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Guidance Document for Performance Measurement of Highway Structures

Part B1: Condition Performance Indicator

Report prepared by:

ATKINS

Report prepared on behalf of:

Highways Agency

CSS Bridges Group

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1. Introduction

This document is based upon and supersedes the *CSS Bridge Condition Indicator: Volume 2: Guidance Note on Evaluation of Bridge Condition Indicators* (Ref. 1).

1.1 Condition Performance Indicator Definition

The Condition PI is defined as:

A measure of the physical condition of the highway structures stock.

1.2 Background, Objectives and Scope

The background, objectives and scope are discussed in *Part A: Framework for Performance Measurement*.

1.3 Terminology

The following terminology is used in the Condition PI procedure:

- **Bridge Condition Indicator (BCI)** – the term used for the Condition PI when it was originally developed by the CSS Bridges Group (Ref. 1).

- **Condition Performance Indicator (Condition PI)** – the generic term used for the Condition PI. For external reporting the Condition PI refers to the highway structure stock, but for internal management/reporting the Condition PI may be used at structure group and individual structure level. The Condition PI is calculated on a scale of 100 (best condition) to 0 (worst condition).

- **Severity and Extent** – approach used in some inspection reporting systems to assess and record the condition of individual structure elements and/or defects. The HA and CSS severity/extent inspection reporting systems can be used directly with the Condition PI.

- **Element Condition Score (ECS)** – the numerical value of the condition of an element evaluated using inspection data (e.g. Severity and Extent) on a scale of 1 (best condition) to 5 (worst condition).

- **Element Importance** – this takes account of the importance of an element to the overall structure in terms of load carrying capacity, durability and public safety, it is designated as Low, Medium, High or Very High. The Element Importance classification is used to identify two factors:

    - **Element Condition Factor (ECF)** – used to weight the ECS to obtain the ECI, this enables direct comparison of element conditions in terms of their contribution to the overall structure condition.

    - **Element Importance Factor (EIF)** – used to weight individual ECI scores (see below) when evaluating the average Structure Condition Score, SCS_{Av} (see below).

- **Element Condition Index (ECI)** – the weighted element condition based on the ECS and ECF.

- **Structure Condition Score (SCS)** – an average and a critical SCS score are evaluated for each structure, where:

  - **SCS_{Av}** – the weighted average of all the ECI scores for the structure, the ECI scores are weighted by their respective EIF. The score is on the 1 (best condition) to 5 (worst condition) scale.

  - **SCS_{Crit}** – equal to the ECI of the Very High importance element on the structure that is in the worst condition. The score is on the 1 (best condition) to 5 (worst condition) scale.

- **Condition PI_{Av}** – the conversion of the SCS_{Av} score to a more readily understood and presentable 100 (best condition) to 0 (worst condition) scale.

- **Condition PI_{Crit}** – the conversion of the SCS_{Crit} score to a more readily understood and presentable 100 (best condition) to 0 (worst condition) scale.

- **Condition $PI_{i\text{-}Av}$ and Condition $PI_{i\text{-}Crit}$** – the *Average* and *Critical* Condition PI scores for structure type group *i*, e.g. bridges, retaining walls etc. The structure group score is the weighted average of the individual Condition PI scores. The weighting is based on the dimensions of the structure, e.g. deck area for bridges, surface are for retaining walls etc. The subscript acronyms used for each structure type are:

  - B = Bridge (also includes culverts)

  - SC = Small Culvert

  - RW = Retaining Wall

  - SG = Sign/Signal Gantry; and

  - HM = High Mast

- **Structure Stock Condition Performance Indicator (SSCPI)** – the Condition PI score for a structure stock is evaluated as the weighted average of the Structure Type Condition PIs, where the Asset Value Factor (AVF) is used to weight the Structure Type score.

- **Asset Value Factor (AVF)** – a weighting factor applied when calculating the Condition PI for a stock of structures, it reflects the importance of one structure type compared to another. An Asset Value Factor (AVF) has been evaluated for each structure type (bridge, retaining wall, sign/signal gantry etc.) based on construction cost data.

2. Overview of Procedure

2.1 General Approach

The Condition PI uses the procedures originally developed for the CSS Bridge Condition Indicator (BCI), Ref. 1 and 2. The Condition PI reiterates the BCI guidance and extends the procedures to cover other structure types (small culverts and high masts) and a more refined level of condition reporting where required.

The Condition PI procedure has been developed for use with the CSS and HA Severity/Extent condition rating systems (see Ref. 3 and 4 respectively). However, condition data collected using other systems can be translated to the aforementioned severity/extent scale if required. The Condition PI is evaluated using condition data collected during General and Principal Inspections.

Inspections should be performed by a suitably qualified inspector or engineer who is capable of applying an appropriate level of engineering understanding and interpretation to the visual information they encounter on-site. Therefore, the Condition PI, in many circumstances, is more than a straightforward reporting of "visual" condition.

2.2 Condition PI Scale

The Condition PI scale is from 0 to 100, where 0 represents the worst possible condition for the structure or stock and 100 represents the best possible condition. Individual structures, structure groups and the structure stock are all reported on the 0 to 100 scale. The scale is divided into five bands (Very Good, Good, Fair, Poor and Very Poor), generic interpretations for these bands are presented in Section 6.

2.3 Condition PI Score

All structures that have regular General and/or Principal Inspections should have a Condition PI score evaluated. The condition score is built up to structure level from the defect and element severity/extent scores. The individual structure scores are used to evaluate the group scores which are weighted by typical dimensions, e.g. deck area for bridges, length for retaining walls etc. The group scores are used to evaluate the stock score which is weighted by the Asset Value Factor (AVF) of each structure type.

2.4 Steps in the Condition PI Procedure

The overall procedure is shown in Figure 1 and summarised below:

Step 1 – Select Structure Type and Structure

The Condition PI procedure uses weightings linked to *Structure Type*, therefore each *Structure Type* needs to be dealt with separately before they are combined to give the Condition PI for the *Structure Stock*. First select the *Structure Type*, i.e. Bridge, Retaining Wall, Sign/Signal Gantry etc., and secondly select an individual structure.

Step 2 – Select Element and Evaluate the Element Condition Score (ECS)

First, select one element from the structure; secondly use the element's condition data to calculate the Element Condition Score (*ECS*). Section 4.1 describes how element condition data are used to evaluate the *ECS*. Section 5 provides guidance on using condition data when a more detailed level of reporting is used, i.e. condition is reported for each longitudinal beam rather than one condition for the whole group.

Step 3 – Element Importance

The Element Importance accounts for the importance of the element to the overall functionality of the structure, e.g. load carrying capacity, durability and public safety. Tables are provided in Section 4.2 for identifying element importance, i.e. *Very High*, *High*, *Medium* or *Low*. The Element Importance and the *ECS* are used to evaluate the Element Condition Factor (*ECF*), Section 4.3.

Step 4 – Element Condition Index (ECI)

The *ECS* (from Step 2) and *ECF* (from Step 3) are combined to produce the Element Condition Index (*ECI*), Section 4.4. The ECI represents the condition of the element on a scale of 1 (Best) to 5 (Worst). Steps 2 to 4 are repeated for all elements on the structure.

Step 5 – Evaluate Structure Condition Score

Two different Structure Condition Scores are evaluated (Section 4.6)

- SCS_{Av} – this is the weighted average of all the *ECI* values for the structure; they are weighted by the Element Importance Factor, *EIF* (Section 4.5).
- SCS_{Crit} – this is the maximum *ECI* value for those elements considered *critical* to the integrity of the structure, i.e. classified as having *Very High Importance*.

The SCS equations are provided in Section 4.6, the output from each is on the same 1 to 5 scale as the *ECI*.

Step 6 – Evaluate Individual Structure Condition PI

The *SCS* values are converted to the corresponding Condition PIs, i.e. Condition PI_{Av} and Condition PI_{Crit}, on the 0 (Worst) to 100 (Best) scale, Section 4.7. Steps 2 to 6 are repeated for all structures in the *Structure Type* group.

Step 7 – Evaluate Structure Type Condition PI

The weighted average of the *Individual Structure* Condition PI scores produces the *Structure Type* Condition PI, Section 4.8. The weighting used is the characteristic dimensions of the structure, e.g. deck area for bridges, wall area for retaining walls, length for sign/signal gantries and area for small culverts.

Step 8 – Evaluate Structure Stock Condition PI

The weighted average of the *Structure Type* Condition PI scores produces the *Structure Stock* Condition PI (average and critical), see Section 4.9. The weighting used is the *Asset Value Factor (AVF)* of each *Structure Type* and the sum of their respective dimensional quantities (which are evaluated as part of Step 7).

