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FACULTY OF ENGINEERING & THE BUILT ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

Implementation of the DER Rating System within a Power Generation Environment

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Submitted in partial fulfilment of the requirements for the degree of

Master of Engineering in Civil Infrastructure Management and Maintenance

By

Bokosa Gombele

Supervised by:

Professor Pilate Moyo

06 December 2017

Declaration

I know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

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06 December 2017

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Considerable information from course material, roads authorities' publications and conference proceedings has been used and are all referenced herein. They are also acknowledged.

Abstract

The main purpose of this research study is to test the applicability of the DER (Degree of defect, Extent and Relevancy of defect) rating system, used for road network infrastructures, to the support structures of a dry cooling tower in a power generation environment. The DER is a defect-based rating system developed locally by the Built Environment Division of the Council for Scientific and Industrial Research (CSIR) in Pretoria, South Africa. This study involved a visual inspection and the rating and analysis of defects of reinforced concrete (RC) structures in an Eskom power generation plant located in Grootvlei in Mpumalanga Province.

Visual inspection and condition rating systems form part of an Asset Management System (AMS) that is used to ensure a safe operation and the economic benefit of the structure throughout its life cycle. For that reason, various organisations and roads authorities have developed condition-rating systems similar to the DER for visual assessment of their road network structures using a Bridge Management System (BMS) as a vehicle to achieve their operation and maintenance objectives. Other condition-rating systems have been identified and their applicability to structures in a power generation environment as compared to that of the DER was also tested. These condition-rating systems are: 1) The Overall Structural Condition Index (OSCI) - proposed by the Australasian Transport Research Forum (ATRF) for bridge condition assessment and prioritisation of maintenance activities and budget allocation. 2) The National Bridge Inspection Standard (NBIS) which establishes a uniform program for all state departments of transportation in the USA to regulate the minimum requirements for inspection types and procedures, inspection intervals, inspector qualifications, and inventory reporting, and 3) The Ontario Structure Inspection Manual (OSIM) which sets standards and provides uniform approaches for visual and detailed inspections and condition evaluation for all types of bridge structures in Ontario, Canada.

Comparative rating analyses of the defects of the same RC structure in a power generation environment was conducted in order to establish the applicability of the DER in comparison with the other rating systems. The use of the DER, amongst other selected condition rating systems, was recommended with the suggestion that further improvement be undertaken so as to extend its usage within a power generation environment.

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List of Acronyms

AAR	Alkali Aggregate Reaction
AASHTO	American Association of State Highway and Transportation Officials
AHP	Analytical Hierarchy Process
AMS	Asset Management System
ATRF	Australasian Transport Research Forum
BMS	Bridge Management System
CF	Causal Factor
CoMSIRU	Concrete Materials and Structural Integrity Research Unit
COTO	Committee of Transport Officials
CPWD	Central Public Work Department of Government of India
CSIR	Council for Scientific and Industrial Research
DER	Defect, Extent, Relevancy
DOT	Department of Transport
EPRI	Electric Power Research Institute
ESKOM	Electricity Supply Commission
ESCI	Element Structural Condition Index
FHWA	Federal Highway Administration
GPS	Geographical Position System
IRC	Infrastructure Report Card
MW	Megawatt
NDT	Non Destructive Test
NBIS	National Bridge Inspection Standard
NBI	National Bridge Inventory
OBMS	Ontario Bridge Management System
OSCI	Overall Structural Condition Index

OSIM	Ontario Structural Inspection Manual
PBOT	Portland Bureau of Transportation
PAS	Publicly Available Specification
TMH	Technical Methods for Highways`
RC	Reinforced Concrete
SAICE	South African Institution of Civil Engineering
SANRAL	South African National Rods Agency
SAP PM	Systems, Applications and Products – Plant Maintenance
SHI	Structural Health Index
SI	Structural Integrity
SR	Sufficiency Rating
UCT	University of Cape Town

1 Introduction

1.1 Background and Context

Degradation of concrete due to ageing and corrosion of reinforcing steel in concrete structures such as in highway bridges is a major concern for maintenance. Although concrete structures, especially, are generally designed for a 100-year (for bridges) lifespan, knowledge of their rate of deterioration is essential for cost effective asset management and long term transportation planning (Tolliver & Lu, 2011). This knowledge is mainly acquired through regular inspections and condition assessments of the structures.

Various organisations and roads authorities have developed Bridge Management Systems as part of their Asset Management System (AMS). The most common approaches adopted in Bridge Management Systems are defects rating based approach and bridge condition rating approach. In the defects based approach, defects on the structures are visually identified and rated following the degree of defect (minor, moderate, warning and severe), extent of defect (local, more than local, less than general and general) and relevancy of defect (minimum, moderate, major, and critical). This is in the case of the DER (Degree, Extent and Relevancy) rating system. An example of a defects based Bridge Management System is the South African STRUMAN Bridge Management System. While in the condition based rating system, a condition index is assigned to the bridge based on a predefined description of the status of the structure, which could vary from excellent to poor or new condition to failed condition, depending on the approach adopted by a particular rating system. Examples of condition based Bridge Management Systems include Pontis, Pennsylvania, PBOT (Portland Bureau of Transportation) used in the United States of America (USA) and OBMS (Ontario Bridge Management System) used in Canada.

A case study to explore and investigate the use of the DER defect rating system for reinforced concrete (RC) structures within a coal-fired power generation plant environment was conducted and a detailed contextual analysis of selected elements of the support structure of a dry cooling tower and the support drainage infrastructure were performed. Each rating system when used in a power generation environment was assessed in terms of flexibility, simplicity of approach and clarity of process (defined in **Section 4.10.4)** as compared to the DER rating system.

Grootvlei power station (**Figure 1**) was selected for the purpose of this case study and a site visit was arranged in order to conduct a visual inspection of the support structure of the

dry cooling tower and to test the applicability of the DER rating system using collected information.

Figure 1: Distant View of Grootvlei Power Station

Source: ***http://www.outdoorphoto.community/gallery/showphoto.php?photo=201969***

1.2 Problem Statement

The basic hypothesis is that "If DER rating methodology is used for a visual inspection of RC structures in a road network such as bridges, then it can also be used for visual inspection of the support system of a dry cooling tower built with the same construction materials but located within a power station environment".

In order to test the applicability of the DER rating system in a power generation plant's environment, this case study identifies some of the available condition-rating systems and compares them with the DER rating system to establish limitations among them and the appropriateness of the use of the DER rating system in such an environment.

1.3 Research Objectives

The overall objective of the research for this dissertation is to investigate and test the applicability of the DER rating system used by the Committee of Transport Officials (COTO) for the rating of national road structures to concrete structures located in a power generation plant environment.

The specific objectives are to:

1. review the DER rating system to understand how it works, what it can achieve and what its limitations are.
2. identify other rating systems and compare them with the DER rating system in terms of their flexibility, simplicity of approach and clarity as defined in **Section 4.10.4.**
3. evaluate the relationship and differences between the systems.
4. develop maintenance and repair plans
5. provide an estimate of maintenance costs
6. establish the applicability of the DER rating system to structures in a power generation environment as compared with that of other selected rating systems.
7. establish the opportunity for improvement

1.4 Scope

The DER rating system is a defect-based method that requires a good understanding of the deterioration mechanisms of reinforced concrete (RC) structures and the consequences thereof, and a good interpretation of various types of RC defects.

In order to get a better understanding of defects and deterioration mechanisms, the study drew its knowledge largely from the course material of the University of Cape Town (UCT), TMH 19 (Technical Methods for Highways), National Bridge Inspection Standard (NBIS), Ontario Structural Inspection Manual (OSIM), Australasian Transport Research Forum (ATRF), PAS 55-1 (2008) (Publicly Available Specification) and other relevant literature in the areas of condition assessment and rehabilitation of RC structures. The focus during the literature review was placed on aspects of an Asset Management System, the service life of structures and the need for maintenance of RC structures.

Data used for the rating of defects were collected during a visual inspection conducted at Grootvlei power station and the applicability of the DER rating system was tested. This station is operational, which makes inspections practically impossible unless there is an outage and the structures are out of service and available for access. Under the current circumstances comprising ongoing operations, the support columns of the dry cooling towers were the only

parts of the structure accessible for a visual inspection. **Figure 2** shows a typical dry cooling tower with support structure to illustrate the limitations of access.

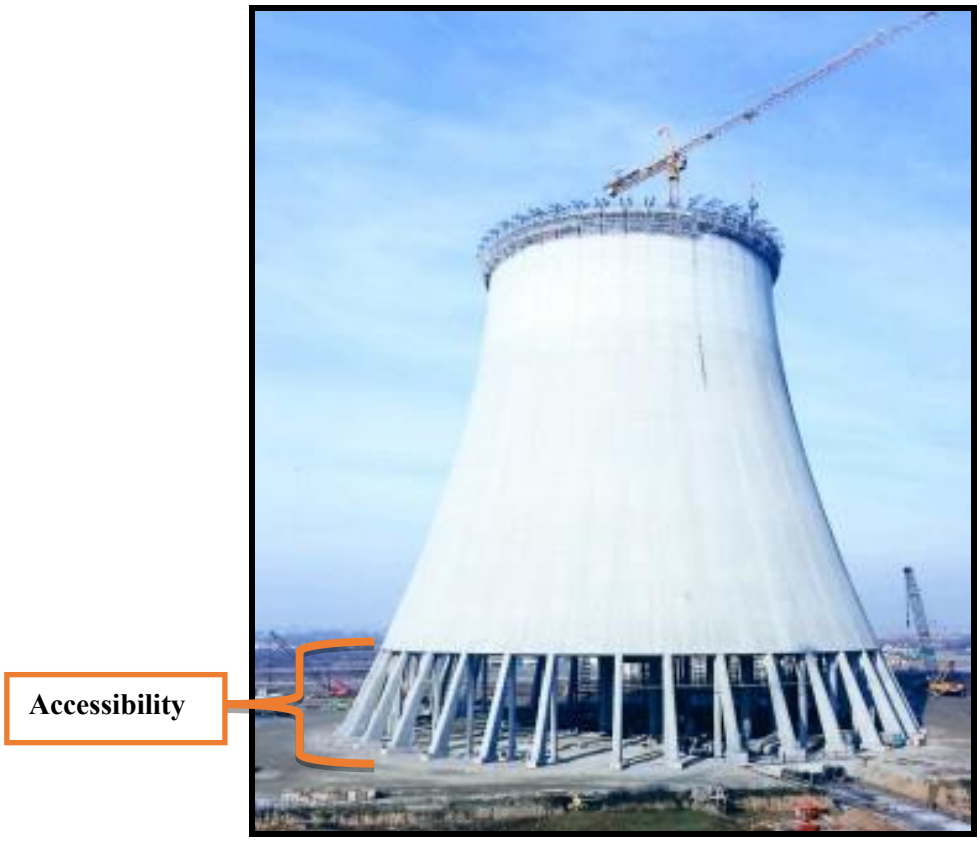

Figure 2: Typical dry cooling tower

1.5 Summary of Research Methodology

A visual inspection of the support pedestals and columns, including the support drainage of the dry cooling tower was conducted. A comprehensive literature review of the deterioration of reinforced concrete structures, their life cycle, the need for repair and maintenance and the types of defects arising from associated factors was conducted.

In addition to the DER rating system, various Bridge Management Systems (Pontis, Pennsylvania, STRUMAN, Portland Bureau of Transportation and Ontario Bridge Management System) and their respective condition-rating systems (NBIS/NBI, OSCI, DER) were reviewed.

The Eskom Inspection Manual was also consulted and an inspection form, in line with the procedure embedded in the manual, was developed and handed over to Eskom's Asset Management Department. This was done to enable a standardised inspection approach to structures listed in the Eskom Inspection Manual.

1.6 Dissertation Organisation

The dissertation contains the background and context that gave birth to the topic that was chosen for the study. It also includes a comprehensive literature review, research methodology and inspection results, and draws conclusions with recommendations. This dissertation is structured in six chapters and presented as follows:

Chapter 1 provides a background to and a context for the study. The research objectives, scope and a narrative on the structure of the dissertation are discussed.

Chapter 2 presents an overview of Eskom plant mix, their location and their generating capacity and different types of cooling systems. It compiles and presents a comprehensive review of Bridge Management Systems with their respective rating systems as part of an Asset Management System. An overview of Asset Management and Eskom's journey to its implementation are also covered, as well as the extent of the implementation of the DER rating system in South Africa.

Chapter 3 attempts to demonstrate the applicability of the DER rating system within a power station environment. The process followed by different rating systems is also discussed. The chapter also covers the output of the study which includes proposed new inspection forms for use with the inspection of support structures of a dry cooling system using the DER rating system.

Chapter 4 provides an overview on how the fieldwork was conducted while endeavouring to test, and to compare with other selected rating systems, the use of the DER rating system on the support system of a dry cooling tower. The extent of their use was analysed in terms of the construction material used, the types of structures and their applicability in a power generation environment.

Chapters 5 concludes the case study.

Chapter 6 provides recommendations, contributions within Eskom and a tentative scope for the further development of the DER system for more extensive use in a power generation environment.

2 Literature Review

2.1 Introduction

The literature review summarises current knowledge about some of the defect and condition-rating systems used in a few selected countries, i.e. Australia, the United States of America (USA), Canada and South Africa. These condition-rating systems are part of the inspection and maintenance processes and they constitute an important element in an established Asset Management System. The review starts with an overview of the status of infrastructure in South Africa and reinforces the need for an established Asset Management System as defined in PAS 55-1:2008 (Publicly Available Specification). This focus is then narrowed down to the status of power generation infrastructure in South Africa, and provides a broad view on the current practice of asset management of power operation facilities, as implemented within Eskom. Various Bridge Management Systems with their respective defect or condition-rating systems were part of the review which also included Eskom's current approach to the visual inspection of civil structures within a power station.

An overview of the geographical location of Eskom Power Stations and their respective installed capacities is presented in **Figure 3,** while **Table 1** provides a list of different types of cooling systems and the number of cooling towers used per station.

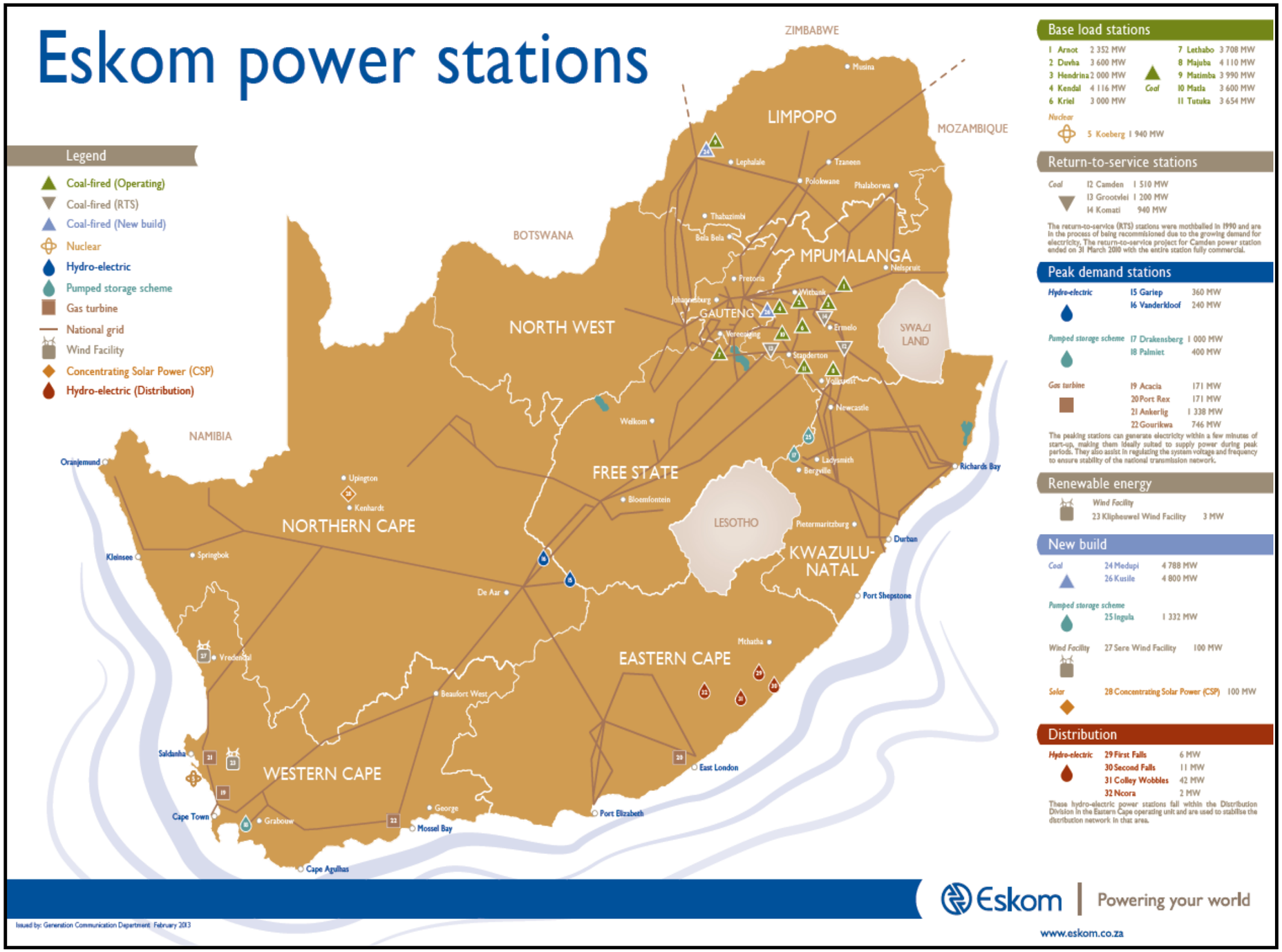

Figure 3: Eskom Power Stations

Source : http://www.eskom.co.za/Whatweredoing/ElectricityGeneration/PowerStations/Pages/Map_Of_Eskom_Power_Stations.aspx

Table 1: Power Station and Related Cooling Systems.

Source: Eskom Engineering

No.	Name of Power Station	Types of Cooling System	Tower Dimensions	No. of cooling towers	Location
1	Arnot	Natural draught	Diameter of top: North 60.60 m, South 51.92 m Diameter of throat: North 54.25 m, South 48 m Diameter of sill: North 85.65 m, South 76.4 m	6	Middleburg, Mpumalanga
2	Camden	Natural draught	Height above sill of 111,86 m Diameter of top: 54.25 m Diameter of throat: 49.99 m Diameter of sill: North 85.65m, South 76.4 m	6	Ermelo, Mpumalanga
3	Duvha	Natural draught	Height above sill of 149 m Diameter at the base: 114 m The minimum thickness of 180 mm	6	Witbank, Mpumalanga
4	Grootvlei	Wet cooling towers Dry cooling towers	Overall height: (Unit 1- 4) of 119 m Diameter of base: (Unit 1– 4) 81 m Overall height of 120 m Diameter of base: 84 m	5 • 3 x wet • 2 x dry	Balfour, Mpumalanga
5	Hendrina	Natural-draught wet-cooling	Height above sill of 116 m Diameter at base: 80 m Diameter of throat: 51.3 m Diameter at top: 57 m	7	Hendrina, Mpumalanga
6	Kendal	Indirect dry cooling	Height above ground level: 165 m Diameter at base: 165 m Diameter of throat: 101.7 m Diameter at top: 104.2 m	6	Witbank, Mpumalanga
7	Komati	Wet cooled system	Height above ground level: 91,44 m Diameter at base: 61.57 m	8	Middleburg, Mpumalanga
8	Kriel	Natural draught	Height above ground level: 136 m Diameter at base: 91.38 m Diameter of throat: 58.3 m Diameter at top: 63.47 m	4	Kriel, Mpumalanga
9	Lethabo	Natural draught – Wet cooling system	Height: 164 m Diameter at top: 63.4 m Throat diameter: 63 m Minimum shell thickness of 200 mm.	6	Sasolburg, Free State

No.	Name of Power Station	Types of Cooling System	Tower Dimensions	No. of cooling towers	Location
10	Majuba	Wet and dry.	Diameter at tower base: 144 m. Total height of 165 m	• 3 x wet • (3 x ACC)	Volksrust, Mpumalanga
11	Matimba	Dry cooled systems (6 Air Cooled Condensers (ACC))	N/A	N/A	Lephalale, Mpumalanga
12	Matla	Natural draught (Wet cooled systems)	Height above ground level: 149 m Diameter at base: 98.25 m	6	Kriel, Mpumalanga
13	Tutuka	Natural draught	Height above ground level: 143 m Diameter of throat: 56 m Diameter at top: 49 m Maximum shell thickness of 180 mm	6	Standerton, Mpumalanga
14	Medupi	6 Air Cooled Condensers (ACC)	N/A	N/A	Lephalale, Mpumalanga
15	Kusile	6 Air Cooled Condensers (ACC)	N/A	N/A	Witbank, Mpumalanga

2.2 Asset Management Systems

The South African Institution of Civil Engineering (SAICE) 2011 Infrastructure Report Card (IRC) awarded the national infrastructure (water, sanitation, roads, ports, airports, solid waste, electricity and hospitals and clinics) an overall grade of C-, meaning that South Africa's infrastructure state is "Satisfactory for now" but needs expenditure and investment in the current medium term to avert serious failure (SAICE, 2011). A similar grade was awarded to the electricity infrastructure, as elaborated in **Section 2.3** of this document. This situation reflects the decades of national capital investment in infrastructure that has culminated in a financial burden due to the backlog in the maintenance, repair, upgrade, renewal or replacement activities needed to keep assets at their optimal service level. Hence, the formulation of an organisational strategic plan that is supported by an Asset Management System is imperative for sound management of assets. PAS 55-1 (2008) defines an Asset Management System as "organisational management policy, asset management strategy, asset management objectives, asset management plan(s) and activities, processes and organisational structures necessary to their development, implementation and continual improvement". Use of this system is critical in order for asset owners to meet their business objectives and their stakeholder expectations.

