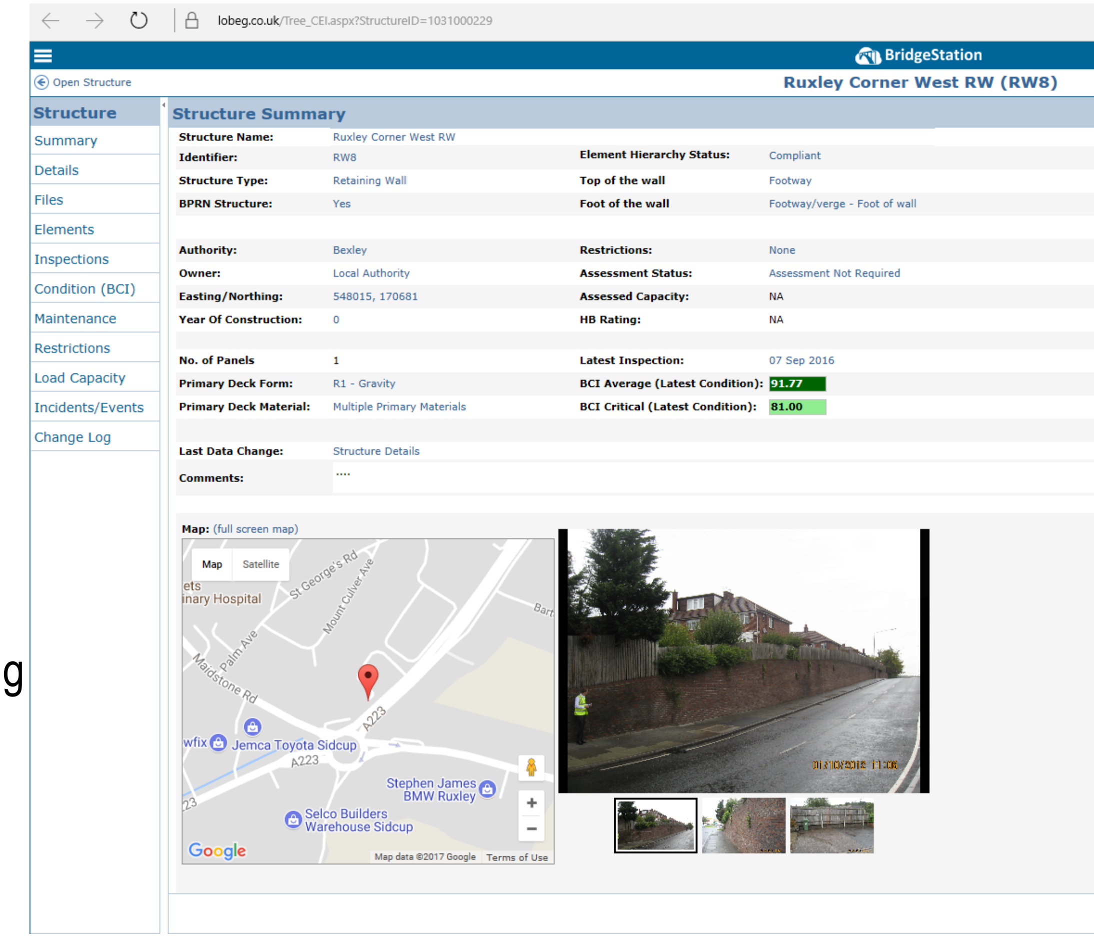
ASSESSMENT CRITERIA	COMMENTARY	SOURCE OF INFORMATION
Structure Type		
Form	Different structural forms can be expected to experience varying degrees of deterioration and have each been rated accordingly to consider this.	(a) Inventory (b) Structure File
Material	The primary constituent material will have an impact on the likelihood of deterioration. Historical performance has been evaluated for different construction materials and is reflected in the scoring.	(a) Inventory (b) Structure File
Age	The age of a structure will usually affect the likelihood and rate of deterioration. In general, it would be expected that an older structure approaching the end of its design life will encounter more maintenance issues and hence be more prone to deterioration. Newer structures may encounter initial teething problems before they are considered to be performing optimally.	(a) Inventory (b) Structure File
Span / Height / Headroom / Length	Although every structure has different design requirements, probabilistic analysis shows that bridges with longer spans and retaining walls with greater retained heights, tend to be at a higher risk of failure. Not only is the likelihood increased but also the associated consequence of failure.	(a) Inventory (b) Structure File
Environment		
Scour	Scour susceptible structures are not suitable for reduced inspection intervals.	(a) Inventory (b) Structure File (c) Scour Assessment in accordance with BA 74/06 or BD 97/12
Flooding	Structures in areas susceptible to flooding should be assessed as having increased risk.	(a) Qualitative assessment of the available information that would inform the likelihood of flooding (b) Environment Agency records
Inspection / Assessment		
Visual Access	Limited visual accessibility to critical elements will reduce the reliability of the General Inspections undertaken between Principal Inspections.	(a) Qualitative assessment of the available information on visual accessibility.
Latent defects	Some structure types are more susceptible to containing defects that are not evident during a Principal Inspection for example, post-tensioned concrete bridges with internal grouted tendons.	(a) Inventory (b) Structure File