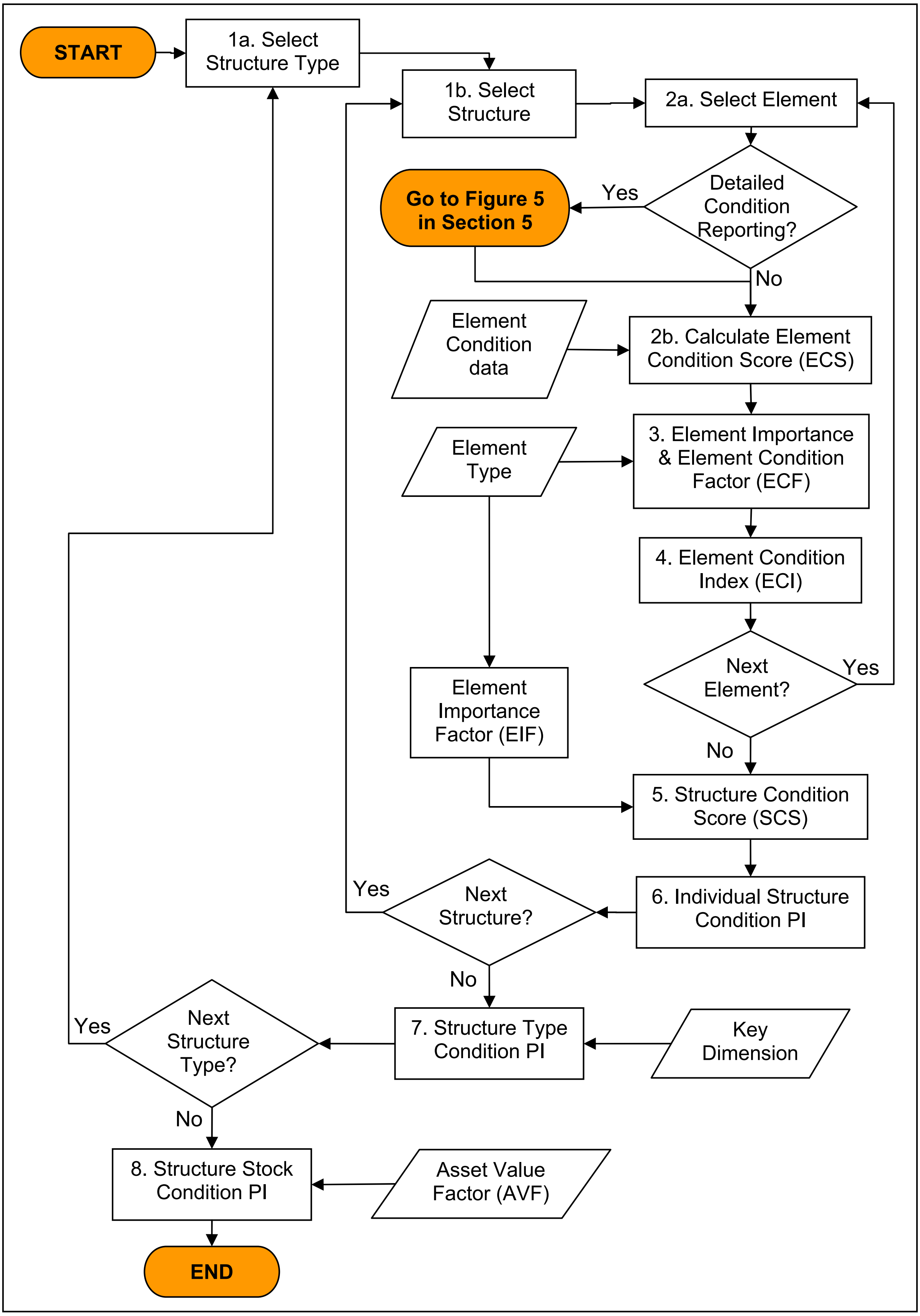

Figure 1 Condition PI Evaluation Procedure

3. Data Requirements

3.1 Relevant structure types

The Condition PI is designed to be applied to all structure types commonly found on the highway network. The typical structure types are shown in Table 1, definitions of the structure types are provided in the Code of Practice, BD62 and BD63 (Refs. 5, 6 and 7).

Table 1 Structure Types

Structure Type	Comment
Bridges and culverts	A standard list of elements and importance classifications are provided in Section 4.2.1
Small culverts (if treated separately from bridges)	Small culverts may be treated separately from bridges, where this is the case a standard list of elements and importance classifications are provided in Section 4.2.2
Retaining Wall	A standard list of elements and importance classifications are provided in Section 4.2.3
Road Tunnel	Road tunnels, as defined in Part A, are not covered by the Condition PI procedure, however, if an authority has a significant number of tunnels they may wish to develop appropriate procedures. To develop a procedure an authority should apply the principles set down in this document and determine a suitable element list with importance classifications
Sign/Signal Gantry	A standard list of elements and importance classifications are provided in Section 4.2.4
High Mast	A standard list of elements and importance classifications are provided in Section 4.2.5
Other structure types	Not covered by the Condition PI. However, if an authority has a significant quantity of other structure types then they may wish to develop an appropriate procedure. To develop a procedure an authority should apply the principles set down in this document and determine a suitable element list with importance classifications

3.2 Essential and Desirable Data

The data required to evaluate the Condition PI is shown in Table 2.

Table 2 Data requirements for Condition PI

Input Data	Type
Condition data	Essential
Element Type	Essential
Structure Type	Essential
Dimensions	Essential
Material type, structural form, year of construction, route etc.	Desirable (for analysis of tactical sets)

4. Evaluating the Condition PI

The following sections describe how the Condition PI is evaluated, building it up from element level to stock level.

4.1 Element Condition Score (ECS)

The first step in evaluating the Condition PI is to determine the Element Condition Score (ECS) for each element based on the condition information obtained from inspections. The CSS BCI Inspection Reporting System (Ref. 3) and HA Inspection System (Ref. 4) use a Severity scale of 1 (Best) to 5 (Worst) and an Extent scale of A (non significant) to E (>50% area affected). The extent and severity values for an element are combined to produce an Element Condition Score (ECS) as specified in:

- Table 3 for the CSS BCI System; and
- Table 4 for the HA Inspection System (see HA SMIS Manuals for explanations of the severity codes, Ref. 4).

The scoring reflects the view that the extent of damage is less critical than the severity of damage.

Table 3 CSS Element Condition Scores (ECS)

<table>
<tr><th rowspan="2">Extent</th><th colspan="5">Severity</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>A</td><td>1.0</td><td></td><td></td><td></td><td></td></tr>
<tr><td>B</td><td></td><td>2.0</td><td>3.0</td><td>4.0</td><td rowspan="4">5.0</td></tr>
<tr><td>C</td><td></td><td>2.1</td><td>3.1</td><td>4.1</td></tr>
<tr><td>D</td><td></td><td>2.3</td><td>3.3</td><td>4.3</td></tr>
<tr><td>E</td><td></td><td>2.7</td><td>3.7</td><td>4.7</td></tr>
</table>

*Shaded boxes represent non-permissible Severity/Extent combinations.

When the condition data is obtained using inspection reporting systems other than the CSS or HA systems, then the harmonisation matrix, Table 5, may be used to translate the condition data to the required scale. The translations in Table 5 may need to be amended to more accurately represent how an individual authority has interpreted/applied a particular inspection system.

Note: If condition data are reported on a more detailed level, e.g. individual beams instead of a group of beams, then the procedure presented in Section 5 should be used to build up the ECS.

Table 4 HA Element Condition Scores (ECS)

		Severity									
CSS Severities		**-**	**1**	**-**	**2**	**3**	**-**	**4**	**-**	**-**	**5**
a) Damage causing defects		-	D1	-	D2	D3	*D3S*	D4	-	*D4S*	D5
b) Paint coatings and protective systems		-	P1	-	P2	P3	-	P4	*P4S*	-	P5
c) Appearance related defects		-	A1	A2	A3	A4	-	-	-	-	-
d) Defects affecting adjacent elements		X1	X2	-	X3	X4	*X4S*	X5	-	-	-
Extent	**A**	1.0	1.0								
	B	1.0	1.0	1.1	2.0	3.0	*3.1*	4.0	*4.1*	*4.2*	5.0
	C	1.0	1.1	1.2	2.1	3.1	*3.2*	4.1	*4.2*	*4.3*	5.0
	D	1.0	1.3	1.4	2.3	3.3	*3.4*	4.3	*4.4*	*4.5*	5.0
	E	1.0	1.7	1.8	2.7	3.7	*3.8*	4.7	*4.8*	*4.9*	5.0

Notes

1. X1 has a score of 1.0 regardless of extent because it does not influence the adjacent element.
2. Appearance related defects (signified by the letter ‘A’) have lower scores due to their reduced impact on safety, durability and capacity.
3. The *italic* text relates to severity descriptions that refer to public safety. The score is increased by 0.1 when the severity description uses ***may*** or ***likely***; however the score is increased by 0.2 when the severity description uses "***is***", for example, "may be danger to public safety" compared to "is a danger to public safety".

Table 5 Harmonisation Matrix

	Element Condition Score (ECS)																
HA & CSS Scale	**1**	**1.1**	**1.3**	**1.7**	**2**	**2.1**	**2.3**	**2.7**	**3**	**3.1**	**3.3**	**3.7**	**4**	**4.1**	**4.3**	**4.7**	**5**
CSS Inspection System (Ref. 3)	1A, 1B	1C	1D	1E	2B	2C	2D	2E	3B	3C	3D	3E	4B	4C	4D	4E	5
HA BE11 Extent & Severity	1A, 1B	1C	1D	1E	2B	2C	2D		3B	3C	3D		4B	4C	4D		
Lancashire Condition Factor	5					4				3					2		1
PJ Andrews (Ref. 8) Condition Factor						0.9				0.7			0.5		0.3		0.1
Good, Fair, Poor (e.g. Cheshire)	G									F				P			
Condition Factor (e.g. Northumberland)	*					3				2				1			

4.2 Element Importance Classification

The Element Importance Classification reflects the importance of an element to the overall structure in terms of:

- Load carrying capacity.
- Durability, and
- Public safety.

Depending on the function performed by an element and its importance to the overall functioning of the structure, the importance of an element is designated as *Very High*, *High*, *Medium* or *Low*. The element importance classifications for each structure type are shown in:

- Table 6 for Bridges and Culverts.
- Table 9 for Small Culverts (if treated separately to bridges)
- Table 10 for Retaining Walls.
- Table 11 for Sign/Signal Gantries; and
- Table 12 for High Masts.

If the inspection reporting system currently used by an Authority contains elements other than those given in the following tables then their element importance should be assigned based on the equivalent element table shown in Appendix A.

4.2.1 Bridges

Table 6 Element Importance Classifications for Bridges

CSS Element Number	Element Description	Element Importance
1	Primary deck element (see Table 7)	Very High
2	Transverse Beams	Very High
3	Secondary deck element (see Table 8)	Very High
4	Half joints	Very High
5	Tie beam/rod	Very High
6	Parapet beam or cantilever	Very High
7	Deck bracing	High
8	Foundations	High
9	Abutments (incl. arch springing)	High
10	Spandrel wall/head wall	High
11	Pier/column	Very High
12	Cross-head/capping beam	Very High
13	Bearings	High
14	Bearing plinth/shelf	Medium
15	Superstructure drainage	Medium
16	Substructure drainage	Medium
17	Water proofing	Medium
18	Movement/expansion joints	High
19	Finishes: deck elements	Medium
20	Finishes: substructure elements	Medium
21	Finishes: parapets/safety fences	Medium
22	Access/walkways/gantries	Medium
23	Handrail/parapets/safety fences	High
24	Carriageway surfacing	Medium
25	Footway/verge/footbridge surfacing	Low
26	Invert/river bed	Medium
27	Aprons	Medium
28	Fenders/cutwaters/collision protection	Medium
29	River training works	Medium
30	Revetment/batter paving	Low
31	Wing walls	High
32	Retaining walls	Medium
33	Embankments	Low
34	Machinery	Medium
35	Approach rails/barriers/walls	Not included in Condition PI calculation
36	Signs	
37	Lighting	
38	Services	
Additional HA Elements	Diaphragms	High
	Cable Anchor Group	Very High
	Cable System Group	Very High
	Cable Hanger Group	Very High

Lists of typical Primary and Secondary deck element types, which relate to rows 1 and 3 in Table 6, are shown in Table 7 and Table 8 respectively.