In financial terms, infrastructure is treated as an asset and it appears in the company's balance sheet as such. Therefore, it is essential for an asset owner to have a thorough knowledge of its physical assets in terms of value, condition, maintenance backlog and remaining life. **Figure 4** demonstrates the make-up of a physical asset showing infrastructure as a non-current asset.

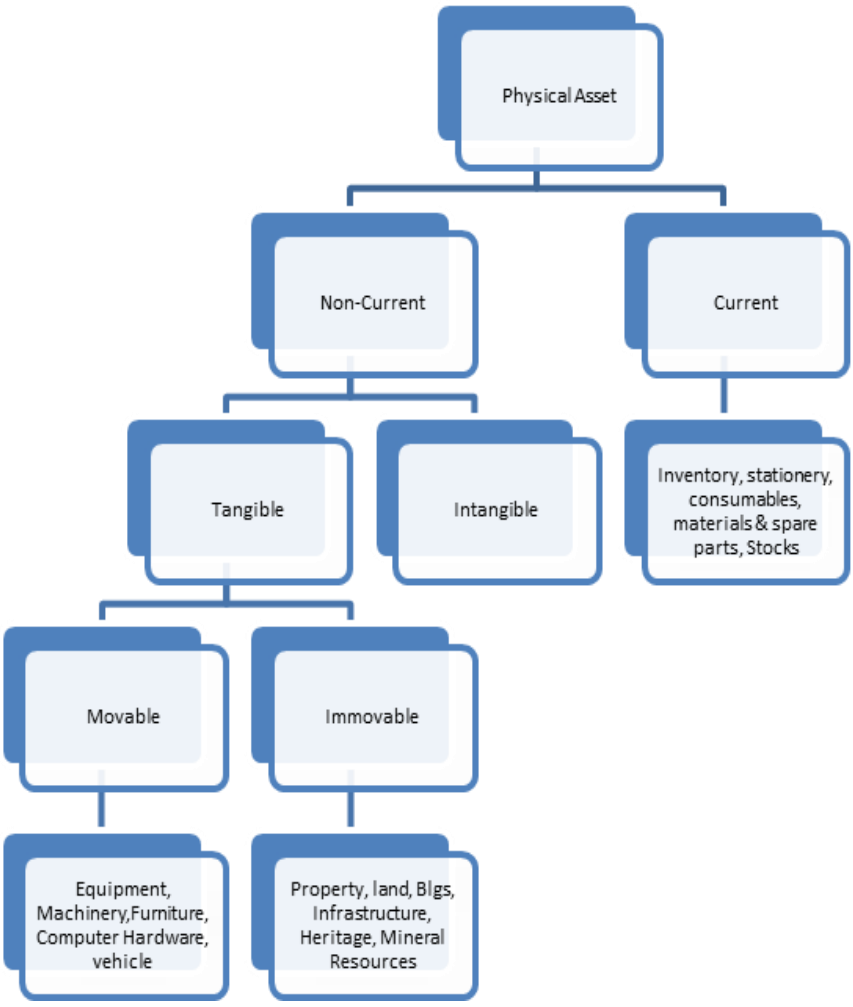

Figure 4: Physical Asset Structure

Source: Physical Asset Management Principles and Practices, Amandi-Echendu, J.E., University of Pretoria, 2010

PAS 55-1 (2008) stresses the importance of establishing an organisational strategic plan that is supported by levels of the Asset Management System (AMS) represented in **Figure 5**. The specification promotes an integrated implementation approach between corporate management and role players at asset management level to optimise the life cycle of assets and to meet stakeholder expectations. This integrated approach and the relationship between supporting organisational strategic goals as well as the relationship between AMS and Organisational Strategic Plan and Stakeholder expectations are shown in **Figure 6**.

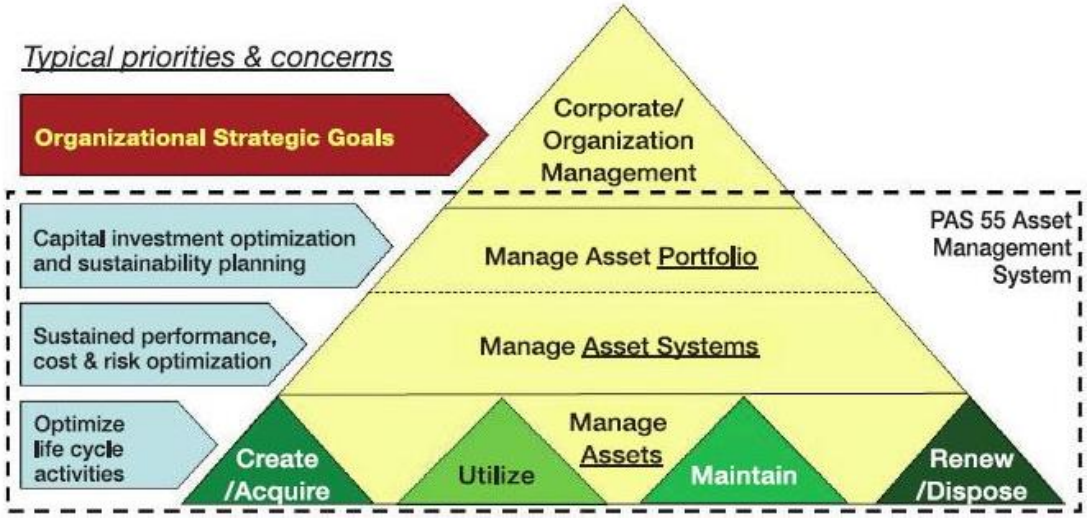

Figure 5: Levels of Assets

Source : https://theiam.org/knowledge/diagrams

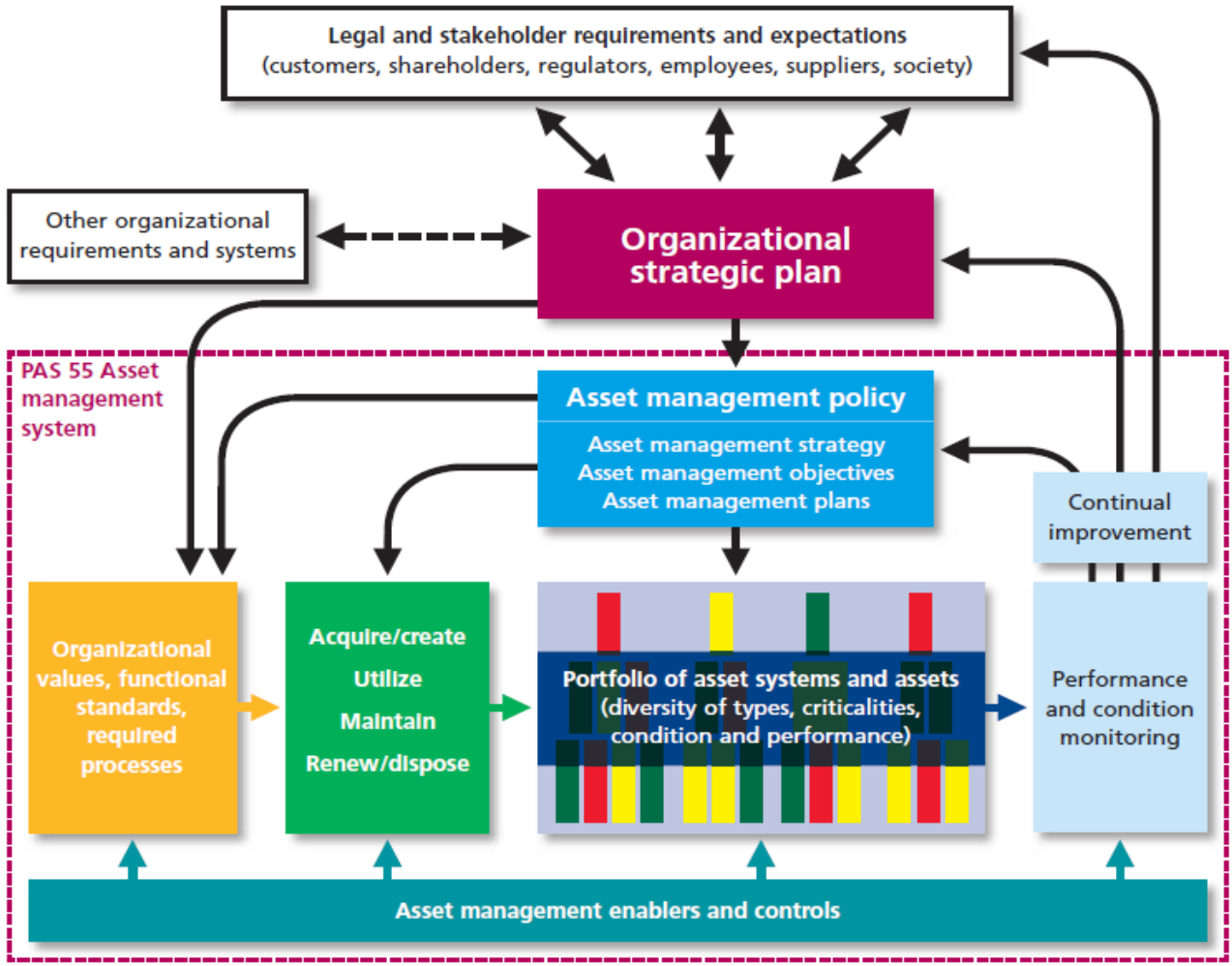

Figure 6: PAS 55-1 Overview of the Asset Management System and its Relationship to Organisational Strategic Plan and Stakeholder Expectations.

Source: http://www.irantpm.ir/wp-content/uploads/2014/01/pass55-2008.pdf

Asset Management Systems should not be implemented in isolation, but should be integrated with other management systems within an organisation. PAS 55-1 sets a requirement structure in a Plan-Do-Check-Act framework (PDCA) (**Figure 7**) to enable the development of such systems in a manner that aligns with standards such as PAS 99 (Specification for Integrated Management) and British Standard Occupational Health and Assessment Series (BS OHSAS 18001) or Occupational Safety and Health Act (OSH) in the case of South Africa.

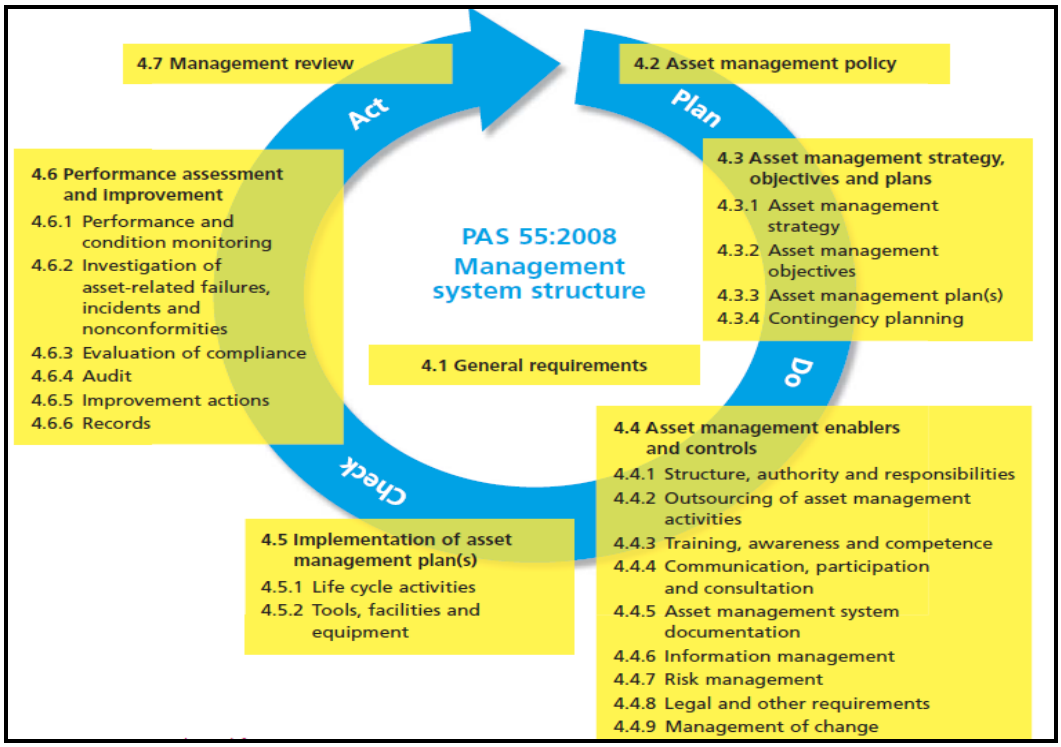

Figure 7: PAS 55-1:2008: Management System Structure.

Source: http://www.irantpm.ir/wp-content/uploads/2014/01/pass55-2008.pdf

2.3 Management of Power Generation Assets

The aforementioned 2011 IRC awarded a grade C+ to the Eskom generating infrastructure, meaning that this infrastructure is in a satisfactory condition, has a reasonable maintenance regime and can meet current demand. However, major capital investment for new infrastructure is needed to meet needs in the next five years. Such investment is being made, but there are a number of risks associated with ageing infrastructure, new project completion and coal supply (SAICE, 2011). Hence, this sets the scene for the necessity of an established and efficiently implemented Asset Management System that includes the maintenance, repair or upgrade of the infrastructure to satisfy the requirements of the organisation's strategic plan. This would be difficult to achieve without an existing Asset Management System.

2.3.1 Overview of asset management systems for Eskom coal-fired power stations

Eskom owns an asset portfolio in its infrastructure value chain with the main one shown in **Figure 8**. This comprises generation, transmission, distribution and sale of electricity. With a total installed capacity of 45 075MW and a total nominal capacity of 42 810MW, Eskom's coal-fired power stations produce about 85% of total installed capacity (Eskom Holdings SOC Limited Integrated Report, 2016). In the 2015/16 financial year, Eskom recorded a customer base of 5 688 640 users who have been profiled as shown in **Table 2** and total assets valued at R660 685 Million (Eskom Holdings SOC Limited Integrated Report, 2016). This represents a huge responsibility on the power utility to provide a high quality service at an affordable cost while ensuring continuity of supply to enable economic growth and development. Such high quality service and continuity of supply can only be attained with a sound Asset Management System which supports the organisational strategic plan and is structured as presented in Figure 8. Generation is the asset under consideration in this study. Transmission and distribution do not form part of the scope of the study.

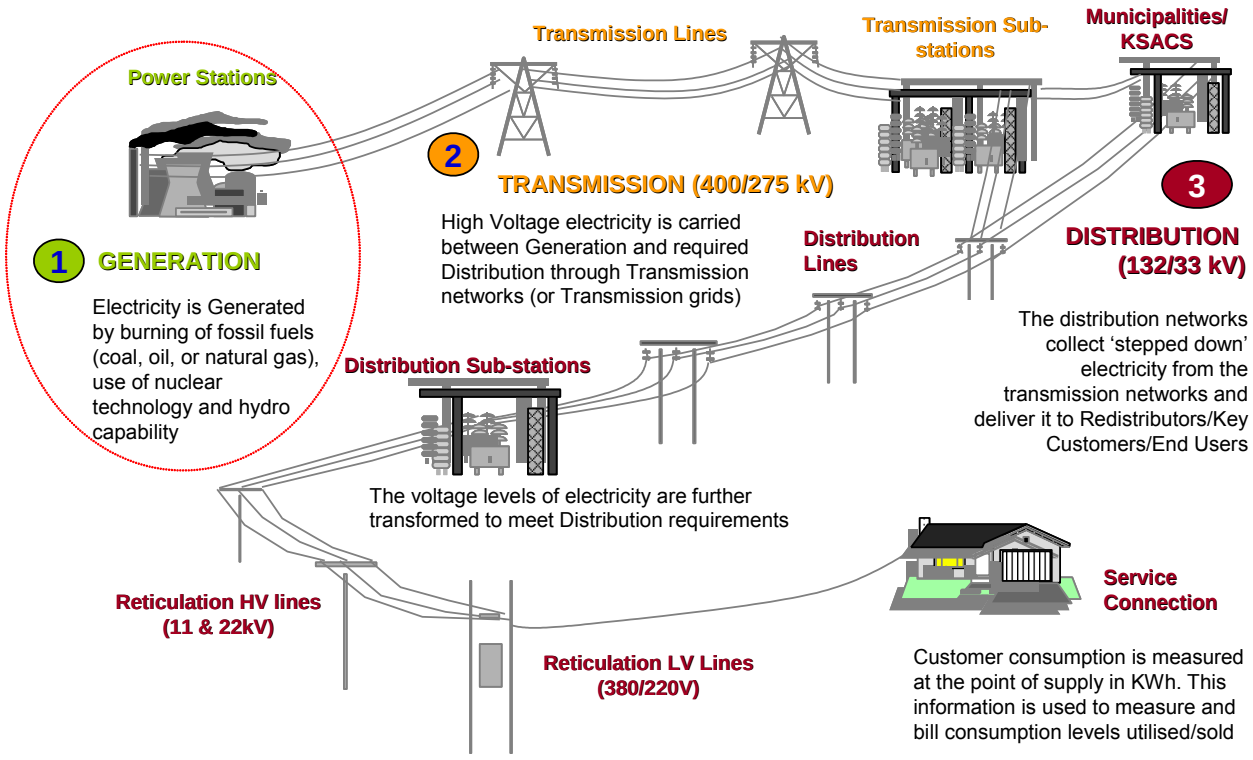

Figure 8: Eskom Value Chain

Source: Eskom, 2009

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Table 2: Eskom Customer Profile

Source: Integrated Report, March 2016, pg11

Category	Number
Redistributors and/or municipalities	801
Commercial	50 816
Industrial	2 733
Mining	1 013
Agricultural	82 450
Rail	509
Residential	5 550 307
International	11
Total	**5 688 640**

2.3.2 Elements of a coal-fired power generation plant

The power generation flow diagram in Figure 9 provides an illustration of the components of a typical coal-fired plant asset. Without describing their respective functions, an overall list of core components is shown in **Figure 9** and listed below.

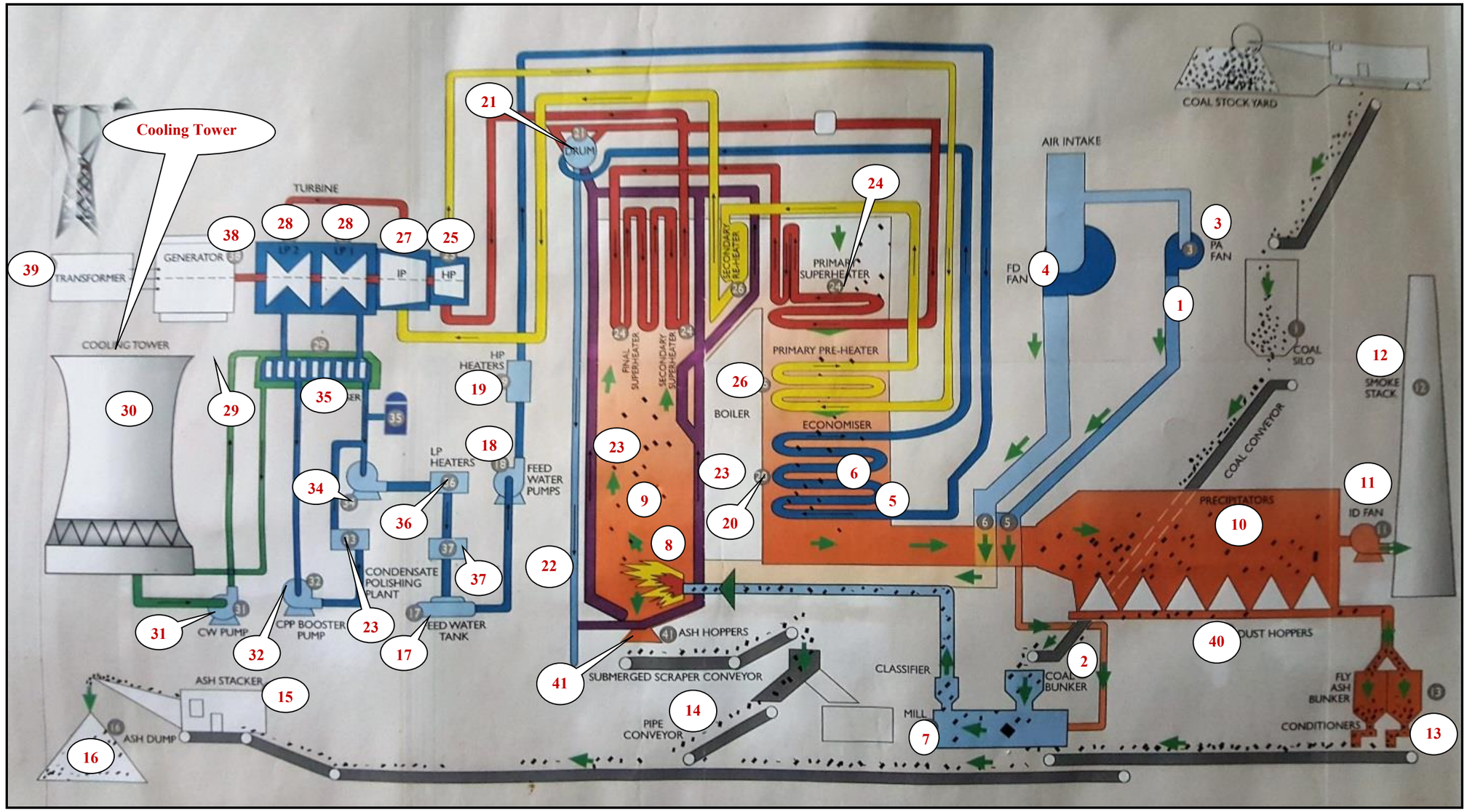

Figure 9: Basic Power Generation Flow Diagram

Source: Eskom Generation

1. Coal silo, 2. Coal bunker, 3. Primary air supply fan, 4. Combustion air supply fan, 5. Combustion air supply fan, 6. Combustion air supply fan, 7. Pulveriser, 8. Burners, 9. Furnace (combustion chamber), 10. Electrostatic Precipitators, 11. Gas extraction (Induced Draft Fan), 12. Smoke stacks (chimneys), 13. Fly ash bunkers and conditioners, 14. Bottom ash, 15. Ash stacker, 16. Ash stacking, 17. Feed Water Storage Tank, 18. Boiler Feed Water Supply Tank, 19. High Pressure Feed Water Heaters, 20. Economiser, 21. Steam-water drum, 22. Steam generation tubes, 23. Condensate Reserve Storage Tank, 24. Superheaters, 25. High Pressure Turbines, 26. Reheaters, 27. Intermediate Pressure Turbine, 28. Low Pressure Turbines, 29. Condenser, 31. Circulating water pump, 32. Condensate Polishing Plant booster pumps, 33. Condensate Polishing Plant, 34. Condensate extraction pumps, 35. Condensate Reserve Storage Tank, 36. Low Pressure Feed Heaters, 37. Gland Steam Condenser, 38. Generator, 39. Transformer, 40. Dust Hoppers, 41. Bottom ash.