Table 1 – Risk Assessment Criteria

ASSESSMENT CRITERIA	COMMENTARY	SOURCE OF INFORMATION
Assessments	Where an assessment has been carried out on a structure, a greater degree of confidence can be achieved with regard to the structure's ability to carry load. The findings of the assessment report should give a clear indication of any current load restrictions and any recommended condition factors. Any current load restrictions in place indicate that the current condition of the bridge is below design standard, resulting in a higher potential risk of deterioration.	(a) Load Management Records (b) Assessment reports (c) Interim Measures Records
Condition		
Inspector's Condition Rating	Condition is to be assessed using two criteria. The first is the Inspector's subjective condition rating of the structure (ie. Good, Fair or Poor), which should give a good overview of the condition of the structure.	(a) inspection records
Condition Performance Indicators	Secondly, Condition Performance Indicators, where available, are to be taken into account. These are an objective measure of the physical condition of the highway structures stock, calculated using the Highways Agency's Severity/Extent condition rating system[5]. They are reported for each structure on a scale of 0 to 100, where 0 represents the worst possible condition and 100 represents the best possible condition. There are two scores to consider: 1. Average Condition PI Score, PI_{Av} (based on all elements) 2. Critical Condition PI Score, PI_{Crit} (based on the most critical elements only)	(a) Condition Performance Indicator Reports
Concrete Deterioration	Any deterioration of concrete including that due to Thaumasite Sulphate Attack, Alkali Aggregate Reaction, Alkali Silica Reaction and Alkali Carbonate Reaction should be scored	(a) Inventory (b) Structure File (c) inspection records
Consequences		
Load Type	Load type may not have an impact on the likelihood of deterioration or failure. However, it will have a bearing on the overall consequence of any potential collapse.	(a) Load Management Records (b) Assessment reports (c) Interim Measures Records
Route supported and obstacle crossed	These attributes are intended to reflect the importance of the structure within the overall road network in the event of a structural collapse.	Inventory
Failure Mode	Brittle failure modes can result in collapse without warning and high consequences whereas ductile modes typically give warning of structural distress.	(a) Inventory (b) Assessment reports

Engineering Judgement

- Typical Brick Retaining Wall – good condition
- High BCI_{CRIT}, high BCI_{AV}
- All inspectable parts generally visible (unlikely to clear vegetation to rear for PI)
- Durable low-maintenance structure
- Propose reduction of PI from 6 yearly to 12 yearly or 18 yearly
- GI every 2 years for safeguarding and routine maintenance/review of deterioration/BCI

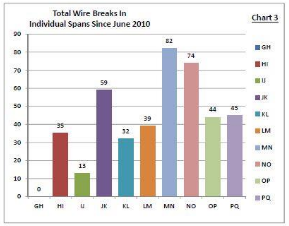


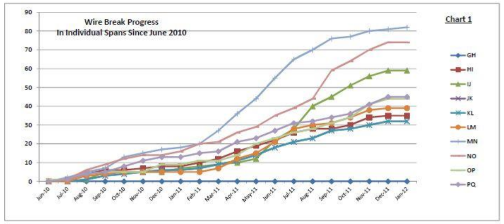
Reliability – Based Inspection

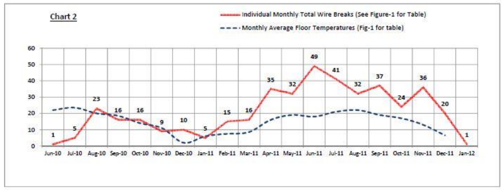
- What can go wrong?
  - Identify damage modes for elements
  - Deterioration mechanisms
- How likely is it?
  - Categorization based on reliability characteristics of bridge elements
    - Based on expert judgment and expert guidance
      - Past experience
      - Analysis of existing or potential damage modes
  - Deterioration data if available (and relevant)
- What are the consequences?
  - How important is it?