Table 7 Primary Deck Elements

Span Structural Form (Primary Deck Element)	
Arch	solid spandrel
	open/braced spandrel
	tied (including hangers)
Beam/Girder	at/below deck surface
	box beams (exterior & interior)
	half through
	filler beam
Truss	at/below deck surface (underslung)
	half through
	full through
Slab	solid
	voided
Culvert/pipe/subway	circular/oval
	box
	portal/U-shape
Troughing	
Cable stayed/suspension	
Tunnel	

Table 8 Secondary Deck Elements

Secondary Deck Element
Buckle Plates
Flat Plate
Jack Arch
Slab
Troughing

4.2.2 Small Culverts

The HA distinguish between small and large culverts, see Part A and also refer to BD62 (Ref. 6), BD63 (Ref. 7) or the SMIS User Manual (Ref. 4) for further information. The Code of Practice (Ref. 5) does not distinguish between small and large culverts and it is recommended that culverts, classified in accordance with the Code of Practice, are dealt within using the bridge guidelines presented in this guidance document.

The list of elements, and their associated importance classifications, that should be used for small culverts, is shown in Table 9.

Table 9 Element Importance Classifications for Small Culverts

<table>
<tr><th>CSS Element Number</th><th>Element Description</th><th>Element Importance</th></tr>
<tr><td rowspan="6">CSS element number not applicable</td><td>Culvert</td><td>Very High</td></tr>
<tr><td>Headwall</td><td>High</td></tr>
<tr><td>Parapet/Guardrail/RRS</td><td>High</td></tr>
<tr><td>Wingwall</td><td>High</td></tr>
<tr><td>Revetment</td><td>Medium</td></tr>
<tr><td>Apron</td><td>Medium</td></tr>
</table>

4.2.3 Retaining Walls

The list of elements, and their associated importance classifications, that should be used for retaining walls is shown in Table 10.

Table 10 Element Importance Classifications for Retaining Walls

<table>
<tr><th>CSS Element Number</th><th colspan="2">Element</th><th>Element Importance</th></tr>
<tr><td>1</td><td colspan="2">Foundations</td><td>High</td></tr>
<tr><td>2</td><td rowspan="2">Retaining wall</td><td>Primary</td><td>Very High</td></tr>
<tr><td>3</td><td>Secondary</td><td>Very High</td></tr>
<tr><td>4</td><td colspan="2">Parapet beam/plinth</td><td>High</td></tr>
<tr><td>5</td><td colspan="2">Drainage</td><td>Medium</td></tr>
<tr><td>6</td><td colspan="2">Movement/Expansion joints</td><td>Medium</td></tr>
<tr><td>7</td><td colspan="2">Surface finishes: wall</td><td>Medium</td></tr>
<tr><td>8</td><td colspan="2">Surfaces finishes: handrail/parapet</td><td>Medium</td></tr>
<tr><td>9</td><td colspan="2">Handrail/parapets/safety fences/RRS</td><td>High</td></tr>
<tr><td>10</td><td rowspan="2">Carriageway</td><td>Top of wall</td><td>Low</td></tr>
<tr><td>11</td><td>Foot of wall</td><td>Low</td></tr>
<tr><td>12</td><td rowspan="2">Footway/verge</td><td>Top of wall</td><td>Low</td></tr>
<tr><td>13</td><td>Foot of wall</td><td>Low</td></tr>
<tr><td>14</td><td rowspan="2">Embankment</td><td>Top of wall</td><td>Low</td></tr>
<tr><td>15</td><td>Foot of wall</td><td>Low</td></tr>
<tr><td>16</td><td colspan="2">Invert/river bed</td><td>Medium</td></tr>
<tr><td>17</td><td colspan="2">Aprons</td><td>Medium</td></tr>
<tr><td>18</td><td colspan="2">Signs</td><td rowspan="3">Elements not used by Condition Indicator</td></tr>
<tr><td>19</td><td colspan="2">Lighting</td></tr>
<tr><td>20</td><td colspan="2">Services</td></tr>
<tr><td>Additional HA Element</td><td colspan="2">Anchoring system</td><td>Very High</td></tr>
</table>

4.2.4 Sign/Signal Gantries

The list of elements, and their associated importance classifications, that should be used for sign/signal gantries is shown in Table 11.

Table 11 Element Importance Classifications for Sign/Signal Gantries

CSS Element Number	Element	Element Importance
1	Foundations	High
2	Truss/beams/cantilever	Very High
3	Transverse/horiz. bracing elements	Very High
4	Columns/supports/legs	Very High
5	Surface Finishes: truss/beams/cantilever	Medium
6	Surface Finishes: columns/supports/legs	Medium
7	Surface Finishes: other elements	Low
8	Access/walkway/deck	High
9	Access ladder	High
10	Handrails/Guard Rails	High
11	Base connections	Very High
12	Support to longitudinal connection	Very High
13	Sign and signal supports	Medium
14	Signs/Signals	Elements not used by Condition Indicator
15	Lighting	
16	Services	
Additional HA Element	Road Restraint System (RRS)	High

4.2.5 High Masts

The list of elements, and their associated importance classifications, that should be used for high masts is shown in Table 12.

Table 12 Element Importance Classifications for High Masts

CSS Element Number	Element	Element Importance
CSS element number not applicable	Mast	Very High
	Foundation	Very High
	Base Connection	High
	Paint System	Medium
	Lighting	Elements not used by Condition Indicator
	Signs	

4.3 Element Condition Factor, ECF

The Element Condition Factor (ECF) is used to reduce the ECS to reflect the influence the condition of an element has on the condition of the overall structure. It is evaluated using the expressions given in Table 13.

Table 13 Expressions for Element Condition Factor (ECF)

Element Importance	Element Condition Factor (ECF)
Very High	$ECF = 0.0$
High	$ECF = 0.3 - [(ECS - 1) \times 0.3/4]$
Medium	$ECF = 0.6 - [(ECS - 1) \times 0.6/4]$
Low	$ECF = 1.2 - [(ECS - 1) \times 1.2/4]$

4.4 Element Condition Index, ECI

The Element Condition Index (ECI) indicates the contribution the condition of an element makes to the condition of the structure as a whole. The ECI is determined by adjusting the Element Condition Score (ECS) to account for the Element Condition Factor (ECF) as shown below.

$$ECI = ECS - ECF \quad \text{but is always} \geq 1$$

Equation 1

The relationship between the Element Condition Index and the Element Condition Score is shown in Figure 2. This shows that the importance of an element is deemed to influence its impact on the overall condition of the structure, for example:

- A *Very High* importance element with an ECS = 3 has an ECI = 3 whereas a *Medium* importance element with an ECS = 3 has a corresponding ECI = 2.7.

Figure 2 also shows that the impact of the reduction factor decreases as the severity of the defect increases, for example:

- A *Low* importance element with an ECS = 2 has a corresponding ECI = 1.0, however as the condition of the element becomes more severe the reduction decreases, i.e. an ECS = 4 has a corresponding ECI = 3.7.

The ECI for elements of *Very High* importance is the same as the ECS implying that damage on this element is equally critical to the function of the overall structure.

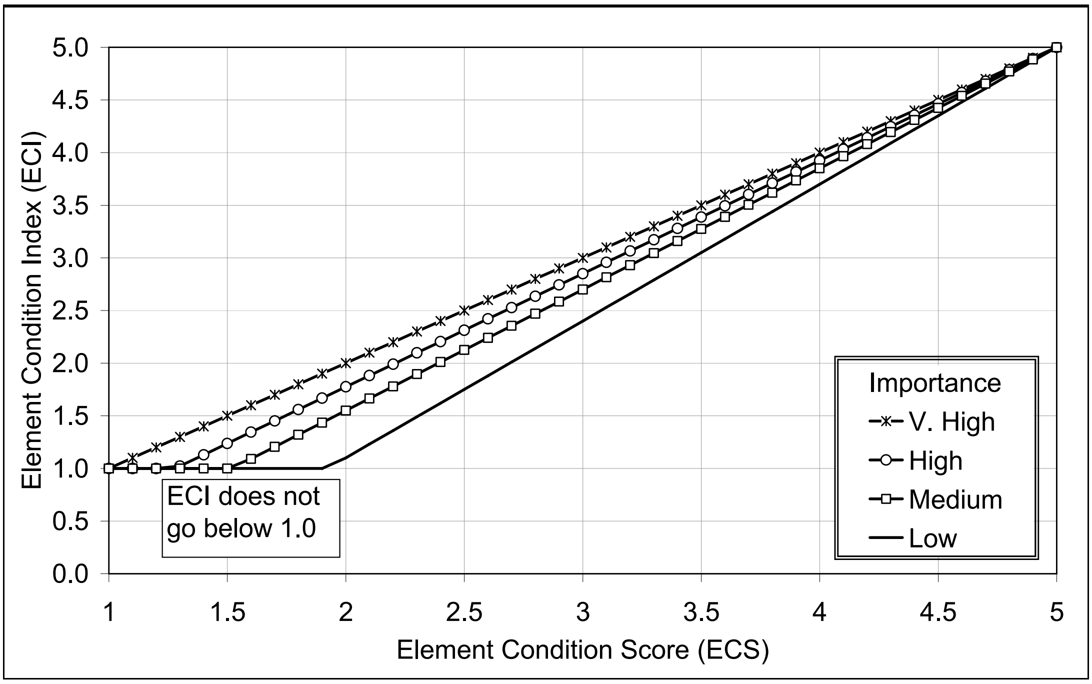

Figure 2 Influence of element importance on the ECI

4.5 Element Importance Factor, EIF

The Element Importance Factor (EIF) is used to weight the ECI values of different elements when evaluating the Structure Condition Score (SCS), see Section 4.6. The EIF represents the importance of the element to the overall functionality of the structure (load carrying capacity, durability and public safety). The EIFs are shown in Table 14.

Table 14 Element Importance Factor (EIF)

Element Importance	EIF
Very High	2.0
High	1.5
Medium	1.2
Low	1.0

4.6 Structure Condition Score, SCS

Two different Structure Condition Scores, SCS_{Av} and $SCS_{Crit,}$ are evaluated using the following expressions. SCS_{Av} considers all the elements in the structure while SCS_{Crit} is based on only those elements which have a *Very High* importance classification. The SCS is on the same scale as the individual elements, that is, 1 indicates best possible condition and 5 the worst possible condition for the structure.