2.3.3 Eskom's journey to an Asset Management System

With their focus on generation assets, Eskom has always strived for good asset management processes. This dates back to as early as 1992 when Eskom initiated what was called Project R (Reliability). The project resulted in the development of 37 guidelines covering 12 major elements of a management control program. It introduced good practices in the form of guidelines for an improved plant performance (Xaba, 2007) and covered organizational, engineering and operational functions. The guidelines are designated with the acronym OPG (Operating Procedures Group) and are listed with a brief description in **Appendix 1**. They constitute the foundation of Eskom's Asset Management System. Ever since the project evolved to documentation of fundamental policies, installation of SAP PM (Systems, Applications and Products – Plant Maintenance) organization-wide benchmarking exercise with the EPRI (Electric Power Research Institute) Solutions and Accenture, which finding confirmed the need for improvement in many areas of maintenance to align with international Best Practice, to the establishment of its Asset Management Department in 2006. The department ensures plant wide asset processes are consistent, relevant and kept current with structured governance on asset management principles. Processes to prove effectiveness, Gap Analysis roll out and further improvement were also undertaken (Volk, 2009). The year 2007 saw the publication of two documents: Plant Asset Management Policy and Plant Asset Management Directive. Policy document GGPP 0975, states the overall intentions and direction of the Eskom Generation Division relating to assets and is intended to support the organization's strategic business plan while the Directive document GGD 1447 specifies the business processes required to address the key asset management principles contained in the policy document. This is represented in Asset Management Document Hierarchy structure (**Figure 10**) for management system documents.

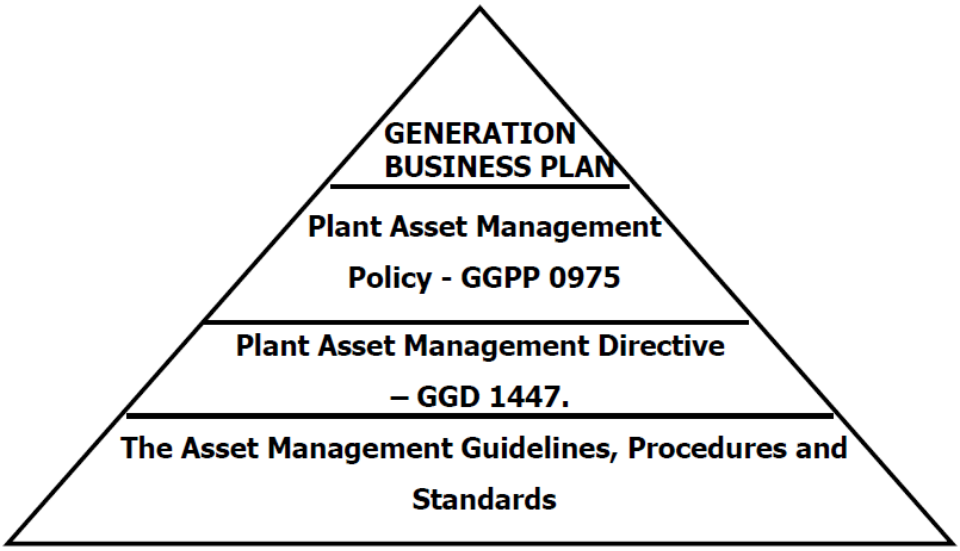

Figure 10: Asset Management Document Hierarchy structure

Source: Asset Management Awareness Presentation slide 08 Baily Consulting, 29-30 June2009,

2.3.4 Implementation of the Asset Management System - Eskom perspective

As a result of the 2005 benchmark exercise with the EPRI Solutions and Accenture as well as to improve its maintenance processes, Eskom introduced an Asset Management Improvement Project. This led to the identification of six streams of activities shown in **Figure 11** and described in **Table 3**

Figure 11: Asset Management Improvement Project

Source: Asset Management Awareness Presentation slide 08 Baily Consulting, 29-30 June2009,

Table 3: Asset Management Improvement

Item	Stream	Description
1	Reliability Basis Optimization	Using EPRI database and Eskom Generation experience to establish effective preventative and condition based maintenance program
2	Work Management	Thorough planning of work requirements (spares, material, special tools, isolations, manpower, etc.) Work program 80% fixed for work week
3	Leading metrics (Measuring the right things)	Measuring schedule compliance, PM compliance, Statutory order violations, Emergent work, SAP PM utilization, Resource utilization, Backlog, Outage readiness indicator, Outage effectiveness indicator.
4	Outage Optimization	Reduce outage durations whilst improving plant performance Implement Modular Spares, Outage Readiness Indicator, Outage Effectiveness Measures as well as apply "Theory of Constraints" (TOC) to Outage planning. Use risk techniques proposed by EPRI
5	Peer Groups	Establishing ways of sharing operational experience to ensure learning
6	Condition Monitoring	Develop plans for inspection and testing of plant Inspection plans linked to data base and CMMS Develop appropriate management strategies.

Implementation of asset management within Eskom is done following the structure depicted in **Figure 12**. The Asset Management Department has received a mandate from Eskom Holding SOC Limited to provide assurance that operation, maintenance and refurbishment of generation, transmission and distribution assets are methodical, consistent, repeatable, auditable and optimised in terms of performance, cost and risk ("The department has…", n.d.).

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Figure 12: Eskom Asset Management Organisational Structure

Source : http://technology.eskom.co.za/assetm/Pages/Structure.aspx

2.3.5 Operational life assessment – Eskom's coal-fired power station

The economic lifespan of the generating plant of a coal-fired power station comprises the operational lifetime of the unit. According to Reddy (2007), this is considered to be 50 – 60 years during which time it contributes to the production of capacity generation. Eskom's procedure on coal-fired plant life and the depreciation period stipulates that a newly-commissioned coal-fired generation plant unit is to be assigned a useful life of 35 years starting on the date that the unit is first placed in commercial operation. For financial accounting purposes, the initial depreciation period will be 35 years in accordance with Generally Accepted Accounting Practice (GAAP) and International Financial Report Standards (IFRS).

Thus, a new coal-fired generation plant is designed for a useful life of 35 years and every year, a Life Determination Study (LDS) is conducted to establish the economic feasibility of operating the existing plant compared with building a new one. At the end of the 15th year of the unit being commercially operative, the LDS is conducted again to investigate the station's life potential up to 50 years. If the assessment results show that the station's operational life of 50 years can be achieved, the findings of the life assessment are reported to the Generation

Operational Investment Committee (GOIC) with the proposal to extend the depreciation period to 50 years.

The same process also applies at the end of the 30th year of the commercial operation of the unit, when the LDC results show that the station's life potential can be extended up to 60 years. Should the station's operational life be less than 50 or 60 years in both stages of the LDC, a project is initiated to decommission the plant and to accurately investigate the remaining life. The same kind of project is also initiated at the end of the 40th year of commercial operation (Reddy, 2007).

A large proportion of the Eskom documentation reviewed places a great deal of importance on the mechanical, electrical, control and instrumentation systems within a power station, but less emphasis has been placed on the reinforced concrete components that comprise the very infrastructure that provides support to these systems.

2.3.6 Maintenance of a cooling tower structure

A cooling tower (**Figure 13**) is designed and built for the purpose of cooling the water that is used to condense the steam under the generating unit's steam turbine as well as for the secondary plant cooling water systems (Kraig and Boshart, 2007). With the exception of mechanical and electrical components, the RC structure components that form part of a cooling tower system need to be maintained to optimise their design life.

The same principle that is highlighted in **Section 2.3.5**, should be applicable to the cooling tower and other reinforced concrete (RC) structures found in a power generation environent. Inspection regimes of RC structures should be established and run in parallel when conducting operational life cycle determinations of mechanical, electrical, control and instrumentation components.

There are three types of cooling systems used within Eskom's coal-fired power stations. Eskom's Inspection Manual for Civil Works at Eskom's Power Station (2015) lists them as: 1) Wet-cooling, 2) Indirect dry-cooling and 3) Direct dry-cooling.

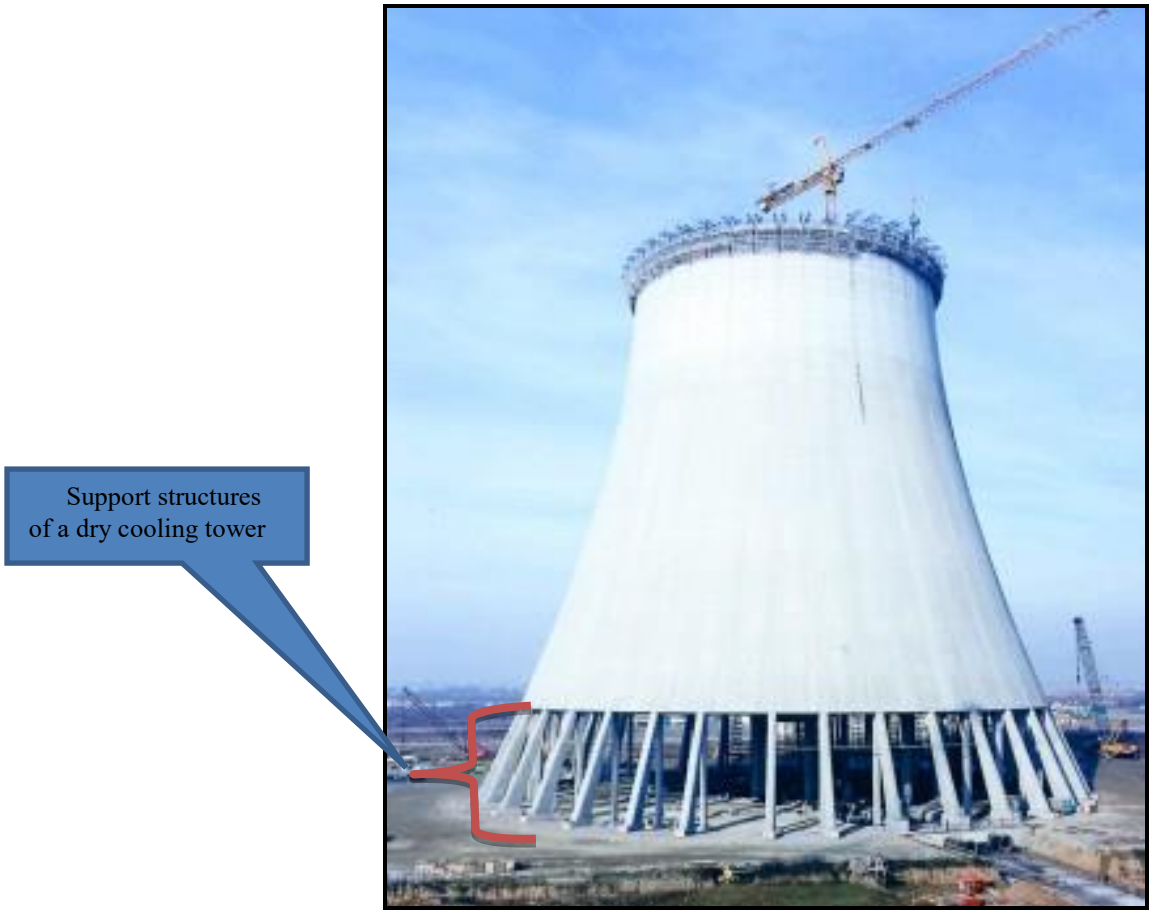

Figure 13: Support Columns of a dry cooling tower

2.3.7 Typical components of a dry cooling tower

Cooling towers are large hyperbolic, thin-shell reinforced concrete structures that contribute to environmental protection and to power generation, efficiency and reliability (Gould & Kratzig, 1999). The RC structure of a typical dry cooling tower consists of the following main components:

1. Towering shell supported by
2. Diagonal, meridional, or vertical columns bridging the air inlet,
3. Column blocks,
4. Pedestals,
5. Ring beam on which the tower shell is concreted/bottom or lower section of the shell,
6. Floor,
7. Support drainage infrastructure.

A photograph of a dry cooling tower support structure is shown in **Figure 14** for illustrative purposes.

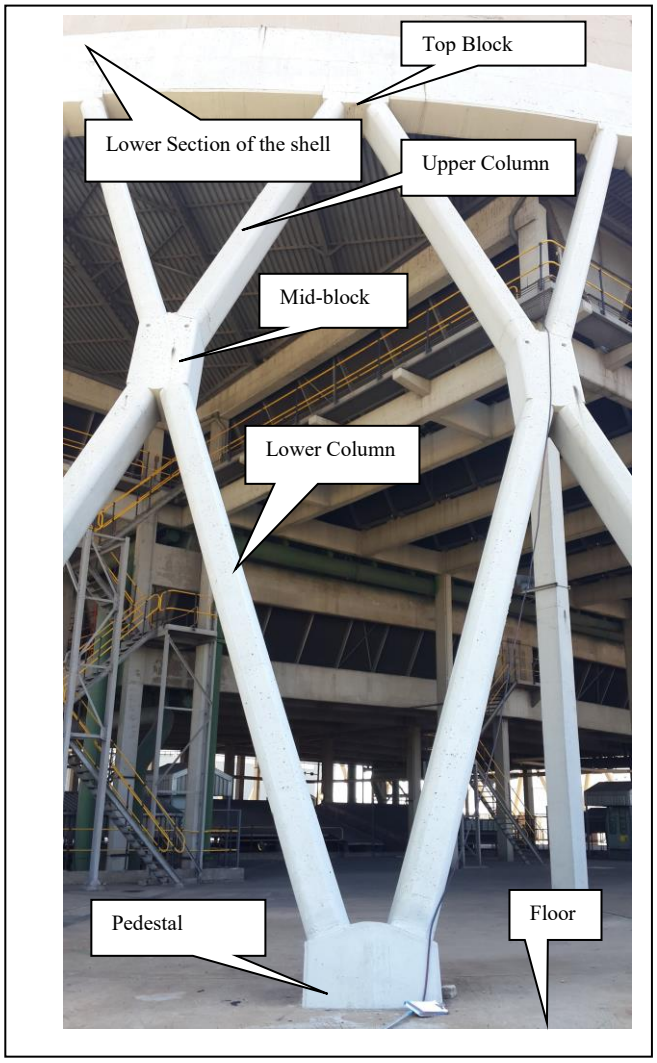

Figure 14: Identified Components

2.3.8 Proposed process for the inspection of a dry cooling tower

The investigation process by Beushausen (2014), outlined in **Figure 15,** has been adopted as a suggestion for the process of planning visual inspections of the RC components of a dry cooling tower. For a successful inspection outcome and subsequently the successful repair and maintenance of the structure that is needed to extend its life cycle, Kurz et al (2012) stress the importance of increased knowledge of the deterioration process at exposed regions as well as a detailed knowledge of the current condition of the whole structure.

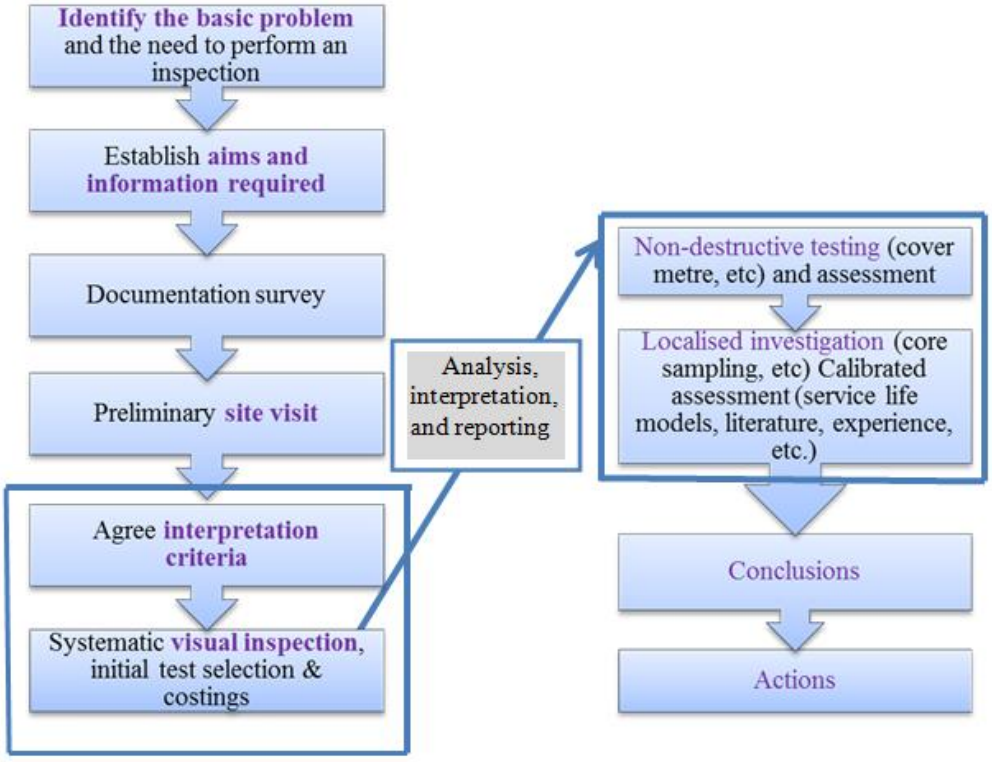

Figure 15: Planning of diagnostic investigations - Beushausen (2014)

Source: condition assessment and diagnostic testing, A/Prof. Hans Beushausen, CIV5116Z, 2014

2.3.9 Asset life cycle

PAS 55-1 (2008) approaches the concept of asset life cycle and defines it as the" time interval from the creation/acquisition of an asset, utilisation to maintenance and renewal/disposal". Thus, a series of interventions need to be planned to extend the asset's life cycle. This means that repair and maintenance activities being performed on the asset should follow an established regime to ensure that they provide the intended services at the required performance level throughout the asset's life cycle. The longer the service life, the more economical the overall performance (Cagle, 2003) and the better the return on investment.

2.3.10 Lessons learnt.

The lessons that were learned in this study resulted from the attempt to test the implementation of the DER rating system in a power generation environment. This system has traditionally been used in South Africa for bridges and associated structures within road networks to rate defects and provide guidance for a repair and maintenance schedule that includes the budget allocation for these activities.

Literature in this specific discipline was reviewed and a site visit followed by a visual inspection was conducted. Engagement with Eskom's Engineering and Asset Management Department staff took place.

The lessons learnt in **Table 4** were identified and recorded and recommendations for continuous improvement of the application of the DER within the power generation environment were provided.

Table 4: Lessons Learnt.

Observation	Effect	Recommendations
Focus on mechanical, electrical and control & instrumentation components	Less attention to RC structure.	DER rating system can be used as the starting point. Further development and use for structures that are not listed in TMH 19
		Develop condition, budget and maintenance modules.
Majuba silo collapse. Lower American Standard used back then compared to now ("Majuba silo design…", 2015)	Reduced power output which led to load shedding daily across the country.	Invest time and resources in developing RC inspection and maintenance procedures and processes for implementation.

2.4 Bridge Management and Defects/Condition-Rating Systems.

A structure may develop cracks, spalling and rebar corrosion during its service life. All this information must be recorded and evaluated before a repair or maintenance strategy is devised, and should be stored in a repository system that forms an integral part of a collection of organizational roles, procedures, data, analytical tools, computer programs, and support services and is called a Bridge Management System (Khan, 2010). In other words, a Bridge Management System (BMS) is a subset of an Asset Management System, as defined in **Section 2.2**.

The road and bridge authorities of various countries have developed their BMSs over time with the goal of balancing activities that extend the life and function of bridges and taking into account the impact on the human and natural environment (Bridge Management System, 2016). In the United States various departments of transportation have developed BMSs such as Pontis, Portland Bureau of Transportation (PBOT's Bridge Management System), and Pennsylvania. In Canada, the Ontario Bridge Management System (OBMS) has been developed and in South Africa the STRUMAN Bridge Management System.

Although developed by different countries and using different rating systems, these BMSs have the same objective - to optimise the life cycle activities of the asset (road structures). These systems are not discussed in detail as they are not the focus of this study. However, an overview of each of the selected rating systems is discussed in the following sections.

2.4.1 Pontis`

Pontis is a Bridge Management System software that is available through the American Association of State Highway and Transportation Officials (AASHTO). The software aids in the development of bridge preservation (maintenance, repair and rehabilitation) and improvement and replacement projects and programs. The results ensure the maximum possible benefit to the user and improvements to the overall condition of a bridge population at given budgets. This is done by using quantitative bridge element level condition data, deterioration and cost models, and agency policies (O'Donnell, n.d.). Pontis uses National Bridge Inspection Standards (NBIS) as a condition-rating system.

As a Windows-based bridge management system (BMS), Pontis is equipped with functionality for recording bridge inventory and inspection data, developing an optimal preservation policy, simulating conditions, generating work candidates and developing a bridge program. Originally developed for the Federal Highway administration (FHWA), now it is an AASHTO product and widely used in the USA and abroad (Pontis overview, n.d.). The simulation results of bridge work level recommendations are shown in **Figure 16**.