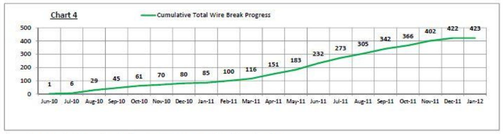
	1	2	3	4	5	6	7	8	9	10	
Month/ Span	GH	HI	IJ	JK	KL	LM	MN	NO	OP	PQ	Cumu Total
Jun-10	0	0	0	0	0	0	0	0	1	0	1
Jul-10	0	1	0	0	0	0	2	1	1	1	6
Aug-10	0	4	1	1	1	3	5	6	4	4	29
Sep-10	0	6	1	5	3	4	7	9	5	5	45
Oct-10	0	6	3	5	4	5	13	12	5	8	61
Nov-10	0	7	3	5	5	5	15	14	5	11	70
Dec-10	0	8	3	5	6	5	17	14	9	13	80
Jan-11	0	8	3	7	6	5	18	16	9	13	85
Feb-11	0	10	4	8	7	5	20	20	11	15	100
Mar-11	0	12	4	9	9	7	27	21	11	16	116
Apr-11	0	16	5	10	11	12	36	26	14	21	151
May-11	0	19	7	12	14	15	44	29	20	23	183
Jun-11	0	22	9	22	18	21	55	35	23	27	232
Jul-11	0	26	9	28	21	28	65	39	26	31	273
Aug-11	0	28	10	40	23	30	70	44	28	32	305
Sep-11	0	28	11	45	27	31	76	59	31	34	342
Oct-11	0	30	12	51	28	34	77	64	34	36	366
Nov-11	0	34	12	56	30	38	80	70	41	41	402
Dec-11	0	35	13	59	32	39	81	74	44	45	422
Jan-12	0	35	13	59	32	39	82	74	44	45	423
Span Total	0	35	13	59	32	39	82	74	44	45	

Table 2: Lists cumulative wire breaks for all the spans









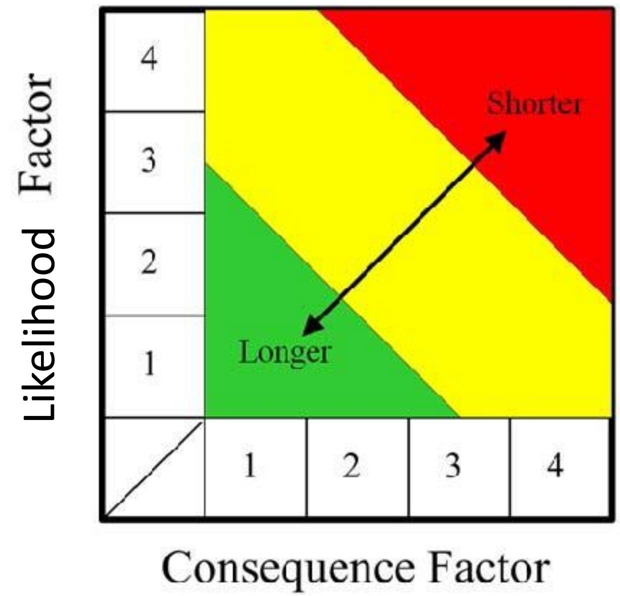
Notes:
1. Refer to PAL drawing no. 024 for the temperature sensor locations.
2: The monthly average internal temperature graph in Chart-2 is based on the approximate estimates deduced by scaling the average temperature graph in 'Mistras' website.

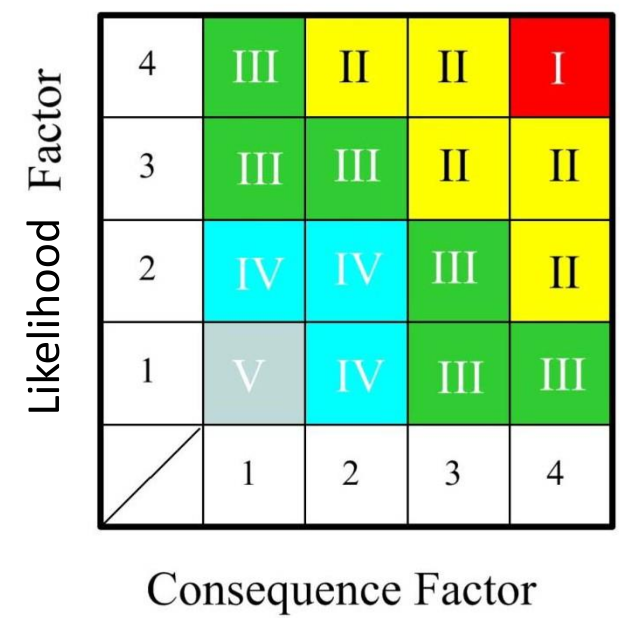
Figure 2: Cumulative Wire Breaks - Comparison of Span Behaviour

Last Updated: 17/01/2012
Last CWB: 01/01/2012

Risk Matrix

- Plot values of likelihood and consequence
- Components in the top right corner are “high risk”
- High likelihood may not mean high risk, if consequence is small
- High consequence may not be high risk, if the likelihood is low





How likely is it?