Average Structure Condition Score (SCS_{Av})

$$SCS_{Av} = \frac{\sum_{i=1}^{N}\left(ECI_i \times EIF_i\right)}{\sum_{i=1}^{N} EIF_i}$$

Equation 2

where N is the total number of elements on the structure that have an ECI score and:

ECI_i = Element Condition Index for element *i*, from Equation 1 in Section 4.4

EIF_i = Element Importance Factor for element *i*, from Table 14 in Section 4.5

Critical Structure Condition Score (SCS_{Crit})

$$SCS_{Crit} = \max\{\text{ECI for elements with Very High Importance}\}$$

Equation 3

SCS_{Crit} for Bridges

$$SCS_{Crit} = \max\left\{\begin{array}{l}\text{ECI for Primary deck elements}\\ \text{ECI for Transverse beams}\\ \text{ECI for Secondary deck elements}\\ \text{ECI for Half joints}\\ \text{ECI for Tie beam/rod}\\ \text{ECI for Parapet beam/cantilever}\\ \text{ECI for Pier/column}\\ \text{ECI for Cross-head/capping beam}\\ \text{ECI for Cable anchor group *}\\ \text{ECI for Cable system group *}\\ \text{ECI for Cable hanger group *}\end{array}\right\}$$

*signifies additional HA elements

Equation 4a

SCS_{Crit} for Small Culverts

$$SCS_{Crit} = \text{ECI for Culvert}$$

Equation 4b

SCS_{Crit} for Retaining Walls

$$SCS_{Crit} = \max \begin{Bmatrix} \text{ECI for Primary element} \\ \text{ECI for Secondary Element} \\ \text{ECI for Anchoring System} \end{Bmatrix}$$

Equation 4c

SCS_{Crit} for Sign/Signal Gantries

$$SCS_{Crit} = \max \begin{Bmatrix} \text{ECI for Truss/beam/cantilever} \\ \text{ECI for Transverse beams} \\ \text{ECI for Columns/supports/legs} \\ \text{ECI for Base connections} \\ \text{ECI for Support to longitudinal connection} \end{Bmatrix}$$

Equation 4d

SCS_{Crit} for High Masts

$$SCS_{Crit} = \max \begin{Bmatrix} \text{ECI for Mast} \\ \text{ECI for Foundation} \end{Bmatrix}$$

Equation 4e

The SCS_{Av} alone may <u>not</u> give a complete picture of the *health* of a structure. For example, a structure may have a low SCS_{Av} score implying it is in a very good condition, however, the structure may be close to collapse if, for instance, one of the critical elements is in very poor condition, hence the need for the SCS_{Crit}. On the other hand, SCS_{Crit} although giving an indication of the criticality of the structure, does not provide an indication of how widespread the deterioration is over the whole structure. Therefore, both of these indicators should be used to obtain a more complete picture of the health of a structure.

4.6.1 Incomplete Inspections

When the inspector has been unable to inspect an element on site the condition should be recorded as *NI* (Not Inspected). In such cases the condition data recorded at the latest inspection (General or Principal) or, if more recent, the condition recorded after the completion of maintenance work, should be used when evaluating the SCS. If there is no previous data available then this element should not be included when evaluating the *SCS*. “Not Inspected” data should be used to:

- Indicate which structures received an incomplete inspection and identify what action is required to enable a complete inspection; and

- Create an annual measure of the number or percentage of incomplete structure inspections.

4.7 Condition Performance Indicator

The Structure Condition Score (SCS) has the same scale as the Element Condition Score (ECS), i.e. 1 (Best) to 5 (Worst), and can in general be interpreted in an analogous way to the ECS. However, this scale is considered to be somewhat difficult to understand and confusing for those outside highway structure engineering. Therefore, a Condition PI is introduced which is defined on a scale of 100 (best possible condition) to 0 (worst possible condition). Guidance on the interpretation and use of SCS and Condition PI scores is given in Section 6.

The SCS_{Av} and SCS_{Crit} values are converted to the corresponding Condition $\mathrm{PI}_{\mathrm{Av}}$ and Condition $\mathrm{PI}_{\mathrm{Crit}}$ values using Equations 5 and 6 and as shown in Figure 3. The non-linear relationship reflects the fact that as the SCS value increases from 1 to 5, the structure condition deteriorates progressively more rapidly.

Average Condition PI for an Individual Structure

$$\text{Condition } PI_{Av} = 100 - 2\left\{(SCS_{Av})^2 + (6.5 \times SCS_{Av}) - 7.5\right\}$$

Equation 5

Critical Condition PI for an Individual Structure

$$\text{Condition } PI_{Crit} = 100 - 2\left\{(SCS_{Crit})^2 + (6.5 \times SCS_{Crit}) - 7.5\right\}$$

Equation 6

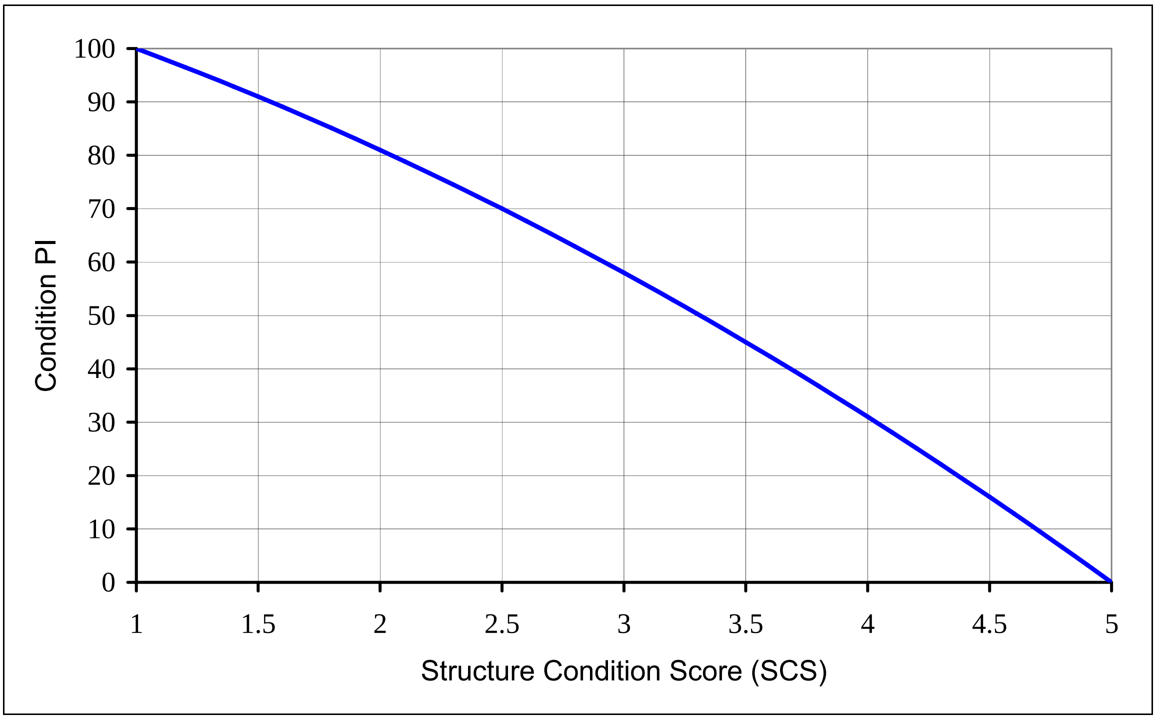

Figure 3 Relationship between SCS and Condition PI

4.8 Structure Type Condition PI

In aggregating the Condition PI values for a *Structure Type* group, the differences in the size and type of structures should be recognised. If size is not considered then, for example, large multi-span bridges carrying four or more traffic lanes which require higher maintenance funding would be unfairly treated compared to small single span bridges carrying one or two lanes of traffic.

4.8.1 Condition PI for Bridges

The Condition PI's for bridges are evaluated using Equations 7a and 7b.

Condition PI for Bridges

$$\text{Condition PI}_{\text{B-Av}} = \frac{\sum_{i=1}^{M}\left(\text{Condition PI}_{\text{Av}-\text{i}} \times \text{Deck Area}_i\right)}{\sum_{i=1}^{M}\text{Deck Area}_i}$$

Equation 7a

$$\text{Condition PI}_{\text{B-Crit}} = \frac{\sum_{i=1}^{M}\left(\text{Condition PI}_{\text{Crit}-\text{i}} \times \text{Deck Area}_i\right)}{\sum_{i=1}^{M}\text{Deck Area}_i}$$

Equation 7b

Where *M* = total number of bridges used in the calculation

Condition $\text{PI}_{\text{Av-i}}$ = Condition PI_{Av} score for bridge *i*, from Equation 5

Condition $\text{PI}_{\text{Crit-i}}$ = Condition PI_{Crit} score for bridge *i*, from Equation 6

Deck Area_i = deck area from bridge *i*

The deck area is in m^2 and is the product of width and length, where:

For bridges:

- Width = distance from outside edge to outside edge of deck; and
- Length = distance from support centreline to support centreline.

For culverts

- Width = distance from left bank support centreline to right bank support centreline, i.e. measured perpendicular to the direction of water flow; and
- Length = distance form outside face of headwall to outside face of headwall i.e. distance from entrance to exit.

4.8.2 Condition PI for Small Culverts

The Condition PI's for small culverts are evaluated using Equations 8a and 8b.

Condition PI for Small Culverts

$$\text{Condition PI}_{\text{SC-Av}} = \frac{\sum_{i=1}^{M} \left(\text{Condition PI}_{\text{Av-i}} \times \text{Area}_i \right)}{\sum_{i=1}^{M} \text{Area}_i}$$

Equation 8a

$$\text{Condition PI}_{\text{SC-Crit}} = \frac{\sum_{i=1}^{M} \left(\text{Condition PI}_{\text{Crit-i}} \times \text{Area}_i \right)}{\sum_{i=1}^{M} \text{Area}_i}$$

Equation 8b

Where M = total number of small culverts used in the calculation

Condition $\text{PI}_{\text{Av-i}}$ = Condition PI_{Av} score for small culvert *i*, from Equation 5

Condition $\text{PI}_{\text{Crit-i}}$ = Condition PI_{Crit} score for small culvert *i*, from Equation 6

Area_i = area for small culvert *i*

The area of a small culvert, in m^2, is the product of width and length, where:

- Width = distance from left bank support centreline to right bank support centreline i.e. measured perpendicular to the direction of water flow; and
- Length = distance form outside face of headwall to outside face of headwall i.e. distance from entrance to exit.