Bridge ID	Year	Prog.	Action	Object	Cost ($)	Benefit ($)
1001 279	2003		Replace	Bridge	581,634	3,216,374
1001 279	2003	X	Replace element	Wing walls	136,000	559,576
1001 279	2004		Min repair	P/Stl Thru Truss/Top	11,171	67,869
3365 015	2003	X	Rehab element	Paint Stl Stringer	7,932	571,171
3365 015	2003	X	Replace paint	P/Stl Thru Truss/Bot	8,688	686,747
3365 015	2004		Min repair	Paint Stl Floor Beam	5,935	34,589
3365 015	2004	X	Rehab element	Movable Bearing	5,000	53,418

Figure 16: Pontis Work Candidate Work List

2.4.2 Portland Bureau of Transportation (PBOT's Bridge Management System)

PBOT Bridge Management System is used to identify and prioritise bridge preventive maintenance, rehabilitation and replacement activities. Bridge inspections are conducted every two years in line with the NBIS and data and related condition-rating are used to update the PBOT's system (Program show case, n.d.) as shown in **Figure 17**.

Sufficiency Rating (SR) is used as a basis for establishing priority for the federal funding of bridges. The lower the rating, the higher the priority for rehabilitation or replacement. SR is elaborated upon in **Section 2.5.5**.

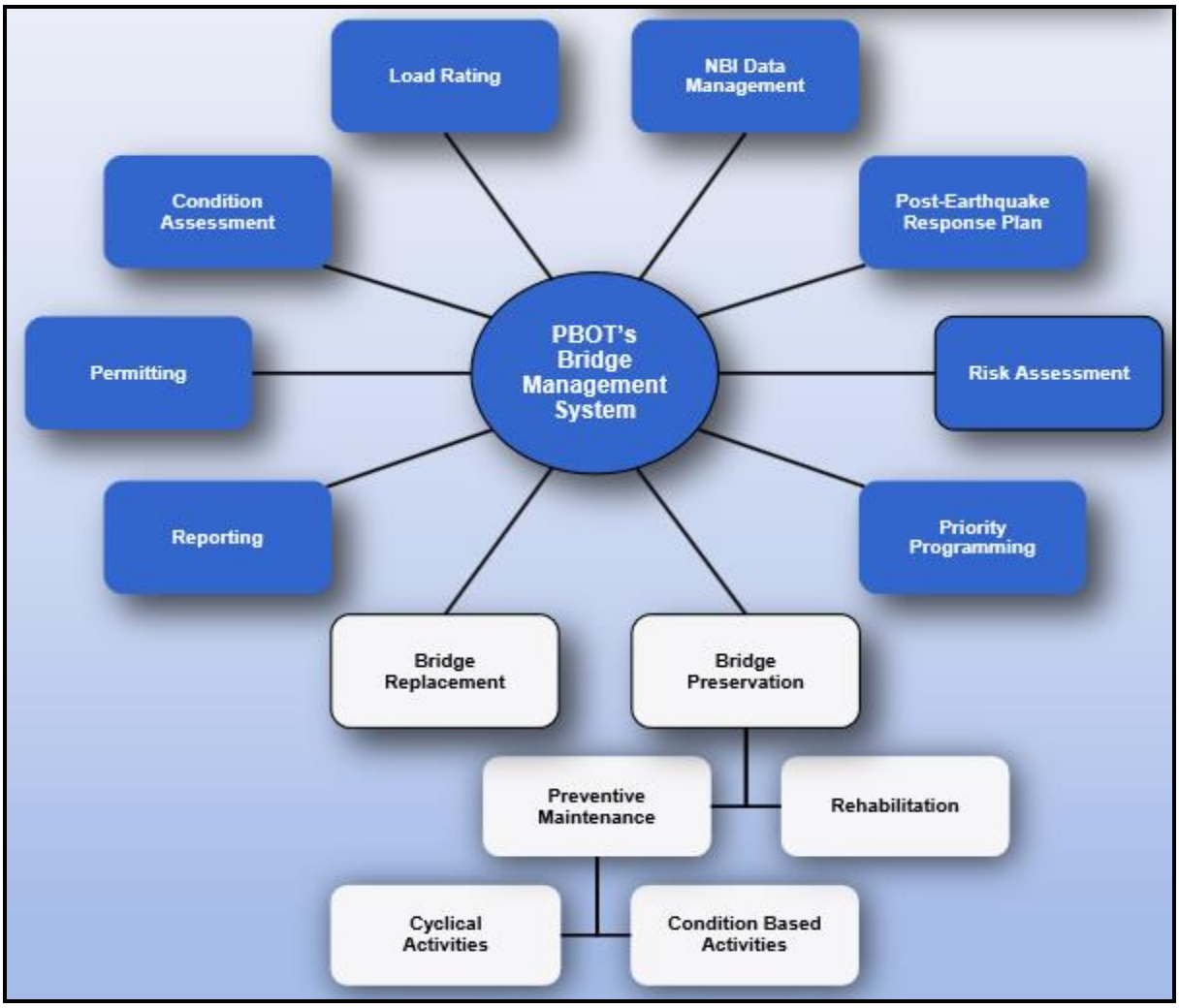

Figure 17: PBOT's Element

Source : https://www.portlandoregon.gov/transportation/62870

2.4.3 Pennsylvania BMS

In full implementation since 1987, the Pennsylvania Bridge Management System was developed as a management tool to handle standardised bridge maintenance activities and costs, to store the needs of various activities on a bridge-by-bridge basis, to rank activities and assign a priority to bridges for maintenance programming, to transfer programmed projects to the maintenance division's programming and scheduling system, and to store the costs of the complete work (Arner et al, 1986).

The Pennsylvania BMS uses the NBIS rating system and the Sufficiency Rating (SR) for bridge maintenance prioritization (Weykamp, 2010). **Section 2.5.5** provides further details of NBIS and SR concepts. Elements of the Pennsylvania BMS are presented in the **Figure 18**.

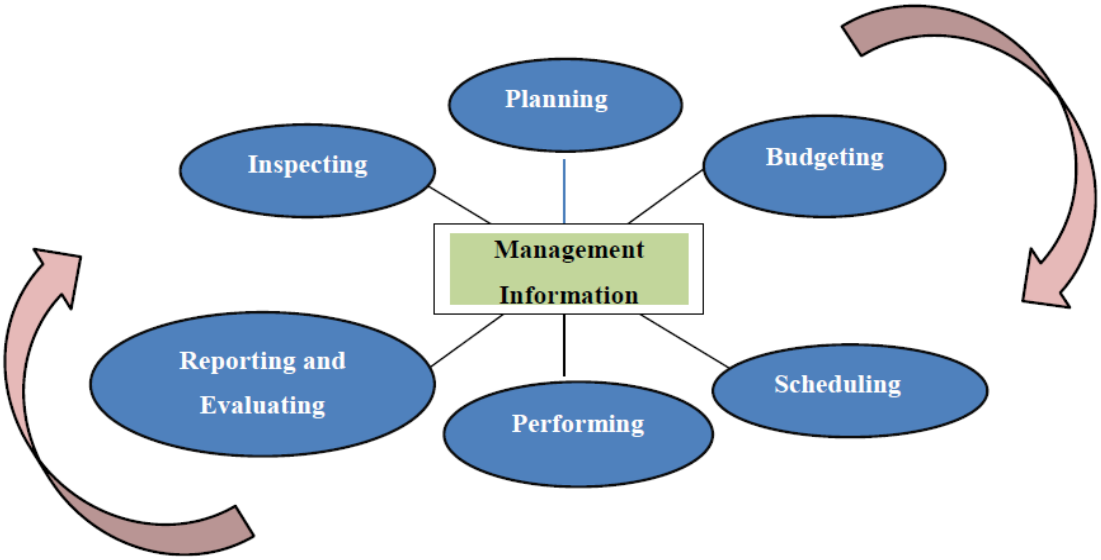

Figure 18: Elements of the Pennsylvania BMS (Mbanjwa, 2014)

Source: *Mbanjwa, T. 2014. An investigation of the relationships between inventory and inspection data of RC bridges and RC culverts in the Western Cape Province. Msc. Thesis. Pg-40)*

2.4.4 Ontario Bridge Management System (OBMS)

The Ontario Bridge Management System (OBMS) is widely used in Canada. Developed in 1998 and first implemented in 2000, OBMS has three main models: the Deterioration Model, the Knowledge Model and the Cost Model (Khanzada, 2012). These models are used to create work alternatives at elemental project and programme levels, and are created by means of the models as shown in **Figure 19,** which demonstrates the structure of the domain models of the OBMS.

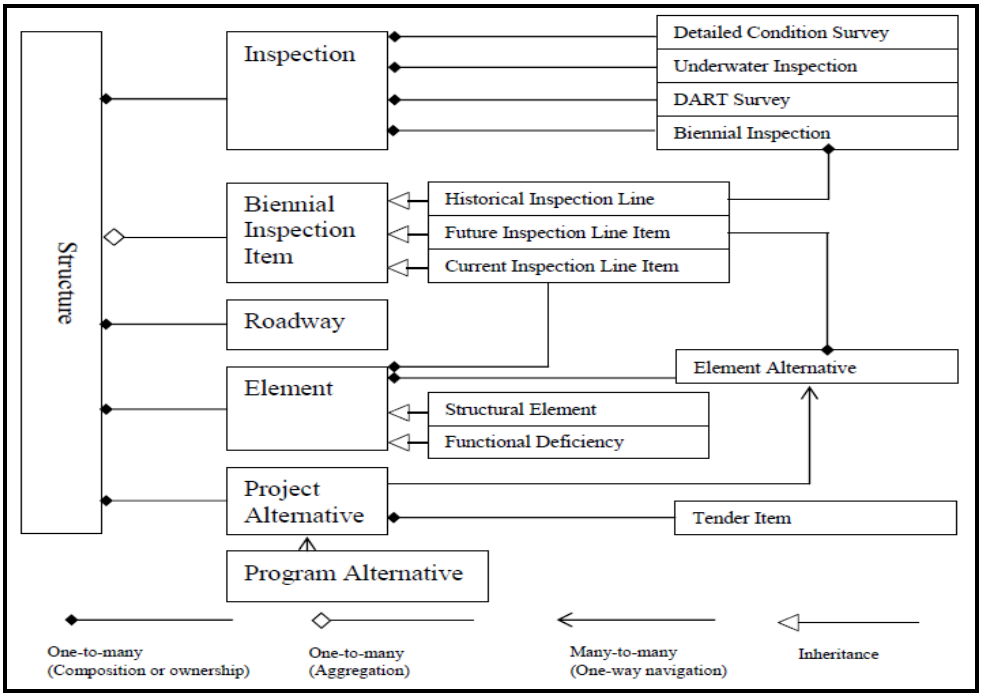

Figure 19: Structure of the domain model of the OBMS (Hamad et al., 2007)

A description of each model, as described by Hammad et al. (2007) is provided in **Table 5**.

Table 5: Description of OBMS Models (Hammad et al., 2007)

Model	Description
Deterioration	The model predicts the deterioration of bridges using the Markovian model, which bases its prediction on the assumption that future deterioration is dependant only on the current condition of the bridge and any other features of the bridge do not influence the prediction results.
Knowledge	The model selects a proper rehabilitation method when there are possibly one or more alternatives. The model uses decision trees and tables based on the Ministry's Structure Rehabilitation Manual and Structural Steel Coating Manual.
Cost	The cost estimates for project alternatives are based on tender item unit costs. The Ministry of Transport Ontario (MTO) updates the unit costs according to actual contracts distributing the different unit costs among the 12 districts in the province of Ontario. The MTO has a comprehensive cost database at the project-level, called the Project Value System (PVS) that is organized by tender item and is used for cost estimates. Each tender item object is responsible for examining the project scope for relevant treatments and for determining the total quantity of the tender item required. The tender item object then consults the PVS for a standard unit cost, and may modify that unit cost based on any known information about the bridge or the project.

2.4.5 STRUMAN Bridge Management System

The STRUMAN Bridge Management System was developed locally by the Built Environment division of the Council for Scientific and Industrial Research (CSIR) in Pretoria, Republic of South Africa. This BMS is used by various roads authorities in South Africa, Botswana, Swaziland and Taiwan (Roux et al., 2010), including Namibia. Like any other BMS, the STRUMAN relies on inspection as the primary source of the data needed to establish the condition of the structure, and to determine which data need to be stored in a repository system and updated on a regular basis.

The BMS is currently a stand-alone system that has been used for the analysis of bridge data only. However, Mbanjwa (2014) states that according to Ryall, in the near future it is expected to be integrated with management systems such as the Highway Management System (HMS), the Traffic Management System (TMS), the Traffic Observation Management System (TOMS) and various other management systems so as to better facilitate the management of asset information (Mbanjwa, 2014).

System Components

The STRUMAN BMS consists of an inventory module, an inspection module, a condition module and a budget module. What is distinct about it, is the inspection module in which the focus is on the observed defects of the various structural elements rather than on the overall condition. (Nell et al., 2008). These modules are inter-related and linked together as shown in **Figure 20**

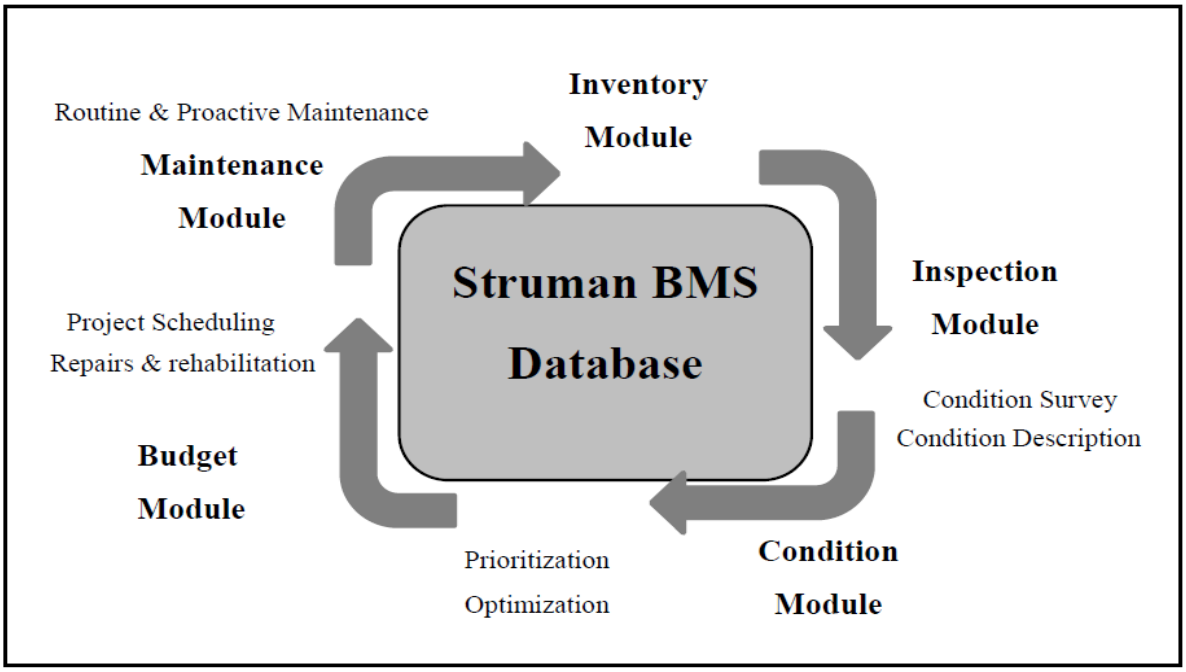

Figure 20: Information Flow in STRUMAN BMS (Mbanjwa, 2014)

2.5 Review of Selected Rating Systems.

2.5.1 Introduction

Bridge Management Systems use defect or condition-rating systems to rate/evaluate defects or the condition of a structure. Its aim is to produce and prioritise repairs and maintenance activities, as well as to allocate a budget for those activities so as to optimise the life cycle of the asset. **Table 6** shows the existing relationship between different BMSs and a specific rating system.

Table 6: Relationship between BMSs and Rating System

BMS	Condition Rating System	Responsible Agency	Province/Country
PONTIS	NBIS	Various	Various/USA
PENNSYLVANIA	NBIS	Pennsylvania Department of Transportation	USA
PBOT	NBIS	Portland Bureau of Transportation	USA
OBMS	4-point scale	Ministry of Transport	Ontario/Canada
OSCI	OSCI	Australasian Transport Research Forum	Australia
STRUMAN	DER-U	**See Table 7**	**See Table 7**

Table 7: Implementing Agencies of STRUMAN BMS

Adapted from Table 2-13 (Mbanjwa, 2014)

item	Responsible Agency	Country
1	The Botswana Roads Department	Botswana
2	The cities of Johannesburg, Cape Town, Port Elizabeth and Pietermaritzburg	RSA
3	The Kwa – Zulu Natal Department of Transport	RSA
4	SANRAL	RSA
5	The Taiwan Area National Freeway Bureau	Taiwan
6	The Western Cape Provincial Administration	RSA
7	Mangaung Metro	RSA
8	Mpumalanga Provincial Government	RSA
9	N3 Toll Concession Ltd, TRAC & Bakwena	RSA
10	Namibia Port Authority (NamPort)	Namibia
11	Namibia Roads Authority	Namibia
12	Nelson Mandela Metro,	RSA
13	Sasol (Secunda)	RSA
14	Swaziland Ministry of Public Works & Transportation	Swaziland
15	Spoornet – The South African railway authority	RSA

It has been noted that all the 9 provinces in South Africa are using the STRUMAN BMS. Zambia Roads Development Agency has been using the STRUMAN BMS since 2016.

2.5.2 DER rating system

The DER is a defect-based method. The system's visual assessment methodology is based on a 4-point DERU (Degree, Extent, Relevancy and Urgency) system for rating observed defects. The relevancy rating forces the bridge inspector to evaluate the consequences of the defect in terms of the structure's serviceability and safety. Each of these parameters is combined in the condition module to determine a priority ranking of structures requiring repair (Nell et al., 2008). **Tables 8, 9 and 10** provide further descriptions of the system in terms of DER rating.

Table 8: Description of DER System (TMH 19, COTO 2013).

System	Stands for	Description
D	Degree of defect	Describing how bad or severe the defect is.
E	Extent of defect	Describing how widespread the defect on the inspection item is.
R	Relevancy	Describing the consequence of the defect with regard to the structural/functional integrity of the inspection item or the safety of the user of the structure

Table 9: Allowable DER Values (TMH 19, COTO 2013).

Rating	D (Degree)	E (Extent)	R (Relevancy)	
X	Not applicable			
U	Unable to inspect			
0	No visible defects			
1	Minor	Local	Minimum	No structural integrity or safety issues
2	Moderate	More than local	Moderate	Some possible structural integrity or safety issues
3	Warning	Less than general	Major	Structural integrity or safety compromised.
4	Severe	General	Critical	Potentially a serious impact on structural integrity and/or user safety

For each inspection item, a D rating has to be allocated. If the D rating is 0; X; or U, then no E and R ratings are given. If the D rating is 1; 2; 3 or 4, an E rating and a R rating have to be given. The D-rating will always be greater than or equal to the R-rating. Conversely, the R-rating can never be greater than the D-rating.

Table 10: Urgency Rating Values (TMH 19, COTO 2013).

U-Rating	Description	Remarks
1	Routine	This rating is used for remedial activities that have been identified as routine by the road authority.
2	Within 10 years	With a five-year inspection cycle, these are defects that only need to be repaired after the next round of principle inspections.
3	Within 5 years	These are defects that should be repaired before the next round of principle inspections.
4	As soon as possible	These are defects that should be repaired as soon as possible. In practical terms, it could take up to two years from the time that a defect is identified during an inspection until a contractor is on-site to carry out the repair. Defects where public safety risk is considered high and that have to receive immediate attention will get an urgency rating of 4, but has to be marked as a "Make Safe" item and treated accordingly.
R	Record only	This urgency rating is used for defects for which no remedial work is envisaged. Such defects would have a D-rating of 1 or 2 and an R-rating of 1.
0	Monitor only	This urgency rating is used for defects for which remedial work is not envisaged for the foreseeable future. A monitoring frequency must be indicated (e.g. 12, 24, 36 months). This urgency rating should not be used frequently, as it is not always practical for a road authority to monitor defects on structures, especially where the structures are dispersed over a wide area, as is the case for national and provincial roads authorities.

The navigation process flow using the DER rating system was developed and is presented in the **Figure 21**.

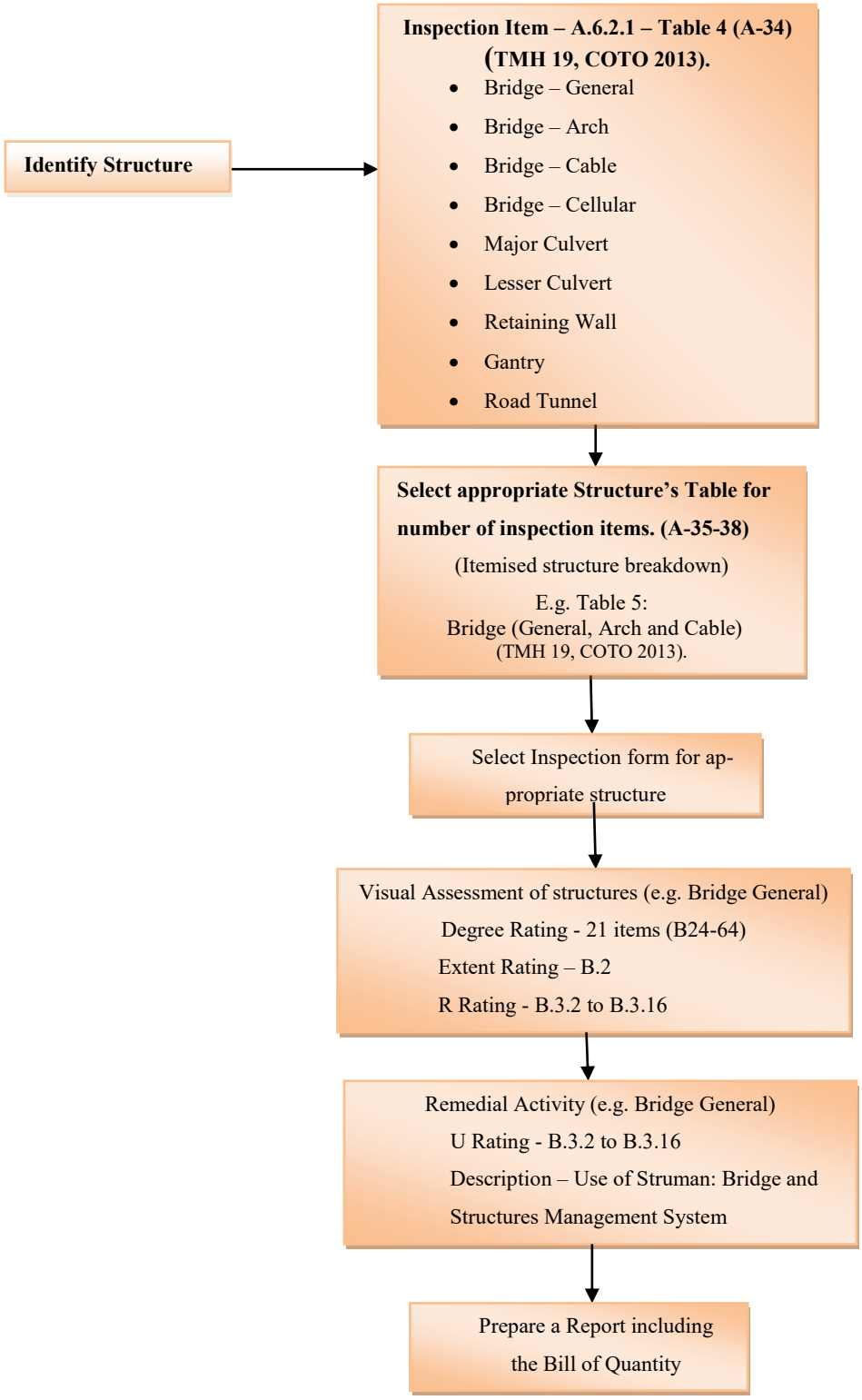

Figure 21: DER - Navigation Process Flow

2.5.3 Overall Structural Condition Index (OSCI) rating system

The OSCI methodology, proposed as a methodology for bridge condition assessment in the Australasian Transport Research Forum 2011 proceeding, is represented by numbers 1 to 4. The methodology enables decision makers to understand and compare the condition of a variety of bridges in a network. OSCI of 1 corresponds to a new bridge while 4 corresponds to the worst condition of a bridge (**Table 11**.)