- Likelihood of failure of a bridge element in the medium term (say 6 years PI interval)?
  - Factors to consider
    - Design e.g. Concrete cover, strength, waterproofing
    - Loading e.g. AADT, High HGV, AIL route
    - Condition - Spalling, cracking etc.
    - Durability risks - Leaking joints

- Experience, expert judgment, deterioration data – factors in HE/TfL guides
- **Prioritise** factors in terms of their importance
  - Develop scoring scheme to estimate Likelihood - example

Level	Qualitative Rating	Description	Likelihood (POF)	Expressed as a percentage
1	Remote	Remote probability of occurrence, unreasonable to expect failure to occur	≤1/10,000	0.01% or less
2	Low	Low likelihood of occurrence	1/1000-1/10,000	0.1% or less
3	Medium	Moderate likelihood of occurrence	1/100-1/1,000	1% or less
4	High	High likelihood of occurrence	>1/100	> 1%

Consequence Factors

- Focus attention on the damage that is *most important*
  - *Could this damage result in collapse, is it a local failure, or is it benign? FMEA methods can assist. Use HE/TfL guidance*
- Consequence scenarios
  - Low, Medium, High, Severe
  - Credible consequence scenarios – case studies – CIRIA Guide on Hidden Defects etc
  - Rule-based to identify analysis needs
    - Documented past experience
    - Analysis or modeling
    - Other rationale

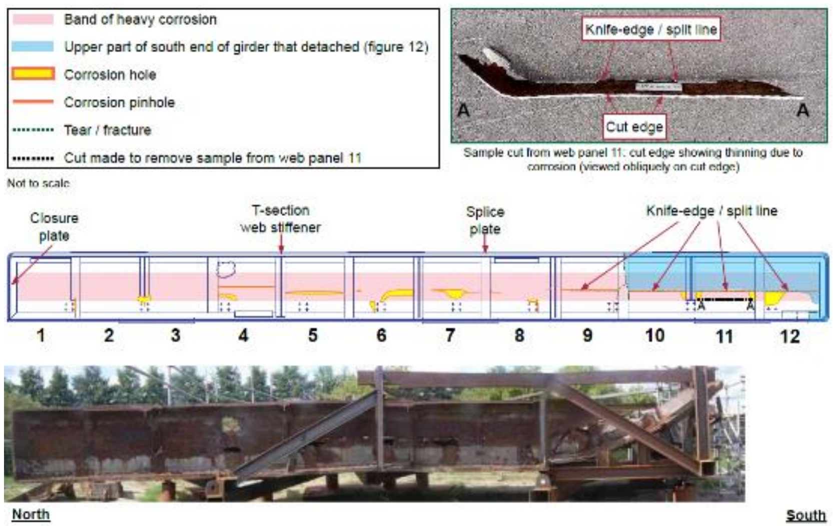
FMEA Examples

Table 3.2 Failure mode effect analysis examples

Failure mode	Location	Defect/event	Initial consequence	Other consequences	Failure type
1	Steel girder transverse stiffener weld to bottom flange	Fatigue crack growth from weld	Growth of crack: new load path formed	Increased brittle fracture susceptibility: sudden, catastrophic failure	Fatigue, brittle
2	Concrete deck at mid-span	Flexural overload to deck (sagging)	Local distress (excessive cracking) at soffit	Loss of durability	Ductile
3	Unreinforced joint in prestressed concrete deck	Corrosion of tendons passing through joint	Loss of prestress force	Collapse of deck	Brittle
4	Half-joint	Corrosion of tensile steel due to chloride ingress	Signs of water leakage through joint but limited outward signs of the onset of failure	Loss of capacity and failure of joint leading to partial or full collapse of supported section	Ductile (but not visible) followed by brittle collapse
5	Arch barrel	Loss of support due to undermining of support	Local distress (cracking and/or separation of arch barrel rings)	Loss of capacity due to separation of rings	Ductile
6	Deck tie down	Loss of restraint	Change in load distribution. Instability of structure	Deterioration of surfacing	Depending on form of structure: ductile or brittle

Inspections to Manage Risks

- Further Guides and Case Studies – CIRIA Hidden Defects - known problems & best practice guidance.
- TfL method assigns an ‘inspectability’ factor recognising potential risks within hidden elements.