4.8.3 Condition PI for Retaining Walls

The Condition PI's for retaining walls are evaluated using Equations 9a and 9b.

Condition PI for Retaining Walls

$$\text{Condition PI}_{\text{RW-Av}} = \frac{\sum_{i=1}^{M} \left(\text{Condition PI}_{\text{Av-i}} \times \text{Wall Area}_i \right)}{\sum_{i=1}^{M} \text{Wall Area}_i}$$

Equation 9a

$$\text{Condition PI}_{\text{RW-Crit}} = \frac{\sum_{i=1}^{M}(\text{Condition PI}_{\text{Crit-i}} \times \text{Wall Area}_i)}{\sum_{i=1}^{M}\text{Wall Area}_i}$$

Equation 9b

Where M = total number of retaining walls used in the calculation

Condition $PI_{Av\text{-}i}$ = Condition PI_{Av} score for retaining wall *i*, from Equation 5

Condition $PI_{Crit\text{-}i}$ = Condition PI_{Crit} score for retaining wall *i,* from Equation 6

Wall $Area_i$ = wall area for retaining wall *i*

The *Wall Area* is measured in m^2 and is the product of the wall length and the average retained height, where the retained height is the level of fill at the back of the wall above the finished ground level at the front of the structure. If the retaining walls are reported per panel then *Wall Area* should be changed to *Panel Area*.

4.8.4 Condition PI for Sign/Signal Gantries

The Condition PI's for sign/signal gantries are evaluated using Equations 10a and 10b.

Condition PI for Sign/Signal Gantries

$$\text{Condition PI}_{\text{SG-Av}} = \frac{\sum_{i=1}^{M}(\text{Condition PI}_{\text{Av-i}} \times \text{Length}_i)}{\sum_{i=1}^{M}\text{Length}_i}$$

Equation 10a

$$\text{Condition PI}_{\text{SG-Crit}} = \frac{\sum_{i=1}^{M}(\text{Condition PI}_{\text{Crit-i}} \times \text{Length}_i)}{\sum_{i=1}^{M}\text{Length}_i}$$

Equation 10b

Where M = total number of sign/signal gantries used in the calculation

Condition $PI_{Av\text{-}i}$ = Condition PI_{Av} score for sign/signal gantry *i*, from Eq. 5

Condition $PI_{Crit\text{-}i}$ = Condition PI_{Crit} score for sign/signal gantry *i,* from Eq. 6

$Length_i$ = length of sign/signal gantry *i*

The length is taken the span length (from support centreline to support centreline) or cantilever length of the sign/signal gantry.

4.8.5 Condition PI for High Masts

The Condition PI's for High Masts are evaluated uisng Equations 11a and 11b.

Condition PI for High Masts

$$\text{Condition PI}_{\text{HM-Av}} = \frac{\sum_{i=1}^{M}\left(\text{Condition PI}_{\text{Av}-\text{i}} \times \text{Height}_i\right)}{\sum_{i=1}^{M} Height_i}$$

Equation 11a

$$\text{Condition PI}_{\text{HM-Crit}} = \frac{\sum_{i=1}^{M}\left(\text{Condition PI}_{\text{Crit}-\text{i}} \times \text{Height}_i\right)}{\sum_{i=1}^{M} Height_i}$$

Equation 11b

Where M = total number of high masts used in the calculation

Condition $\text{PI}_{\text{Av-i}}$ = Condition PI_{Av} score for high mast *i*, from Equation 5

Condition $\text{PI}_{\text{Crit-i}}$ = Condition PI_{Crit} score for high mast *i,* from Equation 6

Height_{i} = height of high mast *i*

The height is taken as the full height above ground level.

4.9 Structure Stock Condition PI

The *Structure Stock Condition* PI_{Av} is the high level indicator shown in the framework in Part A that should be used for external reporting. The *Condition* PI_{Av} and *Condition* PI_{Crit} for structure types, structure groups and individual structures should be used for internal reporting and to aid decision making.

The Condition Indicators for a stock of structures (bridges, retaining walls, sign/signal gantries etc.) are calculated using Equations 12a and 12b.

Average Structure Stock Condition PI

$$\text{Stock Condition PI}_{\text{Av}} = \frac{\sum\left(\left(\text{Condition PI}_{\text{i-Av}}\right) \times \left(\sum Dim\right)_i \times \left(AVF_i\right)\right)}{\sum\left(\left(\sum Dim\right)_i \times \left(AVF_i\right)\right)}$$

Equation 12a

Critical Structure Stock Condition PI

$$\text{Stock Condition PI}_{\text{Crit}} = \frac{\sum\left(\left(\text{Condition PI}_{\text{i-Crit}}\right)\times\left(\sum Dim\right)_i \times \left(AVF_i\right)\right)}{\sum\left(\left(\sum Dim\right)_i \times \left(AVF_i\right)\right)}$$

Equation 12b

Where

Stock *Condition* $PI_{i\text{-}Av}$ = Average Condition PI score for structure type *i* *(outcome of Equation 7a, 8a, 9a, 10a or 11a)*

Stock *Condition* $PI_{i\text{-}Crit}$ = Critical Condition PI score for structure type *i* *(outcome of Equations 7b, 8b, 9b, 10b or 11b)*

ΣDim = Sum of dimension quantity for Structure Type *i* *(Denominator from equations 7 to 11)*

AVF_i = Asset Value Factor of structure type *i*, see Table 15

A fully expanded version of Equation 12a is shown in Appendix B. The same expansion is relevant for Equation 12b except the *Average* values are changed to *Critical* values.

Equation 12 uses an Asset Value Factor, *AVF*, to weight one structure type against another. The factors are based on a comparison of the unit replacement cost of the different structure types. The *AVFs* shown in Table 15 were derived using typical construction and replacement cost data from a sample of HA and Local Authority structures. However, if an authority has evaluated the Gross Replacement Cost (as set out in Ref. 9 or equivalent guidance) of the different structure types, then these values should be used in Equation 12 in place of the (*Dim* × *AVF*) component. (**Note**: The Gross Replacement Cost is used in the calculation, not the Depreciated Replacement Cost).

Table 15 Asset Value Factors, *AVF*

Structure Type	Acronym	*AVF*		Units
		Overseeing Authority	Local Authority	
Bridge	AVF_B	0.30	0.20	m^2
Retaining Wall	AVF_{RW}	0.25	0.10	m^2
Small Culvert	AVF_{SC}	0.10	-	m^2
Sign/Signal Gantry	AVF_{SG}	1.0	1.0	m
High Mast	AVF_{HM}	0.03	0.03	m
Tunnel	AVF_T	0.5	0.5	m^2

Note: the Sign/Signal Gantry *AVF* is higher because it is per m length; whereas it is per m^2 for Bridges, Retaining Walls, Small Culverts and Tunnels.

The AVFs, or Gross Replacement Cost if used, are applied to the *Structure Type Condition PI* and therefore have the potential to substantially alter the overall *Stock Condition PI* score if they change. However, it is envisaged that the Asset Value Factors will stay the same because, while the real cost of constructing a bridge, retaining wall etc. is likely to change over time, the amount by which they change will be relative, i.e. if the cost of constructing a bridge doubles in 20 years then the cost of constructing a retaining wall is also likely to double, hence the *AVFs* would remain the same. These relative changes would also hold true for the Gross Replacement Cost.

4.10 Multi Span Bridges

The condition inspection of a multi span bridge may report all elements on one standard pro forma, such as the CSS pro forma (Ref. 3), or report each span on a separate pro forma. Either way, the Condition PIs evaluated can be used directly in Equations 7 and 12 provided the respective deck areas are applied correctly. However, if an overall Condition PI is required for a multi span bridge that has been inspected per span then the following equations may be used to combine them:

Average Condition PI for Multi Span Bridge

$$\text{Condition } PI_{Av} = \frac{\sum_{i=1}^{S}\left(\text{Condition } PI_{Av-i} \times \text{Span Deck Area}_{i}\right)}{\text{Whole Bridge Deck Area}}$$

Equation 13

Critical Condition PI for Multi Span Bridge

$$\text{Condition } PI_{Crit} = \frac{\sum_{i=1}^{S}\left(\text{Condition } PI_{Crit-i} \times \text{Span Deck Area}_{-}\right)}{\text{Whole Bridge Deck Area}}$$

Equation 14

where

S = the total number of spans in the bridge

Condition $PI_{Av\text{-}i}$ = Average Condition PI for span i

Condition $PI_{Crit\text{-}i}$ = Critical Condition PI for span i

Span Deck $Area_i$ = Deck Area for span i

This approach still applies when the spans are of different construction forms. This approach can also be used when separate Condition PI values have been evaluated for different construction forms within one span.

5. Detailed Condition Reporting

5.1 General

The procedure described in Section 4 assumes that condition (severity/extent) is reported at element level, e.g. columns, parapets, joints etc. This is the standard approach used by the majority of authorities in the UK. However, some authorities report condition at a more detailed level when appropriate in order to provide improved condition data for structures management, i.e. when appropriate the inspector can subdivide elements and report severity/extent at this more detailed level, see Figure 4.