Material vulnerability, and structural importance are considered in the element-based condition assessment and the critical parameters that influence structural efficiency are identified as: age, environment, road type and inspection (**Table 12**).

The weight of each of these factors is evaluated through the analytical hierarchy process (AHP), and the overall factor introduced as the causal factor (CF) is implemented as coefficient to the current structural condition (**Table 13**). This methodology assists in prioritising maintenance action and budget allocations for bridges inspected in a network (Rashidi and Gibson, 2011).

Table 11: Condition States for Concrete Bridge Elements (Rashidi and Gibson, 2011)

Condition State	Description of Defects
1	The element shows no deterioration. There may be discolouration, efflorescence and/or superficial cracking but without effect on strength and/or serviceability
2	Minor cracks and spalls may be present but there is no evidence of the corrosion of non-prestressed reinforcement or deterioration of the prestress system.
3	Some delaminations and/or spalls may be present. No evidence of deterioration of the prestress system. Corrosion of non-presstressed reinforcement may be present but loss of section is minor and does not significantly affect the strength and/or serviceability of either the element or the bridge.
4	Delaminations, spalls and corrosion of non-prestressed reinforcement are prevalent. There may also be exposure and deterioration of the prestress system (manifested by loss of bond, broken stands or wire and failed anchorages). There is sufficient concern to warrant an analysis to ascertain the impact on the strength and/or serviceability of either the element or the bridge

Table 12: Material Vulnerability Factors (Rashidi and Gibson, 2011)

Material of the element	Material Vulnerability Factor, mi
Steel	1
Reinforced concrete	2
Precast concrete	3

Table 13: Rating of Causal Factors (Rashidi and Gibson, 2011)

Rating	Causal Factor			
	Age	**Road Class**	**Environment**	**Inspection Quality**
1	Recently built	Minor	Low	Very High
2	New	Local access	Medium	High
3	Old	Collectors	High	Medium
4	Very old	Arterials	Very High	Low

The navigation process flow using the OSCI rating system was developed and is presented in **Figure 22**.

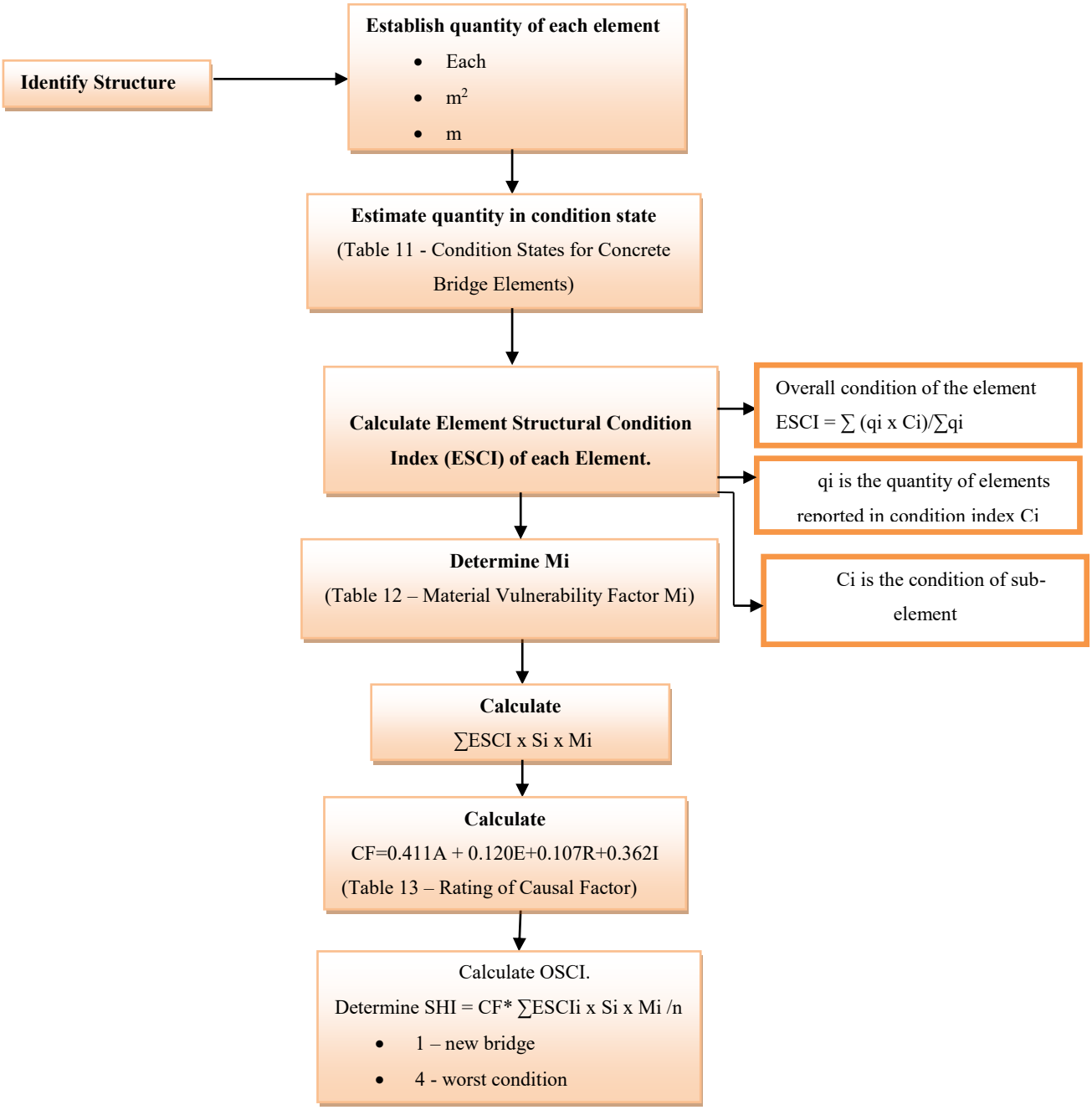

Figure 22: OSCI - Navigation Process Flow

2.5.4 National Bridge Inspection Standard condition rating

The NBIS, issued by FHWA, governs how bridges are inspected, load rated and maintained in the USA. The FHWA Recording and Coding Guide provide an alpha-numeric rating system to be used by bridge inspectors for rating bridge items. The rating system for bridge element conditions and structural appraisals are defined by a 9-point scale with 9 being new condition, and zero implying a failed condition (IOWA DOT Bridge Inspection Manual, 2014). See **Table 14.**

Table 14: NBIS Rating

Code	*Description*
N	NOT APPLICABLE. Code N for culverts and other structures without decks, e.g., filled arch bridge.
9	NEW CONDITION. No noticeable or noteworthy deficiencies which affect the condition of the surface.
8	GOOD CONDITION. Minor cracking less than 1/32" wide (0.8mm) with no spalling, scaling or delamination.
7	GOOD CONDITION. Open cracks less than 1/16" wide (1.6mm) at a spacing of 10 ft. or more, light shallow scaling allowed.
6	FAIR CONDITION. Surface has considerable number of open cracks greater than 1/16" wide (1.6mm) at a spacing of 5 ft. or less. Surface area exhibits 2% or less of spalled or delaminated areas, including repaired areas. Medium scaling on the surface is 1/4" to 1/2" (6.4 mm to 13 mm) in depth
5	FAIR CONDITION. Between 2% and 10% of the surface area is spalled or delaminated. There can be excessive cracking in the surface. Heavy scaling 1/2" to 1" in depth (13 mm to 26 mm) can be present.
4	POOR CONDITION. Large areas of the surface, i.e.10 - 25% is spalled or delaminated.
3	SERIOUS CONDITION. More than 25% of the surface area is spalled.
2	CRITICAL CONDITION. Emergency surface repairs required by the crews.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed

2.5.5 NBI condition rating

Each state or federal bridge inspection agency prepares and maintains an inventory, called the National Bridge Inventory (NBI), of all bridges subject to the NBIS within its jurisdiction. Within this inventory, data are collected and retained by the state or federal agency for compilation by FHWA. The data are reported using FHWA-established procedures as outlined in the "Recording and Coding Guide for Structure Inventory and Appraisal of the Nation's Bridges" (IOWADOT, 2014).

NBI requires the condition rating of the following bridge components: NBI Item 58 (Deck), NBI Item 59 (Superstructure), NBI Item 60 (Substructure), NBI Item 61 (Channel and Channel Protection), NBI Item 62 (Culvert) and NBI Item 113 (Scour Critical)

Ratings of each component are done in accordance with the FHWA's 9-point scale (**Table 14**). NBI ratings form the basis of the calculation of the federal funds to be assigned to deserving bridges nationwide according to a bridge maintenance prioritization formula called Sufficiency Rating (SR) (Weykamp et al., 2010) which is:

- SR= S1 + S2 + S3 - S4, with:

1) S1 = 55% maximum; based on structural adequacy and safety (i.e. superstructure, substructure, or culvert condition and load capacity).
2) S2 = 30% maximum; deals with serviceability and functional obsolescence (items such as deck condition, structural evaluation, deck geometry, under clearances, waterway adequacy, approach road alignment).
3) S3 = 15% maximum; concerns essentially for public use (item such as detour length, ADT, and the Strategic Highway Corridor Network.
4) S4 = 13% maximum, deals with special reductions based on detour length, traffic safety features, and structure type.

As a general rule, the lower the rating, the more eligible the bridge is for maintenance or replacement funds. SR ≤ 80 means the bridge is eligible for federal funding with the highway bridge rehabilitation program and SR< 50 means the bridge is eligible for replacement (Moufti, 2013).

In light of the above, NBIS and NBI rating systems are geared for bridge inspections and the prioritization of maintenance funds. The number of similar structures in a power station that require fund prioritization may be small, hence defeating the main purpose of the systems. Their applicability within a power station environment may not be appropriate due to lack of flexibility. The navigation process flow for the use of these rating systems is shown in **Figure 23.**

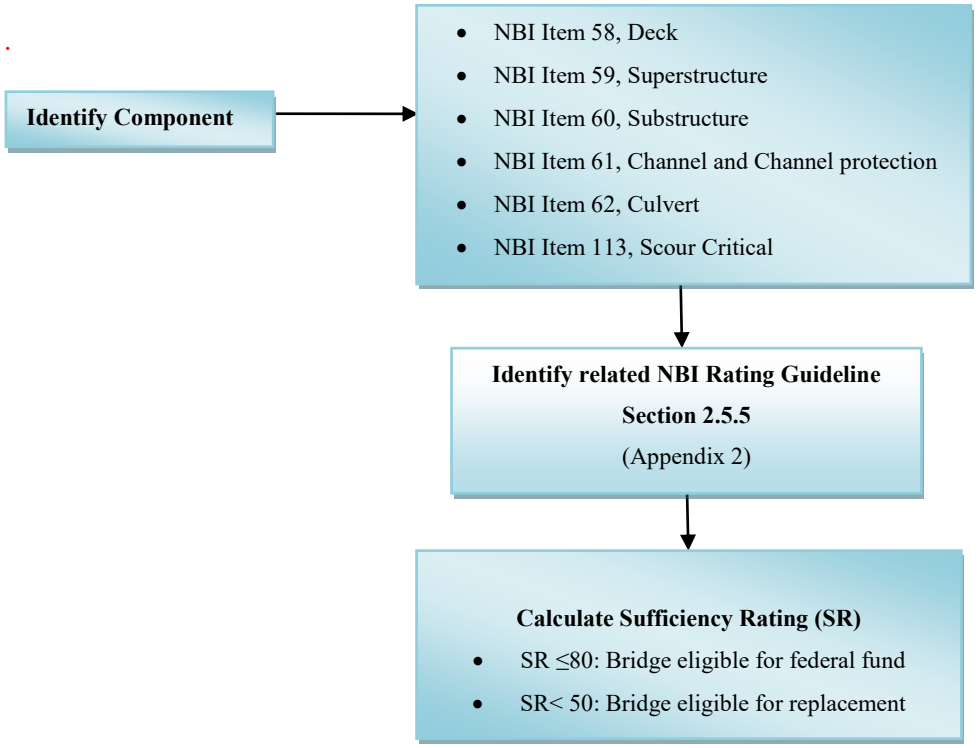

Figure 23: NBI - Navigation Process Flow

2.5.6 OSIM condition rating

The Ontario Structures Inspection Manual (OSIM) gives general details of inspection procedures, bridge components, material defects and performance defects. It sets out three different types of inspections, namely: enhanced OSIM inspections, emergency inspections and additional investigations. The OSIM adopts the "severity and extent" approach as a philosophy in order to simplify the process of recording inspections and to use the information in estimating bridge rehabilitation needs and costs. Four condition states have been defined for bridge elements and material, namely: excellent, good, fair and poor. The condition of bridge elements is defined as being in any one or more of these condition states. For each bridge element, the inspector assesses and records the amount (area, length or unit as appropriate) of the element in each of the four condition states. Although this assessment is predominately based on visual observations, some non-destructive testing, such as hammer tapping of concrete for delamination, is required to determine or verify areas in poor condition. Where an area in poor condition is noted, the area is to be delineated and measured (MTO, 2008).

The navigation process flow for the use of the rating systems is shown in **Figure 24** and the tables provided in **Appendix 3**.

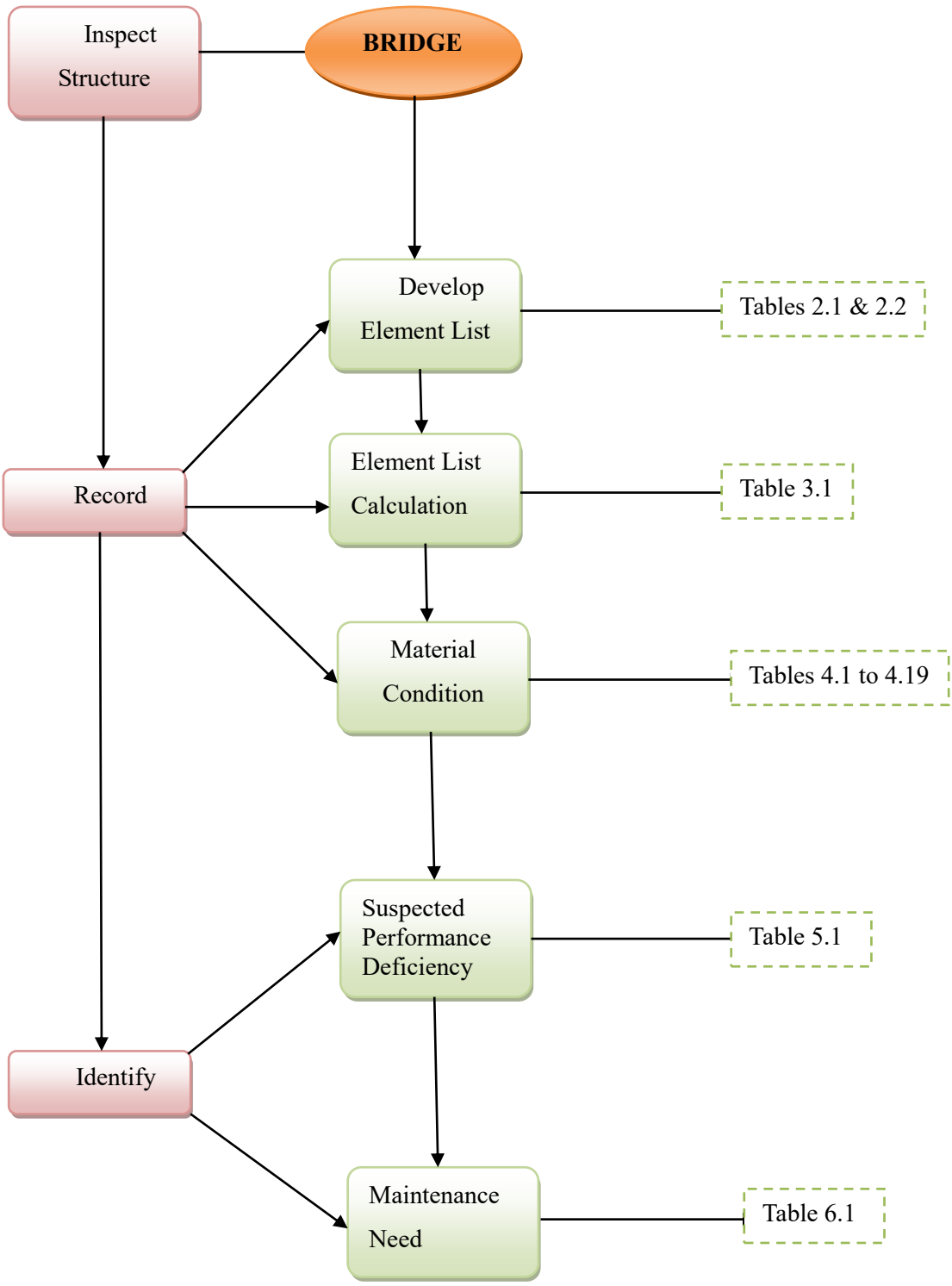

Figure 24: OSIM Navigation Process Flow

2.5.7 Inspection manual for civil works at Eskom's power stations

Eskom Group Technology has compiled a guideline entitled "Inspection Manual for Civil Works at Eskom's Power Stations" with the aim of providing guidance to engineers based at power stations for conducting inspections and identifying and repairing defects. The rating system employs a 6-point scale in which 0 is excellent/new condition, and 5 is severe deterioration as shown in **Table 15**. The manual provides a guideline for the inspection of certain structures found in an Eskom coal-fired power station. These structures are: cooling towers, chimney structures, concrete silos, liquid containing structures, conveyor structures, steel structures, buildings, roads and culverts, railway lines and sidings, surface drains, sub-surface drains, ash dams, ash dumps, coal stockyards and dams. The rating process is begun by establishing the category the condition falls into and the intervals of inspections as shown in **Tables 15 and 16** respectively**.** Repair/maintenance elements are then prioritised following the descriptions set out in **Table 17**. The guideline also provides an outline of the content of the inspection report that should be produced by the engineer based at the power station.

Table 15: Condition Categories

Source: Table 7-1: "Inspection Manual for Civil Works at Eskom's Power Stations" (Xulu, L. 2015)

Category	Description	% Original Strength	Typical Remedial Action
0	The plant assets are in excellent condition, with no deterioration evident. Safe use of the plant assets is assured.	100	None Required
1	The plant assets have slight evidence of surface deterioration, but to an extent that there is no reduction in strength	100	None Required
2	The plant assets have some deterioration, to an extent that there is slight reduction in strength. Safe use of the plant assets is assured	95-100	Repaint, tighten bolts, other minor work
3	The plant assets show deterioration, to an extent that there is some reduction in strength. There is some compromise to safe use of the plant structure. Repair must receive attention in maintenance scheduling.	75-95	Repair, repaint, tighten bolts, other minor work
4	The plant assets show severe deterioration, to an extent that there is a major reduction in strength. Safe use of the plant is severely compromised. Urgent attention	50-75	Repair or replace components

Category	Description	% Original Strength	Typical Remedial Action
	must be given to repair.		
5	The plant assets show severe deterioration, to an extent that they have little useful residual strength. Safe use of the plant is impossible. Urgent attention must be given to repair.	< 50	Repair or replacement of components required urgently

Table 16: Engineering Visual Structural Inspection Interval Guide

Source: Table 8-1: "Inspection Manual for Civil Works at Eskom's Power Stations" (Xulu, L. 2015)

Interval of Inspection	Condition category for worst 30% of the plant structures
3 years	1
2 years	2
1 year	3
1 year	4
6 months	5

Table 17: Prioritisation of Elements

Source: Table 9-1: "Inspection Manual for Civil Works at Eskom's Power Stations" (Xulu, L. 2015)

Priority	Description
X	Where a structure or portion of a structure cannot be used for its intended purpose in its current condition, but may not be required to be used for some time, it must be recorded as Priority X.
1	All members in condition category 5, any primary structural members in conditions category 4, and any other members where the deterioration leads to risk to personnel safety must be recorded as Priority 1. Repair or replacement of the structural members, or other recommended work, requires urgent, immediate action.
2	All secondary or tertiary members in condition category 4, and any other structural members requiring repair or replacement in the short term must be recorded as Priority 2. Repair or replacement of the structural members, or other recommended work, should be scheduled as soon as possible, but not later than one year from date of this report.
3	Repair of the structural members, or other recommended work, will be required within the next three years.