Risk-based approach to Managing Hidden Defects

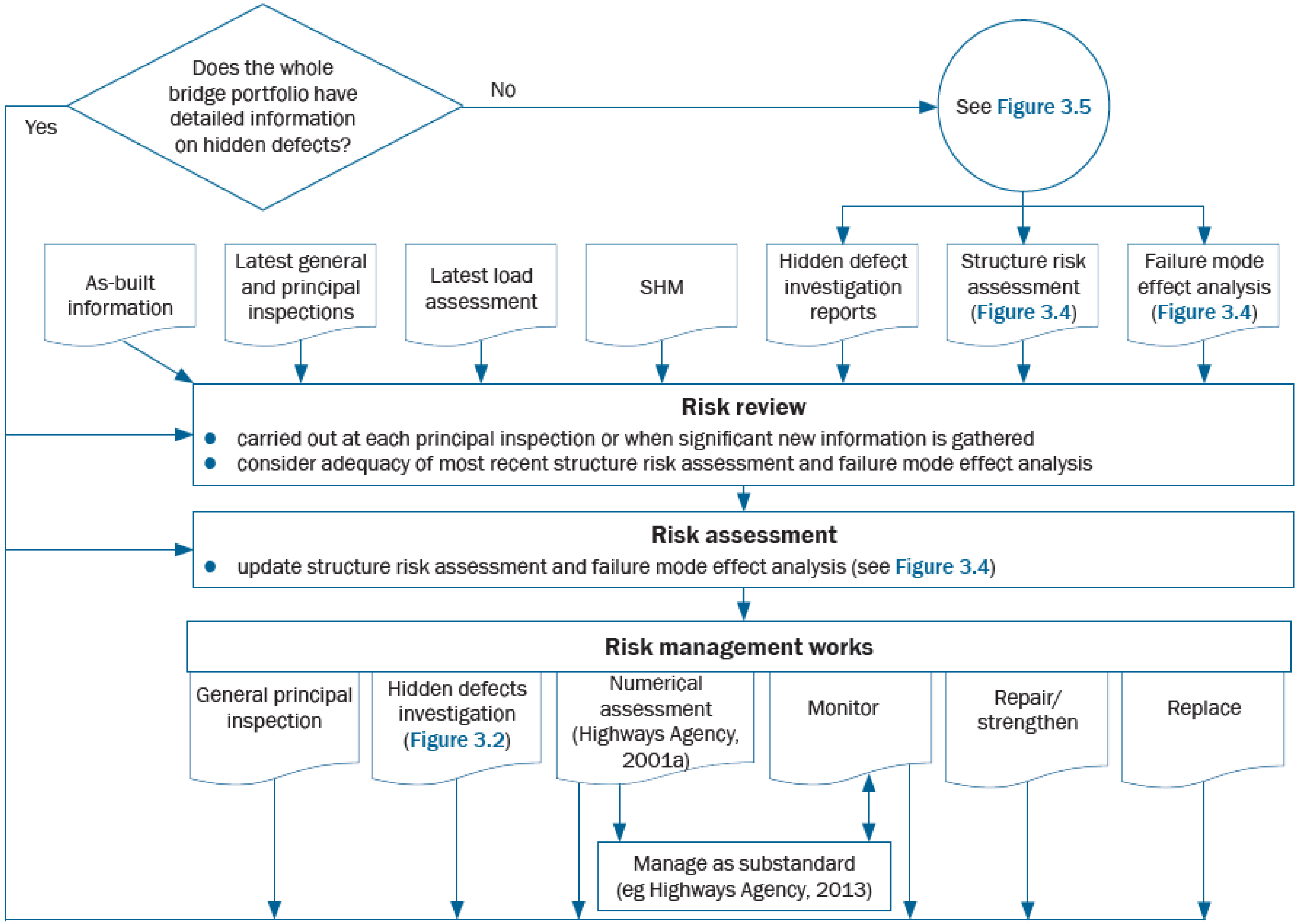


Figure 3.1 Risk-based approach to management of hidden defects in bridges (after Highways Agency, 2015)

Waterman

Risk Based Inspections - Summary

- Engineering analysis to identify bridges for extended/reduced intervals
- Prioritise repair/maintenance
- Identify special inspection needs
- Provide documented rationale for decisions/ actions including maintenance, closures, load restrictions, etc.
- Some decisions can be taken using ‘Engineering Judgement’
- *Not different from what engineers do every day*
  - Documented and systematic – IAN/TfL Guide, BridgeStation etc
- **More efficient and effective bridge inspections within limited budgets**
- **Inspections still based on risk which can never be eliminated**