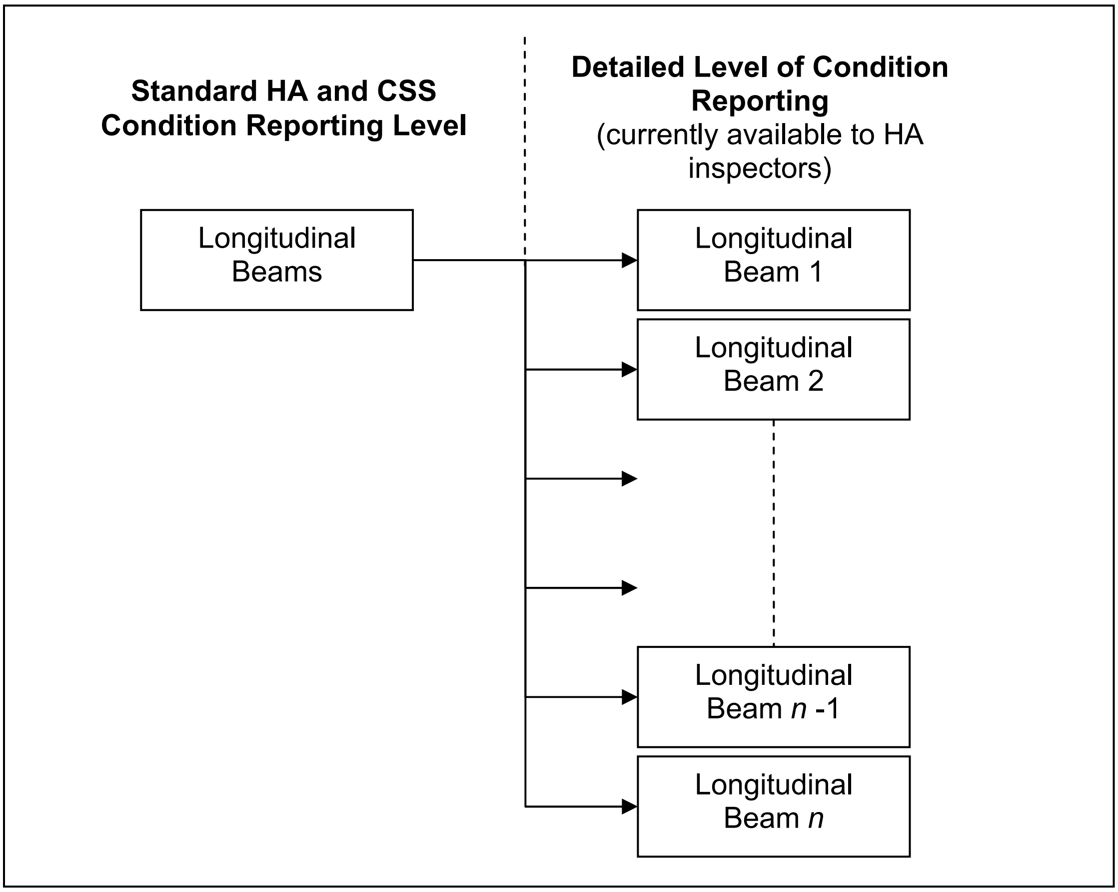

Figure 4 Example of Condition Reporting Levels

The following sections describe how condition data (severity/extent) reported at a more detailed level should be used in the Condition PI procedure. The main focus of the following guidance is to maintain a degree of consistency for Condition PI evaluation regardless of the data reporting procedure used, i.e. *Standard* or *Detailed* level.

5.2 Sub-division of Elements

Element types that inspectors may wish to sub-divide (and can currently do so in the HA SMIS system) are shown in Table 16. The element list shown in Table 16 is not exhaustive and is only for illustration purposes. The principles described in the following sections can be applied to any element sub-division. It is important to remember that the Condition PI does not dictate the level of condition reporting rather the management needs do; the Condition PI is only a procedure that uses the condition data.

Table 16 Element Types that can be Sub-divided

Structure Type	Element Type
Bridge	Transverse Beams
	Longitudinal Beams
	Deck Bracing
	Expansion Joints
	Diaphragms
	Truss Members
	Columns
	Cross-Heads
	Bearings
	Cable Anchors
	Cable System
	Cable Hangars
	Support Bracing
Sign/Signal Gantry	Transverse Beams/Bracing
	Bearings

5.3 Procedure for dealing with Detailed Condition Reporting

The Condition PI procedure described in Section 4 starts at element level, therefore when reporting at a detailed level an additional step is required in the evaluation procedure, i.e. to enable the procedure to progress from *Detailed* sub-element level to *Standard* element level. To do this the procedure shown in Figure 5 and summarised below is used:

1. Select the element type that has been reported at the detailed level, e.g. transverse beams, bearings etc.

2. To ensure consistency this approach requires all the sub-elements, for this particular element, to be identified and their conditions know, even those in 1A condition. If this data is not available then the suitability of the data for evaluating the Condition PI must be challenged.

3. Assign a weighting to each sub-element based on the typical dimensions, e.g. length, deck area served etc., see Section 5.3.1.

4. Select the sub-element/s with the worst **severity** score. The worst sub-element severity is assumed to dictate the element severity (frequently it may only be one sub-element with the worst severity score).

5. Convert the **extent** ratings, for the sub-elements with the worst **severity** score, to numerical extent scores, see Section 5.3.2. Aggregate the **extent** scores of these sub-elements, see Section 5.3.3.

6. Combine the severity and extent scores to give the Element Condition Score (ECS) for the element group, see Section 5.3.4.

7. Proceed with the *Standard* Condition PI procedure described in Section 4.

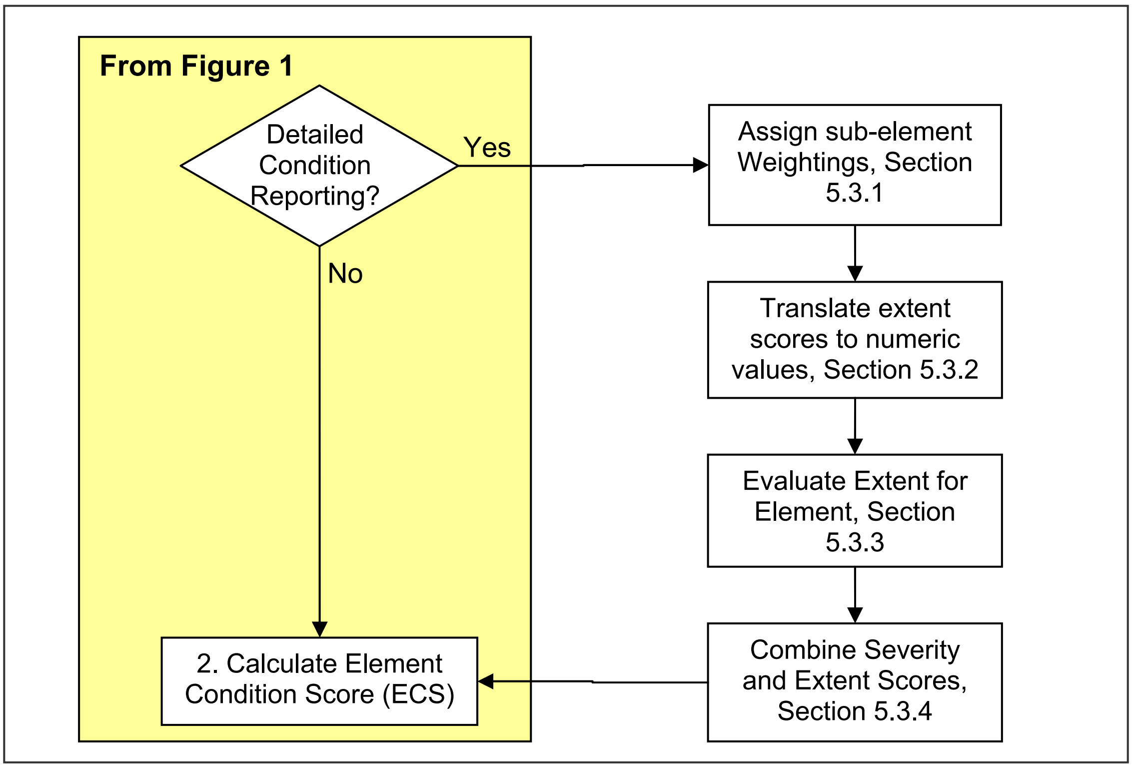

Figure 5 Overview of Detailed Procedure

5.3.1 Sub-Element Weightings, W_{SE}

The sub-elements need to be weighted so that the extent, of the sub-elements in the most severe condition, can be correctly calculated. If all the sub-elements are of the same, or similar, size then the weighting for each can be the same, i.e. W_{SE} = 1.0. However, if the sub-elements are not of equal size then the weightings should reflect this and be based on an appropriate dimension, e.g. length, width, height, deck area served etc. For example, consider expansion joints that have different lengths when sub-divided for inspection, the weightings would be as shown in Table 17.

Table 17 Sub-Element Weighting Examples

Expansion Joint Sub-Element	Length	Sub-Element Weighting, W_{SE}
Sub-Element 1	10m	10/10 = 1.0
Sub-Element 2	8m	8/10 = 0.8
Sub-Element 3	8m	8/10 = 0.8
Sub-Element 4	6m	6/10 = 0.6

Therefore the weighting for each sub-element is simply:

$$W_{SE} = \frac{\text{Dimension of sub-element}}{\text{Maximum Dimension of sub-elements}}$$

Equation 15

5.3.2 Extent Score for Sub-Elements

The extent rating for each sub-element is changed to the numerical score shown in Table 18.

Table 18 Extent Numeric Values

Extent Rating	Numeric Value Range
A	0.0
B	0.0
C	0.1
D	0.3
E	0.7

5.3.3 Extent Score for Element

The overall extent score for the element is evaluated as:

$$Extent = \frac{\sum (Ex_{WS-i} \times W_{SE-i})}{\sum W_{SE}}$$

Equation 16

Where

$Ex_{WS\text{-}i}$ = Extent for sub-elements with worst severity in this element group

$W_{SE\text{-}i}$ = Weighting for sub-elements with worst severity in this element group

ΣW_{SE} = Sum of all sub-element weightings in this element group

Note: the *Numerator* calculations in Equation 16 are only for the sub-elements with the worst severities, while the *Denominator* summation is for all the sub-elements.

5.3.4 Elements Condition Score, *ECS*

The element condition score is evaluated as:

$$ECS = Severity + Extent$$

Equation 17

Where

ECS = Element Condition Score taken forward to the procedure described in Section 4

Extent = Extent score from Equation 16

Severity = Worst severity rating for sub-elements

6. Interpretation of Condition PI Values

6.1 General

This section provides guidance on the interpretation of the Condition PI. One of the main functions of the Condition PI is to enable an authority to monitor change in the condition of individual structures, structure groups and the structure stock over time to determine if the maintenance programme and funding is:

- Sustaining the current condition.
- Improving condition; or
- Allowing condition to deteriorate.

The *Structure Stock* Condition PI provides an overview of condition change at stock level. Evaluating the Condition PI for *Individual Structures*, *Structure Type* groups and/or *Tactical Sets* can provide beneficial information for analysing trends and aiding decision making (where tactical sets are groups of structures that have similar material, construction type, age, etc). The following sections describe how to interpret the Condition PI and present some techniques that may be used to back-up the Condition PI number.