As a guideline, the manual proposes an inspection approach to the structures as listed above. After the inspection has been conducted, the process is not prescriptive in terms of a specific course of action regarding repair and maintenance and the budget allocation.

Navigation process flow for the use of the Eskom's Inspection Manual for Civil Works and rating systems is shown in **Figure 25.**

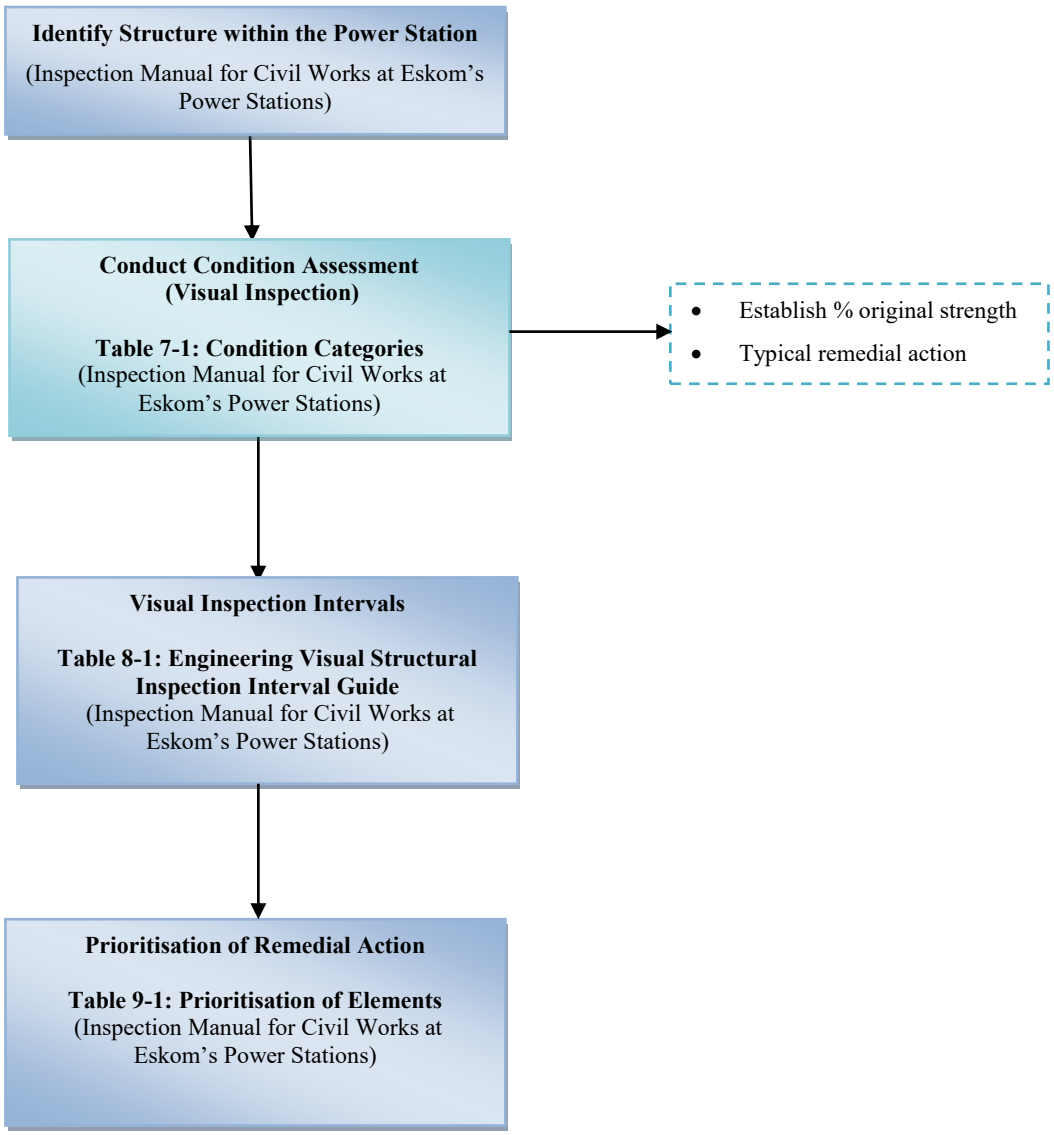

Figure 25: Eskom Visual Inspection Approach - Navigation Process Flow

2.6 Implementing DER Rating System in South Africa.

The STRUMAN Bridge Management System was initially implemented for the Cape Town Municipality and Spoornet (the South African rail authority) during 1996/97 (Nordengen and de Fleuriot, 1998). The DER system is also being implemented for the South African National Roads Agency and the Provincial Administrations, using this system as a guide to decision making, budget allocation and the prioritization of maintenance activities. A detailed list of agencies that are using the STRUMAN BMS in South Africa is provided in **Table 18**.

Table 18: Implementation of STRUMAN BMS in RSA
Adapted from Table 2-13 (Mbanjwa, 2014)

Item	Responsible Agency
1	Johannesburg Roads Agency
2	The City of Cape Town
3	The Kwazulu-Natal Department of Transport
4	SANRAL
5	The Western Cape Provincial Administration
6	Mangaung Metro
7	Mpumalanga Provincial Government
8	N3 Toll Concession Ltd, TRAC & Bakwena
9	Nelson Mandela Metro,
10	Sasol (Secunda)
11	Spoornet – The South African railway authority

It has been noted that all the 9 provinces in South Africa are using the STRUMAN BMS.

3 Proposed Inspection Procedures for Power Generation Structures Based on the DER Rating System.

3.1 Overview

A typical Eskom coal-fired generation system comprises an infrastructure consisting of mechanical, electrical, control and instrumentation elements and civil engineering support. A review of related asset management and inspection documents revealed a great deal about the policies, directives and procedures that have been developed over the years. While conducting the literature review, it was found, as per the first inspection guideline compiled in 2015, that much effort had been devoted to the mechanical, electrical and control and instrumentation components of the assets and little on the civil engineering infrastructure. To enhance operations and extend the life cycle of the asset, it would be a worthwhile exercise to apply the same amount of effort to, or interest in, the reinforced concrete (RC) structures by developing procedures and inspection processes that would also form part of the Asset Management System. This could prevent a recurrence of the unfortunate 01 November 2014 event, in which a coal storage silo at Majuba Power Station collapsed. This event led to Eskom having to implement load shedding across the country ("Majuba silo design…", 2015) with a subsequent domino effect on the economy of the country. Valued at R660 685 Million (Eskom Holdings SOC Limited Integrated Report, 2016), Eskom's assets represent a significant investment for the country so they need to be managed profitably and efficiently. Technical Methods for Highways (TMH 19) provides a platform that is readily adaptable for use within a power generation environment for structures listed in **Table 19,** which are inspected and assessed using the DER (Degree, Extent and Relevancy) rating system following the process flow described in **Figure 21**. Eskom's inspection manual "Inspection Manual for Civil Work at Eskom's Power Stations" also provides a list of civil structures to be inspected within a power station (**Table 19**) following the process flow described in **Figure 25** but using a different approach to the DER.

Applicability of the DER rating system within a power station environment is discussed in detail in Chapter 4. The reasons why the DER rating system can be used in such an environment and the output of this study are provided in the following sub-sections.

Table 19: Structures to Inspect under the Eskom Guideline vs TMH 19

Inspection Manual for Civil Work at Eskom's Power Stations (Eskom Guideline)	Draft TMH 19 (DER): Manual for The Visual Assessment of Road Structures
Ash dams	Bridges
Ash dumps	Culverts
Cooling tower	Retaining Walls
Chimney structure	Gantries
Concrete silos	Tunnels
Liquid containing structure	Low level bridges
Conveyor structures	Low level river crossings
Steel structures	Light Masts
Dams/reservoirs	
Buildings and other structures	

3.1.1 Why use the DER rating system in a power generation environment?

The role played by power utilities in the development and economy of a country and the value the assets represent, argue for the necessity of having a system in place that ensures that the asset is well maintained. The DER rating system provides the basis for good decision making in terms of prioritization of repair/maintenance activities and budget allocations.

The DER rating system should be used in an Eskom power generation environment for the following reasons:

1. It provides a platform for the standardisation of inspection and reporting processes that is not catered for in the current Eskom inspection manual. This would eliminate different interpretations of the assessment report and provide engineers across Eskom power stations with the same understanding.
2. It allows for accurate maintenance plans and budget allocations for repair and maintenance activities on existing RC structures.
3. It comprises a trusted source of evidence on budgeting and the scheduling of repair and maintenance activities.
4. It is a locally developed system.

5. It provides accessibility to local developers and experts, if support is required.
6. It is adaptable and flexible in usage.

At a time where financial resources are dwindling, organisations should develop systems and processes that minimise operation expenditure while maximizing profit. The use of the DER rating system in such an environment could contribute to achieving those cost saving objectives.

3.2 Proposed Inspection Procedures

The proposed procedure based on the DER rating system does not deviate from the inspection process described in Section A.7 of TMH 19 and the process flow in **Figure 21**. However, the element of risk assessment has been introduced as a compulsory activity (**Figure 26)**.

3.3 Outputs from the DER rating system

The inspection process described in Section A.7 of TMH 19 and the process flow shown in **Figure 26** will yield the output listed in **Table 20**. Using the DER rating system to work within a power generation environment involves inherent risks that require that more attention be given to risk assessment and that a sign-off report is implemented. Inspection of structures such as dams, silos, chimneys and cooling towers may require different approaches and training requirements for the inspectors, such as working at heights.

Table 20: Output of DER Rating System in a Power Station Environment

Environment	Outputs
Coal-fired Power Station	Rated defects in terms of DER system (Degree, Extent, Relevancy and Urgency)
	Remedial Activities
	Quantified repair items (defects) to estimate maintenance/repair budget.
	Urgency (set out the maintenance plan)
	Need for Risk Assessment – for inspection at heights
	Inspection Report
	Rating System Navigation Process flow

3.4 Proposed Inspection forms

The DER rating system can be used within a power generation environment with few limitations and little need for further development for structures other than those listed in TMH 19 as shown in **Table 19**. Support structures of the dry cooling tower including the drainage system around the cooling tower were the only structures inspected in this study, on account of the access restrictions of the operating power station under inspection. As a result, only two inspection forms using the DER rating system and covering only the support structures and drainage system were developed and presented (**Figures 27 and 28)**. An additional inspection form aligned with the Eskom ”Inspection Manual for Civil Work at Eskom’s Power Stations” was also developed and presented **(Figure 29)**.

3.5 Conclusion

The value of assets owned by the power utility, Eskom, and the role the organisation plays in the economy of the country highlights the need for an adequate Asset Management System that supports the organisation’s strategic plan. This would ensure that the asset life cycle is optimised to fullfill investment objectives. The DER rating system would constititute one of the most important tools for establishing this since it provides a practical approach to inspection and delivers the information required to plan and budget for maintenance activities, thus helping to extend the service life of the asset. The proposed forms are evidence of the possibility of an extended used of the DER rating system from road structures to the RC structures of a power generation plant.

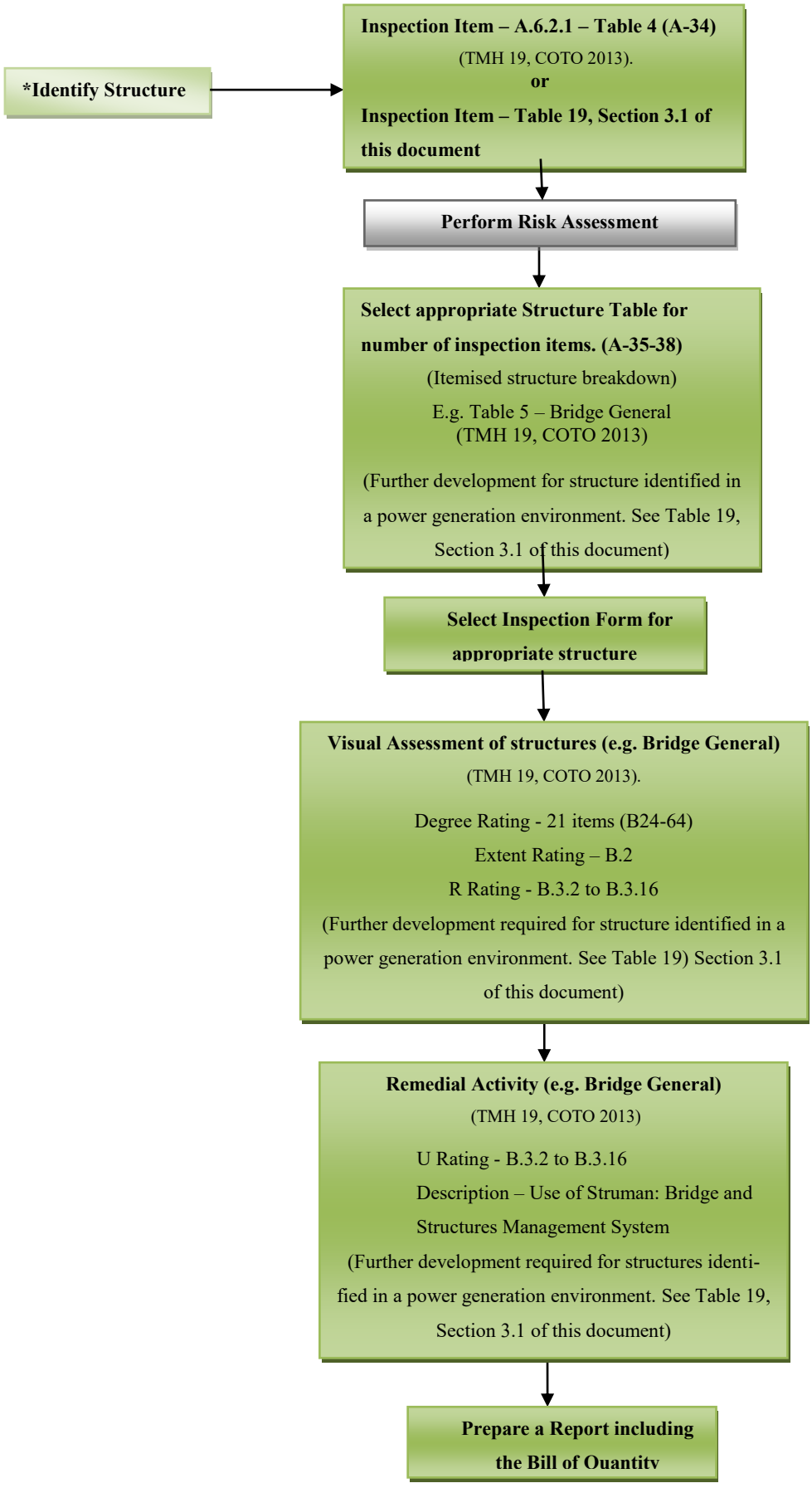

Figure 26: DER – Proposed Navigation Process Flow

*This stage runs as part of the processes in **Figure 15.**

OWNER	STRUCTURE TYPE	STRUCTURE COMPONENT	HEIGHT	LOCATION SKETCH
Eskom	DRY COOLING TOWER	SUPPORT STRUCTURE : BASES AND COLUMNS		

GPS-COORDINATES						INSPECTION INFORMATION			
Latitude (South)			Longitude (East)			INSPECTION TYPE	INSPECTOR NAME	FIRM (if not Eskom Employee)	Date (dd/mm/yyyy)
DD	MM	SS,s	DD	MM	SS's				

STRUCTURE INFORMATION							
Reference Number in Asset Register	Year Constructed	Number of Bases	Overall Length	Overall Width	Overall Heigth	As-Built Dwg No.	Report No.

INSPECTION RATINGS

INSPECTION ITEM	BASE COLUMN No:			COLUMNS (Top & Bottom)			MID BLOCKS (Mid &Top)			BOTTOM OF SHELL			NOTES
POSITION	D	E	R	D	E	R	D	E	R	D	E	R	
LEFT													
RIGTH													
INSPECTION ITEM	BASE COLUMN No:			COLUMNS (Top & Bottom)			MID BLOCKS (Mid &Top)			BOTTOM OF SHELL			
POSITION	D	E	R	D	E	R	D	E	R	D	E	R	
LEFT													
RIGTH													
INSPECTION ITEM	BASE COLUMN No:			COLUMNS (Top & Bottom)			MID BLOCKS (Mid &Top)			BOTTOM OF SHELL			
POSITION	D	E	R	D	E	R	D	E	R	D	E	R	
LEFT													
RIGTH													
INSPECTION ITEM	BASE COLUMN No:			COLUMNS (Top & Bottom)			MID BLOCKS (Mid &Top)			BOTTOM OF SHELL			
POSITION	D	E	R	D	E	R	D	E	R	D	E	R	
LEFT													
RIGTH													
INSPECTION ITEM	BASE COLUMN No:			COLUMNS (Top & Bottom)			MID BLOCKS (Mid &Top)			BOTTOM OF SHELL			
POSITION	D	E	R	D	E	R	D	E	R	D	E	R	
LEFT													
RIGTH													
INSPECTION ITEM	BASE COLUMN No:			COLUMNS (Top & Bottom)			MID BLOCKS (Mid &Top)			BOTTOM OF SHELL			
POSITION	D	E	R	D	E	R	D	E	R	D	E	R	
LEFT													
RIGTH													

ITEM	POSITION	ACTIVITY CODE	REMEDIAL ACTIVITY DESCRIPTION	QTY	UNIT	U	Make Safe	REMARKS	Rpt. Photo	Mon. Freq

Inspector's assessment and further Comment

FURTHER INSPECTION REQUIRED? Y/N		IF FURTHER INSPECTION REQUIRED IS "Y"	
Is the UBIU used? Y/N		Then please indicate any special requirements	
Is the UBIU needed for future inspectionused? Y/N		ie. 6m Ladder, Brush cutting, UBIU, better weather etc. If noting please state 'none'	

D-DEGREE							E-EXTENT				R-RELEVANCY				U-URGENCY					
Not Applicable	Unable to inspect	None	Minor	Moderate	Warning	Severe	Local	More than local	less than general	General	Min	Moderate	Major	Critical	Record Only	Monit or Only	Routine	<10 years	<5 years	ASAP
x	u	0	1	2	3	4	1	2	3	4	1	2	3	4	R	0	1	2	3	4

Figure 27: Proposed Inspection Form 1

Based on TMH 19

OWNER	STRUCTURE TYPE	STRUCTURE COMPONENT	HEIGHT	LOCATION SKETCH
Eskom	DRY COOLING TOWER	SUPPORT STRUCTURE : INTERNAL COLUMNS, FLOOR AND DRAINAGE		

GPS-COORDINATES						INSPECTION INFORMATION			
Latitude (South)			Longitude (East)			INSPECTION TYPE	INSPECTOR NAME	FIRM (If not Eskom Employee)	Date (dd/mm/yyyy)
DD	MM	SS,s	DD	MM	SS's				

STRUCTURE INFORMATION							
Reference Number in Asset Register	Year Constructed	Number of Bases	Overall Length	Overall Width	Overall Heigth	As-Built Dwg No.	Report No.

INSPECTION RATINGS																			
INSPECTION ITEM		INTERNAL COLUMN No:			LONGITUDINAL MEMBERS			TRANSVERSAL MEMBERS			DRAINAGE			FLOOR			EXP. JOINT		
POSITION		D	E	R	D	E	R	D	E	R	D	E	R	D	E	R	D	E	R
LEFT																			
RIGTH																			
INSPECTION ITEM		INTERNAL COLUMN No:			LONGITUDINAL MEMBERS			TRANSVERSAL MEMBERS			DRAINAGE								
POSITION		D	E	R	D	E	R	D	E	R	D	E	R						
LEFT																			
RIGTH																			
INSPECTION ITEM		INTERNAL COLUMN No:			LONGITUDINAL MEMBERS			TRANSVERSAL MEMBERS			DRAINAGE								
POSITION		D	E	R	D	E	R	D	E	R	D	E	R						
LEFT																			
RIGTH																			
INSPECTION ITEM		INTERNAL COLUMN No:			LONGITUDINAL MEMBERS			TRANSVERSAL MEMBERS			DRAINAGE								
POSITION		D	E	R	D	E	R	D	E	R	D	E	R						
LEFT																			
RIGTH																			
INSPECTION ITEM		INTERNAL COLUMN No:			LONGITUDINAL MEMBERS			TRANSVERSAL MEMBERS			DRAINAGE								
POSITION		D	E	R	D	E	R	D	E	R	D	E	R						
LEFT																			
RIGTH																			
INSPECTION ITEM		INTERNAL COLUMN No:			LONGITUDINAL MEMBERS			TRANSVERSAL MEMBERS			DRAINAGE								
POSITION		D	E	R	D	E	R	D	E	R	D	E	R						
LEFT																			
RIGTH																			

ITEM	POSITION	ACTIVITY CODE	REMEDIAL ACTIVITY DESCRIPTION	QTY	UNIT	U	Make Safe	REMARKS	Rpt. Photo	Mon. Freq

Inspector's assessment and further Comment

FURTHER INSPECTION REQUIRED? Y/N		IF FURTHER INSPECTION REQUIRED IS "Y"
Is the UBIU used? Y/N		Then please indicate any special requirements
Is the UBIU needed for future inspectionused? Y/N		ie. 6m Ladder, Brush cutting, UBIU, better weather etc. If noting please state 'none'

D-DEGREE							E-EXTENT				R-RELEVANCY				U-URGENCY					
Not Applicable	Unable to inspect	None	Minor	Moderate	Warning	Severe	Local	More than local	less than general	General	Min	Moderate	Major	Critical	Record Only	Monit or Only	Routine	<10 years	<5 years	ASAP
x	u	0	1	2	3	4	1	2	3	4	1	2	3	4	R	0	1	2	3	4

Figure 28: Proposed Inspection Form 2

Based on TMH 19

Photo of the Structure

Name of Power Station:				Date of Inspection:			
Name of the Inspector:							
Firm Name or Unique No.:							
Location: GPS Coordinates	Longitude (East)			Latitude (South)			
	DD	MM	SS.s	DD	MM	SS.s	
Name of Structure				Length:			
Element Name:				Width:			
Material:				Height:			
Sub-Element Name:				Total No.:			
Environment:	Benign / Moderate / Severe			Total Qties			
Risk Analysis conducted	Yes/No	If NO why:					

Deterioration Mechanism	Crack, rebar corrosion						
Condition Category Table (7.1)		0	1	2	3	4	5
Inspection Interval Table (8.1)			3 years	2 years	1 year	1 year	6 months
Prioritization Table (9.1)		x	1	2	3		

Comments:

Figure 29: Proposed Inspection Form

Based on Eskom Inspection Manual

4 Case Study

4.1 Overview

The main purpose of this case study was to test the applicability of the DER (Degree, Extent and Relevancy) rating system used for road network infrastructure to a power generating environment, commonly referred to as a power station.

The literature review was followed by a visual inspection of the reinforced concrete (RC) structures at an Eskom power generation plant located at Grootvlei in Mpumalanga Province. This visual inspection was followed by an analysis of the recorded defect data to determine the degree, extent and relevancy of deterioration using the DER rating system.

The station visited was operational and inspections during such periods are practically impossible unless there is an outage, which would allow access to most of the structures that are out of service at the time. Under such circumstances and taking into account ongoing operations, dry cooling towers were, with limitations, the most accessible structures of the plant. Only the support columns of dry cooling towers were accessible at the time of the visit. To conduct close up visual inspections of those parts of the structure located above the support columns, such as the cooling tower shell, a mechanised means of accessibility was required as was specialised training for working at heights. The process flow for this case study is summarised in **Figure 30.**

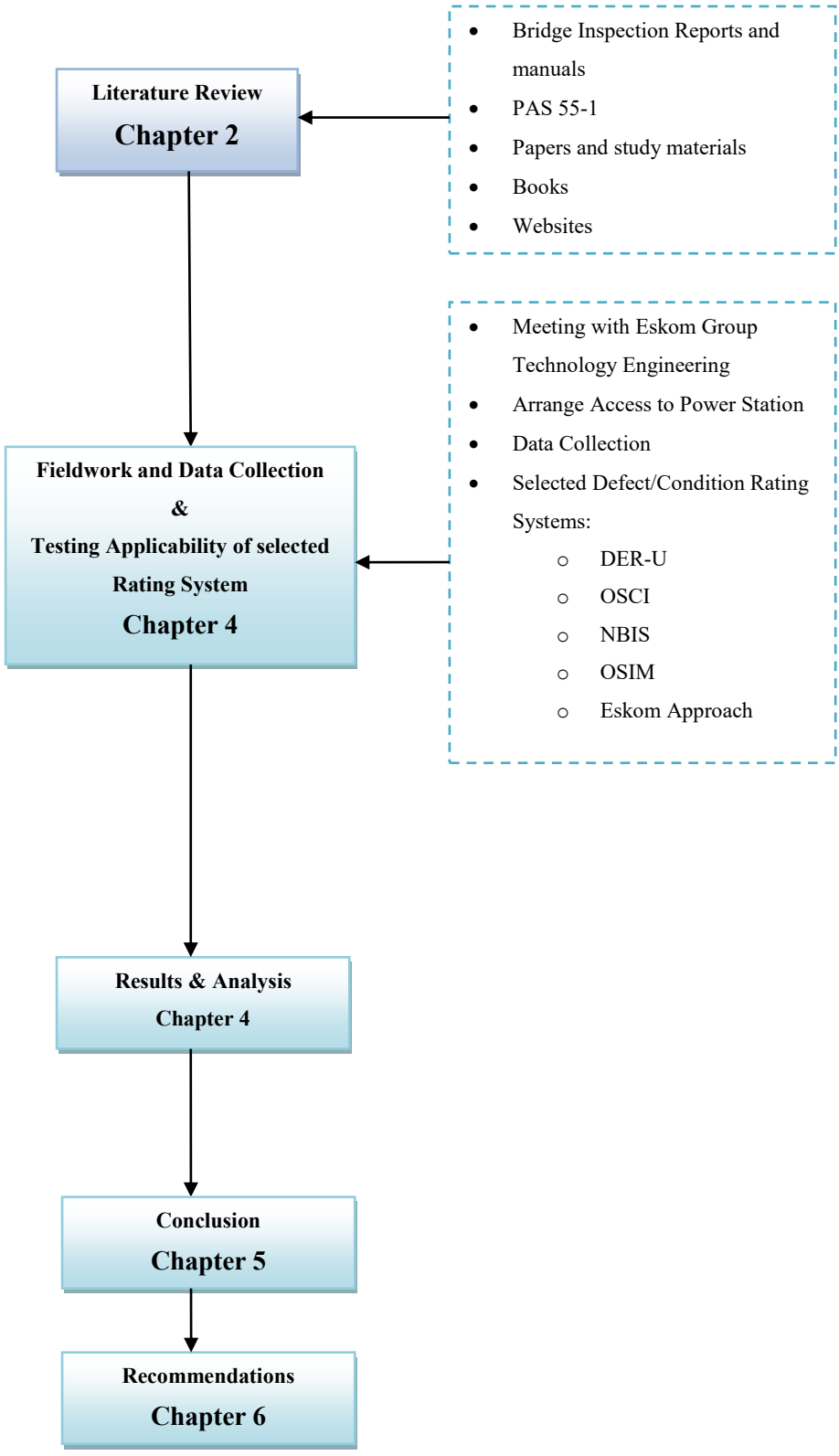

Figure 30: Case Study Process Flow

4.2 Fieldwork

Grootvlei Power Station was built in the late 1960's, shut down in 1990 and then moth-balled. The first set (unit 3) was commissioned in 1969 and the last of the six units (unit 6) was commissioned in 1977. Due to an energy crisis, Eskom decided to bring some of its stations back into service through a large Return to Service (RTS) programme of which the Grootvlei Power Station was one. The return to service of the first unit occurred during 2007 and all six units were re-commissioned during 2010. The station is currently 47 years old.

This case study revolves around a typical power station environment, which generally consists of several structures built in reinforced concrete (RC), steel, wood and plastic. The scope of this study was limited to reinforced concrete structures.

There were no as-built drawings available apart from a report on structure investigation and monitoring, prepared by Westhuizen and Kellerman (2013), the contents of which mostly provided information on the shell structure but very little on the support systems of the dry cooling towers.

Access to the power station was granted on the 19th of November 2015. This was followed by a visual inspection that was conducted on the 04th and the 09th of December 2015 to collect, collate and analyse data using the DER rating system. The results of the inspection were discussed with Eskom engineers and the representative of Asset Management Departments. They have shown interest in the DER rating system and acknowledged the merits of the system in the provision of a better approach to the maintenance of reinforced concrete structures than their current system. The solutions based on the DER rating system were then compared with those of other rating systems.

The inspection started from the most accessible areas such as those from which photographs could be taken at an arm's length distance. All the 38 pedestals with associated components were inspected and only few were selected and assessed. This was done with the intention of testing the applicability of the DER rating system rather than a full blown visual inspection being conducted.

Since the station was operational, structure selection was based on availability and accessibility. Three main structures were identified, comprising the cooling towers, the flue gas chimney stacks and the RC structures of the fabric filter plant. It should be noted that the station has 5 cooling tower structures; 3 wet cooling towers and 2 dry cooling towers. Some of these main structures are shown in **Figure 31**.

There were limitations of accessibility to these structures. Dry cooling towers (pedestals and columns) and the RC fabric filter plant (walls, steel columns and plinths) were the structures that could have been inspected but due to on-going operations and safety requirements within the power station, only the dry cooling tower (pedestals, columns and floor) was available for inspection.

A cell phone camera was used to take pictures. Not all the equipment and material required for inspection in terms of TMH 19 (COTO, 2013) was used **(Table 21).**

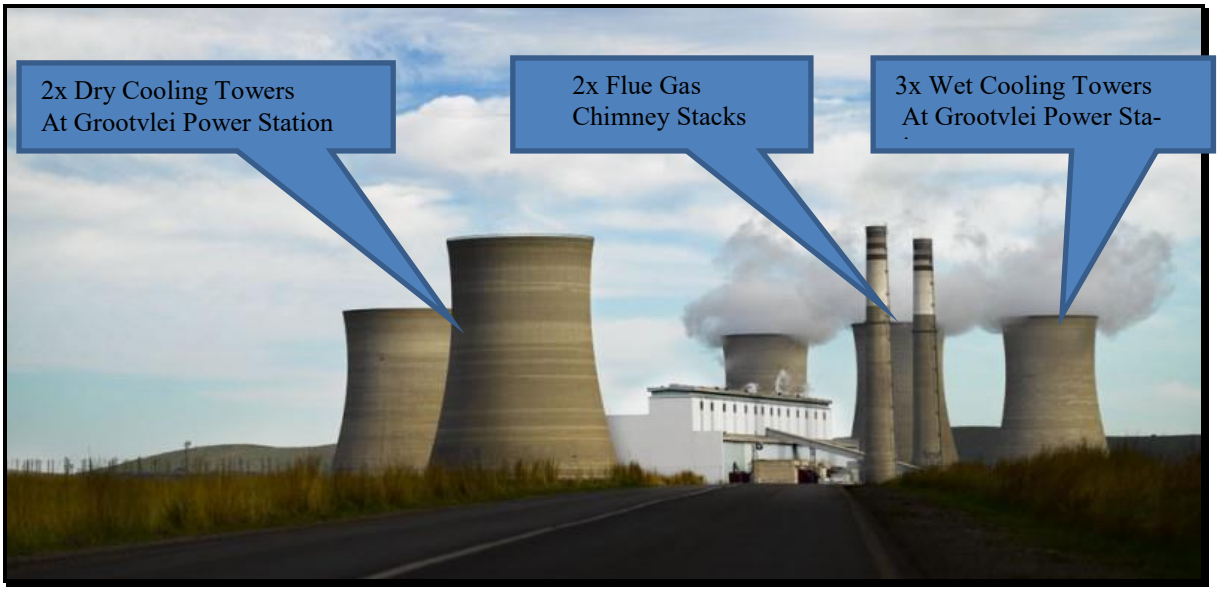

Figure 31: View of Grootvlei Power Station

Source : http://www.outdoorphoto.community/gallery/showphoto.php?photo=201969

Table 21: Inspection Material

Equipment and Material	Used Yes/No	Comment
Clipboard, pen and eraser	Yes	
Notebook	Yes	
As-built drawings	No	Not available
Torch	Yes	Not required
Binocular	Yes	
Digital camera	No	Used a cell phone camera
Handheld GPS device (minimum of 5mm accuracy, WGS84format)	No	Not required
Access equipment, e.g. 6m ladder	No	Not required
Gumboots (for culvert inspection)	No	Not required but used normal safety shoes
Laser distance meter	No	
Crack width gauge	No	Used tape measure instead
Tape measure	Yes	
Measuring wheel	No	Not available
High-visibility vest	Yes	
Non-skid shoes/boots	Yes	
Amber flashing light	Yes	

4.3 Application of DER to the Selected Components of a Dry Cooling Tower

To test the applicability of the DER rating system, the support columns i.e., the pedestals and columns of the dry cooling tower were selected. The junction-block, lower section of the shell, one of the inner columns, the floor and the support drainage systems were the components that were assessed following Table 5 of TMH 19 **(Appendix 4)** as reproduced and adapted in **Table 22**.

Table 22: Inspected Items and Sub-items of Dry Cooling Tower

Inspected Items (Support structure of dry Cooling Tower)	Number of Inspected items/Sub items	Number of Selected items/Sub-items to test DER Applicability	Relationship with TMH 19 – Table 5, A-35&36
Pedestals (PD)	38	3	Table 5 – Item 13
Bottom of the shell, (BS)	1	1	Table 5 – Item 6
Columns (Upper), (CU)	2 x 38	0	Table 5 – Item 14
Columns (Lower), (CL)	2 x 38	1	Table 5 – Item 14
Drainage (DR)	3	3	Table 5 – Item 9/16
Expansion Joints (EJ)	1	1	Table 5 – Item 17
Floor (FL)	1	1	Table 5 – Item 8
Inner column (IC)	1	0	Table 5 – Item 14
Junction blocks (JB)	38	0	Table 5 – Item 14
Saddle blocks, (TB)	38	0	Table 5 – Item 14

Description of Pedestals.

There were 38 pedestals, all made of reinforced concrete with an approximate front size of 1390 mm x 970mm and a varying height of 545mm to 970 mm **(Figures 32-33).** Three pedestals (PD01, BC03 and BC28) with different types of defects, mainly cracks ranging ranging from hairline to wide, i.e., from < 0.1mm to > 0.7 mm, were selected to test the applicability of the DER rating system.

Figure 32: Pedestal 01 – Front view

Figure 33: Pedestal 01 – Rear view

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
01	Pedestal	PD01	1	2	1

Remedial work required in relation to STRUMAN: Bridge and Structures Management System.

Item	Posi-tion	Remedial Activity Description	Quan tities	Unit	Urgency (U)	Make Safe	MF`
13. Pier Foun-dations	PD01	13.101. Apply protective coating	5	m^2	1	N/A	N/A

Comments:

1. Evidence of earlier maintenance (coating) of the pedestal was apparent.
2. Scaling, local flaking or peeling of the finished surface of hardened concrete due to freezing and thawing was noted. `
3. There was no visible evidence of corrosion of reinforcement.
4. The degree and relevancy of scaling were not of the nature that would affect the structural integrity of the pedestal and the safety of users.
5. The application of a protective coating soon after repair is required to extend the life of the structure

Figure 34: Pedestal 03 – Front view

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
03	Pedestal	PD03	4	3	3

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
13. Pier Foundations	PD03	13.101. Apply protective coating	5	m^2	3	N/A	N/A
13. Pier Foundations	PD03	13.120. Seal cracks	3	m	3	N/A	N/A

Comments:

1. Evidence of earlier maintenance (coating) of the pedestal was detected.
2. The cracks were less than general and showed signs of a corroded reinforcement. Thus the structural integrity of the pedestal may have been compromised.
3. A close look showed Alkali Aggregate Reaction (AAR) crack patterns.
4. The cracks varied from less than 0.3 mm to greater than 0.6 mm (wide) and showed evidence of corrosion of the reinforcement.
5. The level of urgency was kept to 3 due to earlier maintenance.

Figure 35: Pedestal 28 – Front view

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
28	Pedestal	PD28	4	3	3

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
13. Pier Foundations	PD28	13.101. Apply protective coating	5	m^2	4	N/A	N/A
Ditto	Ditto	13.102. Apply silanes	1	m^2	4	N/A	N/A
Ditto	Ditto	07.953. Clean concrete surface	3	m^2	4	N/A	N/A

Comments:

1. The cracks were less than general and showed signs of corroded reinforcements.
2. The cracks varied from less than 0.3 mm to greater than 0.6 mm and may have affected the structural integrity of the pedestal.
3. Due to past repairs, there were no signs of water passing through the cracks, but evidence of the corrosion of reinforcements was visible.
4. There was evidence of core drilling for test purposes, the results of which were not available.

Figure 36: Lower Column of Pedestal 18

Description of columns

There are 76 support columns approximately 450 mm x 750 mm in size. The lower column is connected to the upper column by a junction-block of approximately twice the size of the column. This lower column of pedestal 18 showed a shear crack (due to load carrying capacity of the concrete, inadequate steel reinforcement and/or inferior concrete quality) ranging from hairline to wide, i.e., from < 0.1mm to > 0.7 mm.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
018	Lower Column of pedestal (PD18)	LC18	3	1	3

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
14. Piers & columns	CL18	14.120. Seal crack	3. 5	m	3	N/A	N/A
14. Piers & columns	CL18	14.654. Access – using scaffold (<10m)	1	No.	N/A	N/A	N/A

Comments:

1. The cracks varied from less than 0.3 mm to greater than 0.6 mm
2. The structural integrity of the column may have been compromised.
3. Recent repairs may have obscured other defects.

Figure 37: Bottom of the dry cooling tower shell

Description of bottom of the shell

The bottom of the cooling tower shell forms a ring shape that is built with reinforced concrete. Its dimensions could not be specified due to lack of as-built drawings and inaccessibility to that part of the structure.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
039	Bottom of tower shell.	BS1	U		

Remedial work required in relation to STRUMAN: Bridge and Structures Management System (N/A)

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
N/A							

Comments:

1. Looking from a distance with a binocular, signs of cracks showing leaching or leakage of brownish material as indications of corroded reinforcement were evident around the shell.
2. A close up inspection of the shell could have provided further details on the degree, extent and relevancy of defects in the bottom section of the shell.

Figure 38: Expansion Joints (Floor)

Description of Expansion Joints

Vegetation growing at the joint with disintegration (cracks) at the intersection of the joints was detected. The sealant had begun to fail at the intersection as well as in some other locations where vegetation was growing.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
040	Expansion Joint	EJ	1	1	1

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
17. Expansion Joint	EJ	17.203. Clean joint of loose material.	1	m	2	N/A	**N/A**
17. Expansion Joint	EJ	17.301. Install silicon.	1	m	2	N/A	**N/A**

Comments:

- Remove vegetation ASAP.

Figure 39: Spalling on the edge of floor slab

Description – spalling on floor's edge

The reinforced concrete floor slab of the dry cooling tower showed spalling on the edge with a lack of cover.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
041	Floor	FL	4	2	3

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Posi-tion	Remedial Activity Description	Quan tities	Unit	Urgency (U)	Make Safe	MF`
8. Floor (Surfacing)	FL	08.207. Clean debris	1	m^3	3	N/A	N/A
8. Floor (Surfacing)	FL	08.502. Resurface or patch	1	m^2	3	N/A	N/A
8. Floor (Surfacing)	FL	08.953. Repair spall	6	L	3	N/A	N/A

Comments:

- Spalling of concrete was a result of reinforcement corrosion
- A lack of cover was evident.

Figure 40: Missing Grid

Description of Drainage Channel

A drainage channel on the floor was missing sections of the drainage grid.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
042	Drainage channel	DC	4	2	4

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
9. Superstructure Drainage	FL	09.206. Clear channel	.25	m	4	N/A	N/A
9. Superstructure Drainage	FL	09.361. Replace grid inlet	1	No.	4	✓	N/A

Comments:

- Although the channel was shallow, it comprised a safety concern since sections of the grid were missing.
- Immediate replacement of the grid was required.

Figure 41: Catch Pit

Description of drainage channel

An approximately 450mm x 450mm catch pit with a missing gully inlet (cover) was detected.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
043	Catch pit with missing inlet cover.	CP	4	1	4

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF `
9. Superstructure Drainage	DC	09.361. Replace grid inlet (fullbore in this instance)	1	No.	4	✓	N/A

Comments:

- None.

Figure 42: Missing Drainage Catch Pit Cover Grid

Description of catch pit cover

An approximately 450mm x 450mm catch pit with an old grating cover and signs of overflow was visible.

Rating Defect

Inspection Item No	Inspection Item Name	Position Code	D	E	R
044	Catch pit grating cover	CP	4	1	4

Remedial work required in relation to STRUMAN: Bridge and Structures Management System

Item	Position	Remedial Activity Description	Quantities	Unit	Urgency (U)	Make Safe	MF`
9. Superstructure Drainage	DC	09.206. Clear channel/Catch pit	1	mm	4	N/A	N/A
9. Superstructure Drainage	DC	09.361. Replace grid inlet/Catch pit grating cover	1	No.	4	✓	N/A

Comments:

- There is no mention of a catch pit or grating cover in STRUMAN: Bridge and Structures Management System.

4.4 Cost Remedial Activities using Appendix III of TMH 19

The cost estimates shown in **Table 23** are based on the components assessed and do not represent the total cost of repair to the support structures of the dry cooling tower. This is a simple demonstration of the applicability of the TMH 19 in calculating the estimated costs of remedial activities.

Table 23: Estimate Costs of Remedial Activities

Act. ID	Activity Description	Qties	Unit	Unit Cost (2013 Rand Value)	Unit Cost (*2016 Rand Value)	Total Cost (*2016 Rand Value)	Scheduled Maintenance
PEDESTALS						**13 741.65**	Routine
101	Apply protective coating	15	**m^2**	200	226.20	3 393.00	
120	Seal crack	5	m	200	226.20	3 393.00	
102	Apply silanes	1	**m^2**	150	169.65	169.65	
953	Clean concrete surface	3	**m^2**	1000	1131.00	3 393.00	
LOWER COLUMN						**1 356.70**	Within 5 Years
120	Seal crack	3.5	m	200	226.20	791.70	
654	Access-Using scaffold (<10m)	1	No.	500	565.50	565.00	
BOTTOM OF SHELL						**0.00**	
EXPENSION JOINT						**282.75**	Within 10 Years
203	Clean joint of loose material	1	m	50	56.55	56.55	
301	Install silicon	1	m	200	226.20	226.20	
EDGE OF FLOOR SLAB						**7238.40**	Within 5 Years
207	Clean debris	**1**	**m^3**	100	113.10	113.10	
502	Resurface or patch.	**1**	**m^2**	300	339.30	339.30	
953	Repair spall	**6**	**L**	1000	1131.00	6 786.00	
DRAINAGE SUPPORT						**1 540.99**	ASAP
206	Clear channel	3.25	m	50	56.55	183.79	
361	Replace grid inlet	3	No.	400	452.40	1 357.20	
TOTAL (R)						**24 159.50**	

*Using Time Value of Money formula $FV=PV\ (1+i)^n$

PV represents cost in the year 2013

FV= Future Value, PV=Present Value, i= nominal interest (used 10%) and n=time period expressed in year (say 3) ---------→ FV = PVx1.131

4.5 Application of OSCI to the Selected Components of a Cooling Tower

As discussed in **Section 2.5.3**, high quality of inspection criteria used for OSCI methodology is imperative since it leads to the provision of information that will enable decision makers to understand and compare the condition of a range of similar structures. With reference to **Figure 22**, the calculation of OSCI factor can be proven to be cumbersome, thus the method is not ready for use in a power station environment. It is geared for road network infrastructure and still requires further development for adaptability and adoption in power stations

4.6 Application of NBIS to the Selected Components of a Cooling Tower

The NBIS and NBI rating systems are geared for bridge inspection and the prioritization for maintenance funds. Their applicability within a power station environment may not be appropriate due to lack of flexibility.