6.2 Interpretation of Individual Structure Condition PI

The Condition PI scores range from 100 (best possible condition) to 0 (worst possible condition) and can be interpreted broadly as the “percentage service potential” of a structure. Thus, a Condition PI value of 100 implies that the structure has retained 100% of its service potential; a value of 60 implies that the structure has lost 40% of its service potential; while a value of 0 implies that the structure is no longer serviceable.

Figure 3 in Section 4.7 shows that when the Structure Condition Score (SCS) is 2 the corresponding Condition PI is 81 implying that the structure retains 81% of its service potential, while at an SCS value of 4 the structure is considered to retain only 31% of its service potential.

It should be recognised that the effort involved, and hence the maintenance funding required, to improve the SCS value of a structure, for example from 2 $\rightarrow$ 1 can be significantly different from improving it from 4 $\rightarrow$ 3. This is reflected in the Condition PI scale, e.g. an improvement in the SCS from 2 $\rightarrow$ 1 is an improvement of 81 $\rightarrow$ 100 (19%) on the Condition PI scale, where as a SCS improvement of 4 $\rightarrow$ 3 is an improvement of 31 $\rightarrow$ 58 (27%) on the Condition PI scale.

Generic categories for interpreting the Condition PI for an individual structure are shown in Table 19. These categories are based on typical structure types and engineering judgement and therefore may not be suitable in all circumstances. An authority may wish to develop more detailed descriptions that match the characteristics of their structures and material types.

Table 19 Interpretation of Condition PI for individual structures

Range	Condition PI_{Av} (All Structure Elements)	Condition PI_{Crit} (Worst Critical Element)
90 ≤ x ≤ 100	• Likely to be no significant defects in any elements • Structure is in a "Very Good" condition overall	• Insignificant defects/damage • Capacity unaffected
80 ≤ x < 90	• Mostly minor defects/damage, but may also be some moderate defects • Structure is in a "Good" condition overall	• Minor defects/damage • Capacity unlikely to be unaffected
65 ≤ x < 80	• Minor-to-Moderate defects/damage • Structure is in a “Fair” condition overall • One or more functions of the structure may be significantly affected	• Minor to moderate defects/damage • Capacity may be slightly affected
40 ≤ x < 65	• Moderate-to-Severe defects/damage • Structure is in a "Poor" condition overall • One or more functions of the bridge may be severely affected	• Moderate to severe defects/damage • Capacity may be significantly affected
0 ≤ x < 40	• Severe defects/damage on a number of elements • One or more elements may have failed • Structure is in a "Very Poor" condition overall • Structure may be unserviceable	• Severe defects/damage • Failure or possible failure of critical element • Capacity may be severely affected • Structure may need to be weight restricted or closed to traffic

6.3 Interpretation of Structure Stock Condition PI

The interpretation of the Average and Critical *Structure Stock* Condition PI values in terms of the general condition of the stock is given in Table 20. These interpretations are based on experience to date with the CSS Bridge Condition Indicator and are only provided as broad guidelines. The characteristics of individual stocks mean they may not adhere to the descriptions provided and it is down to the experience and knowledge of the local engineer/s to interpret the Condition PI and the significance of changes and trends.

Table 20 Interpretation of Average and Critical Stock Scores

Score	Average Stock Condition	Critical Stock Condition	Addition Comments
Very Good **90 ≤ x ≤ 100**	The structure stock is in a very good condition. Very few structures may be in a moderate to severe condition.	A few critical load bearing elements may be in a moderate to severe condition. Represents very low risk to public safety.	If it is a relatively new stock of structures then an appropriate maintenance funding level needs to be identified through Asset Management. If it is a mature stock then continuing with the same level of funding is likely to sustain a high condition score and an effective preventative maintenance regime. If not already in place, appropriate asset management practices should be implemented to identify the optimum condition for the stock and the associated level of funding.
Good **80 ≤ x < 90**	Structure stock is in a good condition. Some structures may be in a severe condition.	Some critical load bearing elements may be in a severe condition. Some structures may represent a moderate risk to public safety unless mitigation measures are in place.	As a minimum the current level of funding should be continued, however it may be unclear if this is the appropriate level of funding. If not already in place, appropriate asset management practices should be implemented to identify the optimum condition for the stock and the associated level of funding. There is the potential for rapid decrease in condition if sufficient maintenance funding is not provided. Minor to Moderate backlog of maintenance work.
Fair **65 ≤ x < 80**	Structure stock is in a fair condition. A number of structures may be in a severe condition.	A number of critical load bearing elements may be in a severe condition. Some structures may represent a significant risk to public safety unless mitigation measures are in place.	Historical maintenance work under funded and structures not managed in accordance with Asset Management. It is essential to implement Asset Management practices to ensure work is adequately funded and prioritised and risks assessed and managed. Moderate to large backlog of maintenance work, essential work dominates spending.
Poor **40 ≤ x < 65**	Structure stock is in a poor condition. Many structures may be in a severe condition.	Many critical load bearing elements may be unserviceable or close to it and are in a dangerous condition. Some structures may represent a high risk to public safety unless mitigation measures are in place.	Historical maintenance work significantly under funded and a large to very large maintenance backlog. An Asset Management approach must be implemented. Re-active approach to maintenance that has been unable to contain deterioration. A significant number of structures likely to be closed, have temporary measures in place or other risk mitigation measures. Essential work dominates spending.
Very Poor **0 ≤ x < 40**	Structure stock is in a very poor condition. Many structures may be unserviceable or close to it.	Majority of critical load bearing elements unserviceable or close to it and are in a dangerous condition. Some structures may represent a very high risk to public safety unless mitigation measures are in place.	Historical maintenance work grossly under funded and a very large maintenance backlog. Re-active approach to maintenance that has been unable to prevent deterioration, only essential maintenance work performed. An Asset Management approach must be implemented. Many structures likely to be closed, have temporary measures in place or other risk mitigation measures. All spend likely to be on essential maintenance.

6.4 Reporting and Presentation of Condition Indicator Data

The following sections suggest reporting and presentation techniques for the Condition PI. The techniques discussed are:

1. Time dependent plots (Section 6.4.1)
2. Histograms (Section 6.4.2); and
3. Stacked bar graph (Section 6.4.3).

An authority should consider using these techniques for some or all of the following categories when analysing and presenting results:

1. The whole stock of structures.
2. Comparison of different structure types, e.g. bridges, retaining walls, sign/signal gantries etc.
3. Comparison of different material types, e.g. reinforced concrete, steel, masonry, timber etc.
4. Comparison of different structure ages, e.g. pre 1975 vs. post 1975 etc.
5. Comparison of structures in different areas, districts, parishes, routes etc.

This list is not exhaustive and an authority should consider additional comparators. The Condition PIs are management tools and should be used to best represent the characteristics of a structure stock and any issues that need to be highlighted.

All presentations/reporting should be in a clear and easily understood format. If possible establish a fixed format for annual/periodic reporting so it can be easily compared with historical reports.

6.4.1 Time Dependent Plots

The time dependent plots should including three lines:

1. Average Condition (Condition PI_{Av})
2. Critical Condition (Condition PI_{Crit}) ; and
3. Target Condition PI_{Av} (an additional line can be added if different targets are set for the *Average* and *Critical* Condition PI)

An example plot is shown in Figure 6. The Y-axis is truncated at a Condition PI score of 50 in order to place more emphasis on fluctuations in the group score. It is very <u>unlikely</u> that any group of structures will score less than 50, although individual structures do score less than 50.

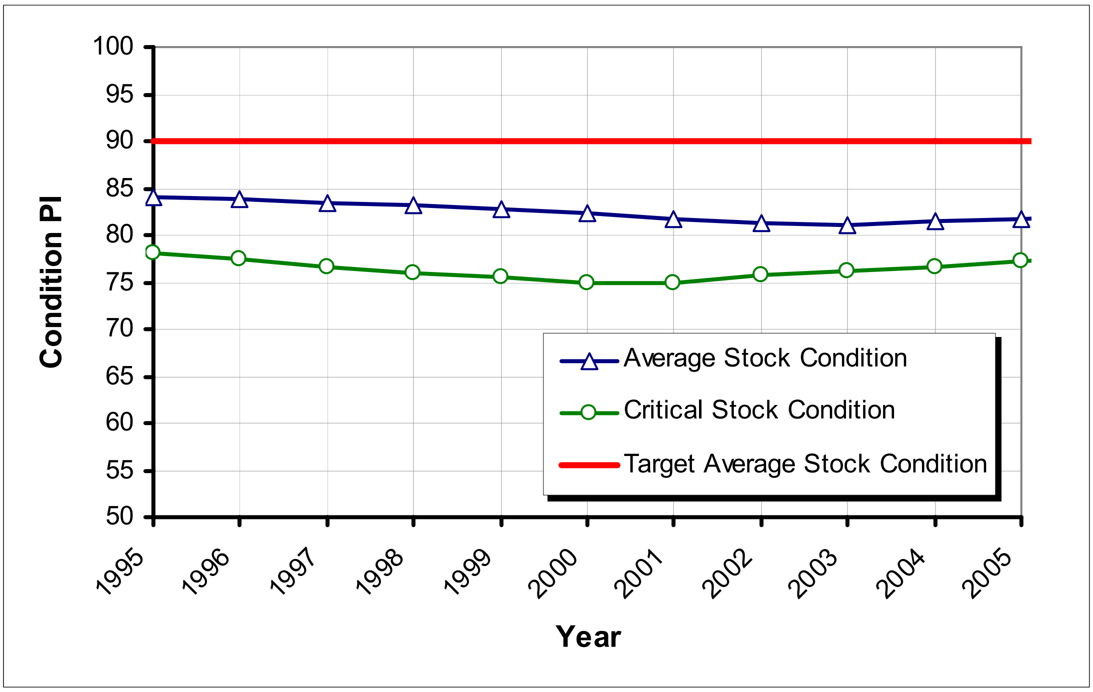

Figure 6 Time Dependent Plot of Condition PI

6.4.2 Histograms

The time dependent plot can be supported by histograms that show the spread of structure conditions, an example is shown in Figure 7.

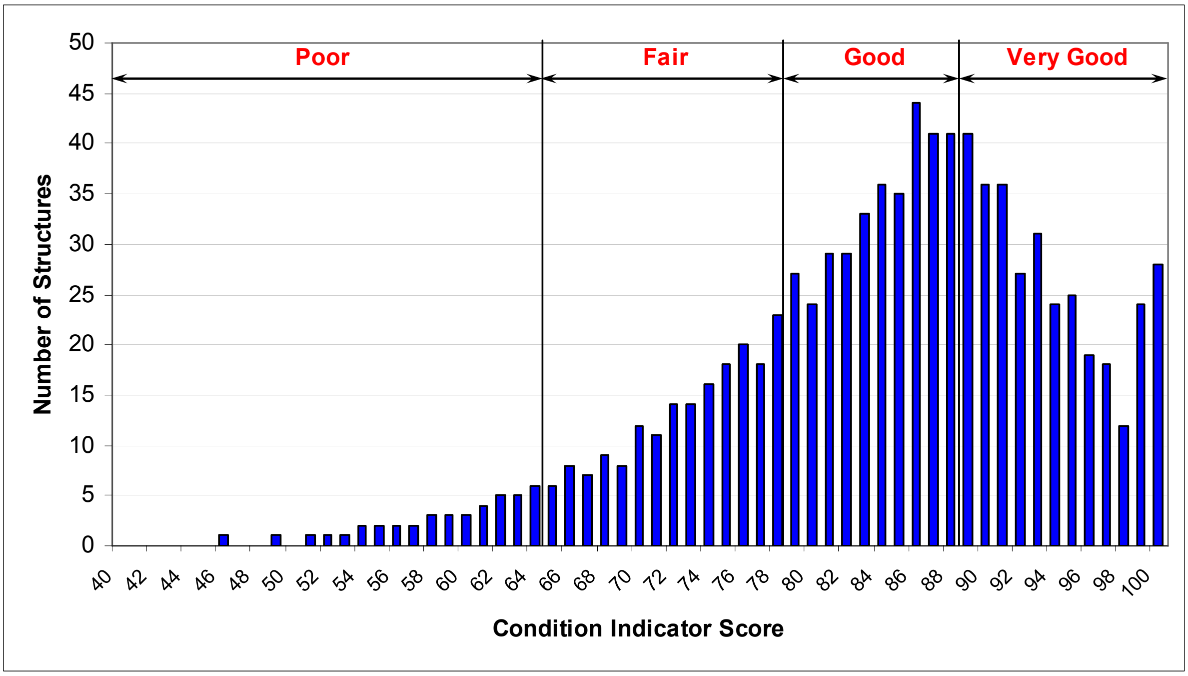

Figure 7 Condition PI Histogram

The y-axis can also be presented as the proportion or % of structures stock, provided different structure types are weighted by the appropriate *Asset Value Factor* (shown in Table 15) and their dimensional quantity.

6.4.3 Stacked Bar Graph

The spread of conditions scores can also be presented in stacked bar graphs as shown in Figure 8.

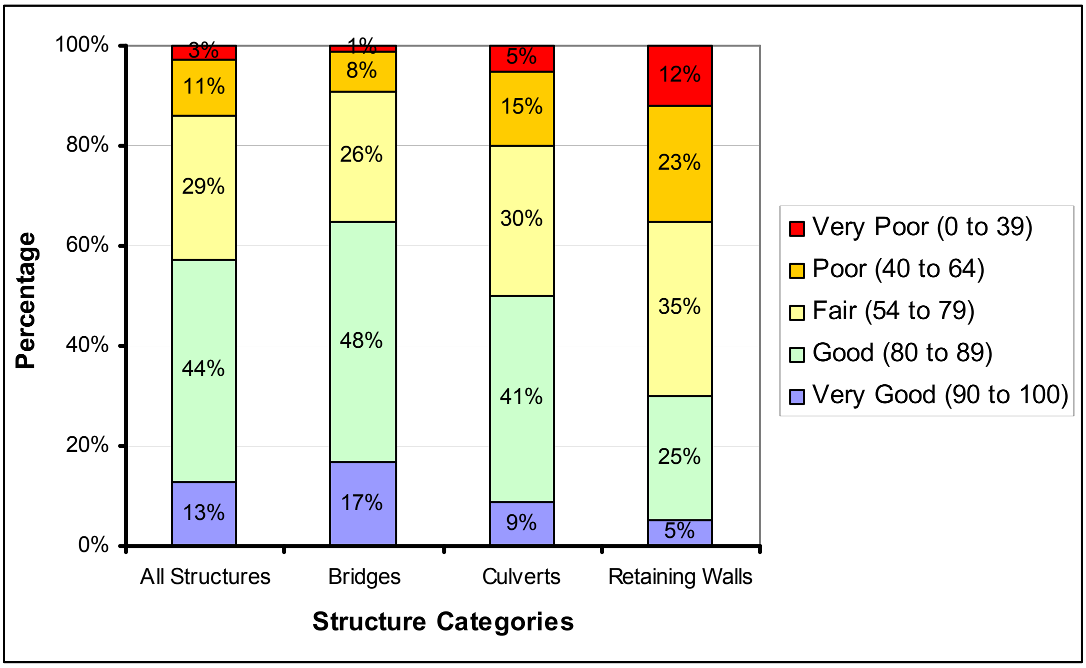

Figure 8 Stacked Bar Graph

7. References

1. Bridge Condition Indicator Volume 3, Guidance Note on Evaluation of Bridge Condition Indicators, CSS Bridges Group, April 2002.

2. Addendum to CSS Guidance Note on Bridge Condition Indicators, August 2004.

3. Bridge Condition Indicator Volume 2, Guidance Note on Bridge Inspection Reporting, CSS Bridges Group, April 2002.

4. HA SMIS Manuals: *A Guide for Structure Inspectors* and *A Guide for Structure Engineers*.

5. Management of Highway Structures: A Code of Practice, UK Bridges Group, September 2005, TSO.

6. BD62 As Built, Operational and Maintenance Records for Highway Structures (DMRB 3.2.1).

7. BD63 Inspection of Highway Structures (DMRB 3.1.4).

8. P.J. Andrews, *Objectivity in Bridge Engineering*, IHT, April 1984.

9. Guidance Document for Highway Infrastructure Asset Valuation, Roads Liaison Group, July 2005, TSO.

APPENDIX A
Equivalent Element Table

No.	ELEMENT DESCRIPTION	EQUIVALENT ELEMENTS
1	Primary deck element	Main Beams
		Truss members
		Culvert
		Arch Arch Ring Vousoirs/Arch Face Arch Barrel/Soffit
		Encased Beams
		Subway
		Box beam interiors
		Armco/Concrete pipe
		Portal/Tunnel portals
		Pre-stressing
		Sleeper bridge
		Tunnel Linings
2	Transverse Beams	
3	Secondary deck element	Concrete deck slab
		Timber deck
		steel deck plates
		Jack Arch
		Troughing
		Stone slab (or primary member)
		Troughing Infill
		Buckle plates
4	Half joints	
5	Tie beam/rod	
6	Parapet beam or cantilever	Edge Beams
7	Deck bracing	Diaphragms
8	Foundations	Piles
9	Abutments (incl. arch springing)	Arch Springing
		Abutment slope
		Bank seat
		Counterfort/Buttresses
10	Spandrel wall/head wall	Stringcourse
		Coping
11	Pier/column	
12	Cross-head/capping beam	
13	Bearings	
14	Bearing plinth/shelf	
15	Superstructure drainage	
16	Substructure drainage	Subway drainage
		Retaining wall drainage
17	Water proofing	
18	Movement/expansion joints	Sealants
19	Painting: deck elements	Sealants
		Decorative Appearance
20	Painting: substructure elements	Sealants
		Decorative Appearance

21	Painting: parapets/safety fences	Sealants
		Decorative Appearance
22	Access/walkways/gantries	Steps
23	Handrail/parapets/safety fences	Balustrade
		Barrier
24	Carriageway surfacing	Ramp Surface
		Approaches
25	Footway/verge/footbridge surfacing	
26	Invert/river bed	Channel bedstones
27	Aprons	
28	Fenders/cutwaters/collision prot.	Flood Barrier
29	River training works	
30	Revetment/batter paving	
31	Wing walls	Newel
32	Retaining walls	Counterfort/Buttresses
		Gabions
		Wall
33	Embankments	Approach Embankments
		Side slopes
34	Machinery	
35	Approach rails/barriers/walls	Posts
		Remote approach walls
36	Signs	
37	Lighting	Subway Lighting
		Primary Lighting
		Secondary Lighting
38	Services	Manholes
		Pipes
		Mast

APPENDIX B
Equation 12 Expanded

Equation 12 is defined as:

Structure Stock Condition PI

$$SSCPI_{\mathrm{Av}} = \frac{\sum\left(\left(\text{Condition PI}_{\text{i-Av}}\right)\times\left(\sum Dim\right)_i \times\left(AVF_i\right)\right)}{\sum\left(\left(\sum Dim\right)_i \times\left(AVF_i\right)\right)}$$

Equation 12a

Expanding Equation 12a gives:

Structure Stock Condition PI

$$SSCPI_{\mathrm{Av}} = \sum\begin{bmatrix}\left(\left(\text{Condition PI}_{\text{B-Av}}\right)\times\left(\sum \text{Bridge Deck Area}\right)\times\left(AVF_B\right)\right)+\\ \left(\left(\text{Condition PI}_{\text{SC-Av}}\right)\times\left(\sum \text{Small Culvert Area}\right)\times\left(AVF_{SC}\right)\right)+\\ \left(\left(\text{Condition PI}_{\text{RW-Av}}\right)\times\left(\sum \text{Retaining Wall Area}\right)\times\left(AVF_{RW}\right)\right)+\\ \left(\left(\text{Condition PI}_{\text{SG-Av}}\right)\times\left(\sum \text{Sign Gantry Length}\right)\times\left(AVF_{SG}\right)\right)+\\ \left(\left(\text{Condition PI}_{\text{HM-Av}}\right)\times\left(\sum \text{High Mast Height}\right)\times\left(AVF_{HM}\right)\right)\end{bmatrix} \Bigg/ \sum\begin{bmatrix}\left(\left(\sum \text{Bridge Deck Area}\right)\times\left(AVF_B\right)\right)+\\ \left(\left(\sum \text{Small Culvert Area}\right)\times\left(AVF_{SC}\right)\right)+\\ \left(\left(\sum \text{Retaining Wall Area}\right)\times\left(AVF_{RW}\right)\right)+\\ \left(\left(\sum \text{Sign Gantry Length}\right)\times\left(AVF_{SG}\right)\right)+\\ \left(\left(\sum \text{High Mast Height}\right)\times\left(AVF_{HM}\right)\right)\end{bmatrix}$$