4.7 Application of OSIM to Selected Components of a Cooling Tower

Referring to the pedestal described in **Section 4.3** and presented below as **Figure 43**, the inspection form developed by the Ministry of Transport, Ontario, was used to assess the condition of the column following the process shown in **Figure 24.**

Figure 43: Pedestal 03

Rating Defect

Element Group	Support – Pier (OSIM)					**Length:**	**1.390 m**
Element Name:	13 Pier Foundation – Caps (OSIM)					Width:	0.970 m
Location:	Dry cooling tower – Pedestal No.03					Height:	0.545-0.865 m
Material:	Cast-in place concrete					Count:	25
Element type:	Pedestal					*Total Quantity:	25 x 1.2 = 30.0 m^2
Environment:	Benign / Moderate / Severe**					Limited Inspection	
Protection system	Protective coating layer on the concrete						
Condition Data	Units	Exc.	Good	Fair	Poor	Performance Deficiencies	
	m^2/m/each/%/all				x	Load carrying Capacity	
Comments: cracks widths vary from hairline like to medium and wide in some small area over a short distance.							
Recommended Work: ☐ Rehab ☐ Replace ☐ 1-5 years ☐ 6-10 years						Maintenance Need	**14**
						☐ Urgent ☐ 1Year ☒ 2Year	

* A quantity must be estimated using the appropriate unit (e.g.m^2). Percent should not be used

**To be redefined in terms of power station environment.

4.7.1 Conclusion

OSIM provides for detailed visual inspection and qualitative rating systems that open the door to subjectivity **(See Appendix 3).** However, the rating system can be used within a power station environment with the following challenges:

1. It requires a close up inspection at arm's length, which could be a challenge for accessing a cooling tower shell and chimney.
2. The inspection forms are detailed and busy.
3. The process leaves room for subjectivity in the interpretation of defects.
4. The forms would need to be revised in order to align with a power station environment.

4.8 Using Eskom Inspection Manual

The Eskom's guideline (Inspection Manual for Civil Works at Eskom's Power Stations) suggests the process flow in Figure 25**.** The guideline is not prescriptive of a specific course of action in terms of post-inspection repair and maintenance. It remains silent on how the maintenance and repair budget should be prepared and allocated. Since the Eskom guideline does not provide an inspection form for the structures listed in **Table 19**, **Figure 29** was used for inspection of the pedestal.

Pedestal 03

Name of Power Station:	Grootvlei			Date of Inspection:		04 December 2015	
Name of the Inspector:	Yvon Gombele						
Firm Name or Unique No.:	Eskom Group Capital						
Location: GPS Coordinates *(Center of the cooling tower)*	Longitude (East)			Latitude (South)			
	DD	MM	SS.s	DD	MM	SS.s	
	28	29	48.75	26	46	17.19	
Name of Structure	Dry Cooling Tower			Length:	1.390 m		
Element Name:	Support Structure			Width:	0.970 m		
Material:	Reinforced Concrete			Height:	0.545-0.865 m		
Sub-Element Name:	Pedestal			Total No.:	38		
Environment:	Benign / Moderate / Severe			Total Qties	38 x 1.2 m^3 = 45.6 m^3		
Risk Analysis conducted	Yes/No	If NO why: Not required.					
Deterioration Mechanism	Crack, rebar corrosion						
Condition Category Table (7.1)		0	1	2	3	~~4~~	5
Inspection Interval Table (8.1)			3 years	2 years	1 year	~~1 year~~	6 months
Prioritization Table (9.1)		x	1	~~2~~	3		

Comments: crack widths vary from hairline like to medium and wide in some small area over a short distance.

The output is similar to the DER-U rating system. However, the description of condition in terms of Table 7.1 of Eskom Inspection Manual **(Table 15)** needs some refinement for use on the structures listed in **Table 20**. The guideline needs to be developed further with the goal of standardizing the reporting format, developing inspection forms, defining an inspection approach for individual or groups of structures, identifying inspection equipment, describing the profile of the inspector, developing a breakdown structure and creating a coding system for each structure's components. Further development will need to take quality assurance into account and spell out remedial activities for each identified deterioration mechanism and for defects on individual structure's components.

4.9 Comparison between DER and Other Selected Rating Systems

This section provides a comparative summary (**Table 24**) of selected rating systems that have been used in an attempt to test their applicability to a power generation environment.

Table 24: Comparative analysis between selected rating methods

Rating Method	Methodology	Applicability	Limitations
DER	*Defects-based system* Degree, Extent, Relevancy and Urgency.	Bridges, Culverts, Low Level Structures, Retaining Walls, Gantries, Road Tunnels, Light Masts	Does not cover underwater and timber structures.
OSCI	*Condition based system* 1 to 4; 1 corresponds to a new bridge while 4 correspond to a worst condition of a bridge.	Bridges	Focuses on bridges
NBIS	9-point scale; with 9 being excellent/new condition, and zero implying absolute failure	Bridges	Focuses on bridges
NBI	*Condition based system* Ratings in accordance with the FHWA's 9 point scale:	NBI requires the condition rating of three main bridge components, namely: deck, superstructure, and substructure.	Focuses on bridges
OSIM	*Condition based system* Condition state: Excellent, Good, Fair and Poor	All types of bridge structures.	Focuses on bridges
Eskom (Inspection Manual for Civil Works at Eskom's Power Stations)	*Condition based system* 0 to 5 with 0 (Zero) being excellent, new condition and 5 (Five) being deterioration to the extent that the assets are unusable	Dams, Coal stock yards Ash dams, Ash dumps Surface drains, Sub surface drains, Roads and Culverts, Railway lines and Siding, Structures (cooling towers, chimney, concrete silos, liquid containing structures, conveyor structures, steel structures, buildings and other power station structures)	Does not cover: Bridges, Low Level Structures, Retaining Walls, Gantries, Road Tunnels, Light Masts

4.10 Analysis of Results

This study analyses and summarises each of the selected defect/condition rating systems, including the Eskom's "Inspection Manual for Civil Works at Eskom's Power Stations, in terms of the following: the environment in which the rating system is used, the construction material of the structure the rating system is used on, the type of structure and the rating system's applicability to other structures

4.10.1 Environment

In this study "environment" refers, to the area in which the rating system is used. This could be a road network or a coal-fired power station. Analysis of each selected rating system shows that they are all applicable to bridges in a road network environment but have some limitations when it comes to their use within a power station environment. The review and analysis of rating systems listed in **Table 25** concluded that OSCI & NBIS were not appropriate for use in a coal-fired power station environment but the DER and OSIM rating systems were applicable with limitations.

Table 25: Environment

Rating System	Environment	
	Road network (Bridge)	Power Station (Coal-fired Power Station)
DER (COTO)	✓	(✓)
OSCI (ATRF)	✓	✗
NBIS/NBI (FHWA)	✓	✗
OSIM (MOT)	✓	(✓)

✓ Appropriate/suitable,

(✓) Appropriate with limitations or can be accommodated

✓ Not appropriate.

4.10.2 Material

Structures located in a road network or inside a power station are all constructed using one or more of the following construction materials: reinforced concrete, mass concrete, pre-stressed concrete, steel, corrugated steel, cast-iron, plastic, rubber, asphalt, masonry,

wood/timber and gravel. Twelve construction materials were selected as shown in **Figure 44** and the amount of construction material used in the construction of the structures assessed is presented below. This is done in comparison with the material used in the construction of structures covered in the Eskom Inspection manual.

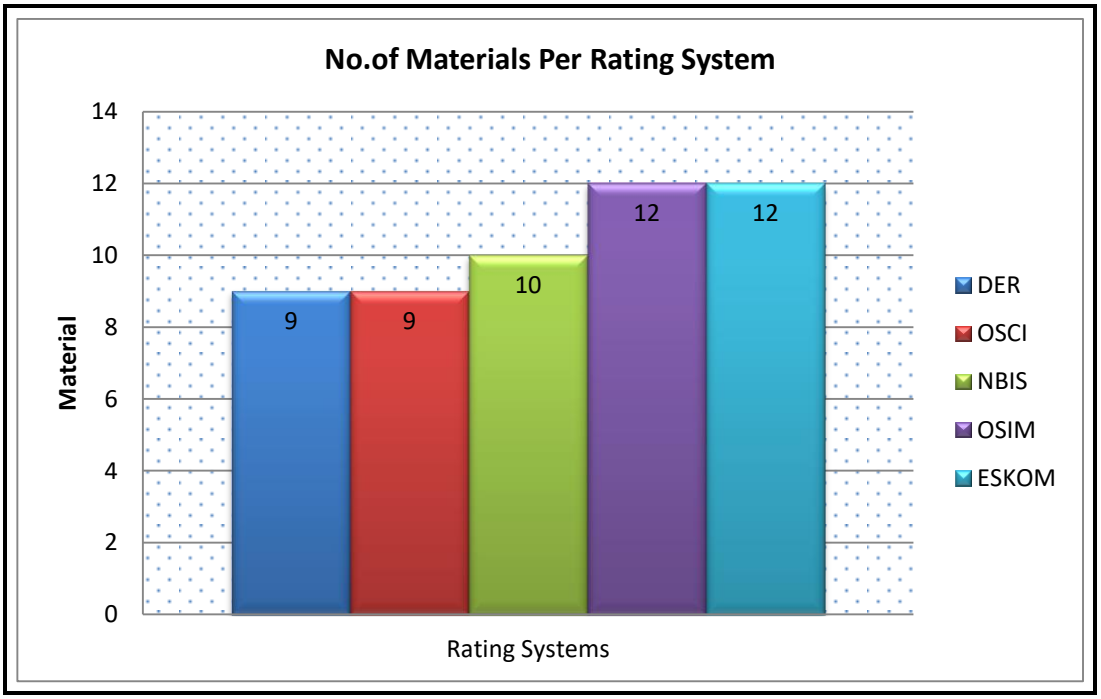

Figure 44: Material per Rating System

From **Figure 44**, it can be deduced that OSIM covers all the twelve aforementioned construction materials found in a power station environment, followed by NBIS, and DER and Eskom.

Table 26 shows that the DER and OSCI rating systems are used to rate structures constructed with the materials listed above (see Section 4.10.2) except for those constructed with masonry, wood/timber and gravel. NBIS is not used for masonry and gravel.

Table 26: Rating Method Vs Material.

RATING METHOD / MATERIAL	COTO (DER)	ATRF (OSCI)	FHWA (NBIS)
Masonry	✗	✗	✗
Wood/Timber	✗	✗	✓
Gravel	✗	✗	✗

It should be noted that, at least for the STRUMAN rating system, any material can be included. It simply involves an expansion of the remedial work activity lists to cater for repairs relevant to such additional materials such as timber and masonry.

4.10.3 Structure types

The Inspection Manual for Civil Works at Eskom's Power Stations provides a list of concrete structure types that are subject to inspection in Eskom Power Stations. All the four selected condition-rating systems (DER, OSCI, NBI/NBIS and OSIM) deal with bridge structures, but some of them go further and deal with additional structures such as culverts, retaining walls, gantries, tunnels, low level bridges, light masts, low level river crossings, cooling towers, signage, chimney structures, concrete silos, liquid containing structures, conveyor structures, steel structures, buildings, roads (wearing surface), railway lines and siding, surface drains, ash dams, coal stockyards and dams. The twenty-four structure types are represented in **Figure 45** in terms of the number of structure types that can be rated by a specific rating system as compared with the types of structures covered in the Eskom Inspection manual.

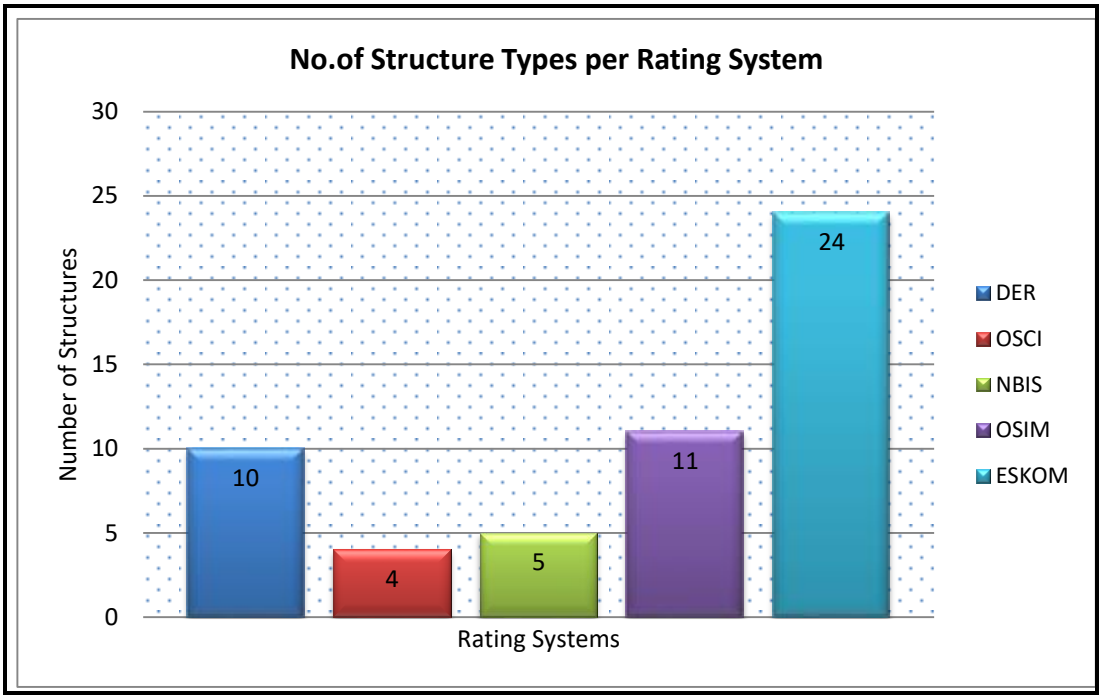

Figure 45: Structures Types per Rating System

Figure 45 concludes that DER followed by OSIM are the rating systems with the most number of structures that can be tested to rate defects and condition.

Note that the STRUMAN system that has been adapted for the Namibia Port Authority has 23 different structure types, including underwater structures.

4.10.4 Applicability

Table 27 presents the outcome of the evaluation of the selected rating systems in terms of the environment in which the structures are located, the construction material used, and the types of structures found in coal-fired power stations. The table constricts the rating systems to one rating system (OSIM) which was evaluated against the DER for use in a power station environment, hence disqualifying OSCI and NBIS/NBI which were eliminated from consideration due to lack of flexibility, simplicity of approach and/or clarity of the rating process as elaborated in **Sections 4.5-4.7** of this document and defined as follows:

- Flexibility of the rating process is the ease with which a particular rating system can be used to rate defects of other RC structures than those listed in a specific inspection manual.
- Simplicity of the rating process refers to the straightforwardness of the approach. The rating process is easy to understand and to use.
- Clarity refers to how explicit and less cumbersome the rating process is.

Table 27: Applicability

RATING METHOD / APPLICABILITY	COTO (DER)	MOT (OSIM)
Flexibility	✓	✓
Simplicity of Approach	✓	✗
Clarity of the process	✓	✓

In light of the above analysis, it has been concluded that the DER rating system is more appropriate for use in a coal-fired power station than the other rating systems examined. However, the OSIM rating system also comprises a valuable information system that could be taken into consideration if the possibility of further development of the DER rating system for an extended use within a coal-fired power station is raised

5 Conclusions

The current economic situation calls for the reprioritisation of projects, budget cuts and controls and cost saving initiatives to be implemented in order for an organisation to realise a better return on investment. A good organisational strategic plan, supported by a sound asset management system is one of the constituents for achieving this. Asset management and inspection and maintenance were presented as part this system. Eskom's approach to asset management was reviewed within the context of a power generation company. The finding was that more attention has been devoted to the mechanical, electrical and control and instrumentation components of the plant than on the civil engineering infrastructure. Failure of the silo at the Majuba Power Station can be used as an example.

An Asset Management System comprising planned maintenance and repairs is an important mechanism for ensuring that the service life of an asset is extended. Successful implementation of this plan leads to reduced operation expenditure, maximisation of profit and a sound balance sheet. This is why various organisations and authorities have developed inspection techniques and guidelines as a means of ensuring continued good service to the public and their customers during the service life of an asset as well as ensuring a good return on investment regarding the assets.

For future maintenance and repair activities, the Built Environment division of the Council for Scientific and Industrial Research (CSIR) in Pretoria, South Africa have developed the STRUMAN Bridge Management System using the DER (Degree of defect, Extent and Relevancy of defect) defect-rating system. The system also provides repair/maintenance schedules, as well as budget allocations for implementation.

The DER rating system together with other selected rating systems such as Overall Structural Condition Index (OSCI), the National Bridge Inspection Standard (NBIS)/the National Bridge Inventory (NBI) and the Ontario Structural Inspection Manual (OSIM) were tested within a power generation environment in order to determine their applicability to three selected criteria: flexibility of usage (from road network to power generation environment), simplicity of approach and clarity of the process (how explicit the process is). These systems are all geared for application to road structures, thus some of the rating systems showed some limitations for use within a power station. Others, however, showed potential for further use in a power generation plant environment. Among them, the DER and OSIM were the two rat-

ing systems that stood the test. Proposed inspection forms based on the DER rating system and the Eskom inspection guidelines were developed as a result of this study.

Although the primary intent of the study was not to compare the DER rating system with other available rating systems but rather to test its applicability in a power generation environment, the final analysis showed that the DER system was the most applicable rating system than the others for use in a power station on account of its flexibility, simplicity of use and the clarity of its rating process.

6 Recommendations

The assessment of the condition of the support structure of the dry cooling tower was conducted using the DER (Degree of defect, Extent and Relevancy of defect) rating system and other selected rating systems such as the Overall Structural Condition Index (OSCI), National Bridge Inspection Standard (NBIS)/ the National Bridge Inventory (NBI) and and the Ontario Structural Inspection Manual (OSIM) to test their applicability to a power generation plant environment. The application of the DER system was proven satisfactory and consequently is recommended for use, especially for the support structure of the dry cooling tower. The top part of the tower, the shell, could not be inspected due the lack of accessibility to the upper section of the structure which required mechanized means.

It should be noted that the DER rating system requires further development in terms of its use for other structures within a power station environment. When this is done, the OSIM and other relevant rating systems should be taken into consideration for complementing the DER rating system and extending its use.

6.1 Contributions

The outcome of this study is evidence that the DER rating system is ready for use within parts of an Eskom power station environment but needs further development for a total adoption.

The Inspection Manual for Civil Works at Eskom's Power Stations' does not provide inspection forms for identified structures **(Table 20).** However, an attempt to develop one was undertaken through this study and the outcome was proposed to the Eskom Asset Management Center of Excellence for current use or for further improvement, as needs be. The proposed form is depicted in **Figure 29.**

This study has also introduced a certain level of knowledge of the DER rating to the Eskom Civil and Structural Engineering Department and the Eskom Asset Management Center of Excellence Business Units.

6.2 Areas of Improvement

The DER rating system is ready for use within a coal-fired power station environment on structures similar to those listed in TMH 19 (COTO, 2013) and presented in **Table 20.** For other structures such as cooling towers and chimney reservoirs, the DER rating system is ready for use but needs expansion for total adoption.

The DER rating system is a defect-based rating system and not a condition-based system, such as the other selected rating systems. Defects that are dealt with in TMH 19 are also identifiable in structures found in a power generation environment. Therefore, a total adoption of the DER rating system would be based on the following improvement activities:

i. The inclusion of the structures listed in the Eskom's inspection guideline, The Inspection Manual for Civil Works at Eskom's Power Stations', or a separately developed manual based on the structures listed in the Eskom guideline that follows the principles outlined in TMH 19.

ii. Confirmation of the relevancy of remarks and activity descriptions for urgency/relevancy rating tables provided in TMH 19 for similar structures identified in the power station.

iii. Confirmation of observations and defects in defect rating tables that are provided in TMH 19 for similar structures. **(Appendix 4).**

iv. Development of similar observation and defect tables as provided in TMH 19 for structures not listed in TMH 19 but found in a power station environment.

v. Development of position codes in relation to the current coding system used by Eskom.

vi. Development of an inspection remedial activity list, similar to STRUMAN: Bridge and Structures Management System (See **Appendix 5** for structures not listed in TMH 19).

vii. Creation of inspection forms and risk assessment procedures.

viii. Redefining the profile of the inspector after including structures not listed in TMH 19.

ix. Redefining types of inspection tools for structures such as chimneys, cooling towers and dams.

x. Development of a training manual.

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Appendix 1 – Project R List of Guidelines

Reference	Rev	Title	Status	Comment
OPG0159-01	0	PROJECT R GUIDELINE	CANCELLED	Number reserved but never used.
OPG0159-02	0	CLASSIFICATION GUIDELINE	CANCELLED	
OPG0159-02	01	CLASSIFICATION GUIDELINE	AUTHORISED	
OPG0159-03	01	MODIFICATION CONTROL GUIDE-LINE	AUTHORISED	
OPG0159-03	0	CLASSIFICATION GUIDELINE	CANCELLED	
OPG0159-04	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-05	0	PROCUREMENT CONTROL GUIDE-LINE	AUTHORISED	
OPG0159-06	0	MATERIALS CONTROL GUIDELINE	CANCELLED	Replaced by rev 1
OPG0159-06	1	MATERIALS CONTROL GUIDELINE	AUTHORISED	
OPG0159-07	01	DEVIATION REPORTING GUIDE-LINE	AUTHORISED	
OPG0159-07	0	DEVIATION REPORTING GUIDE-LINE	CANCELLED	Replaced by Rev 1.
OPG0159-08	0	MAINTENANCE QUALITY CON-TROL GUIDELINE	AUTHORISED	
OPG0159-09	0	ROUTINE TESTING OF PLANT SAFETY-RELATED DEVICES GUIDELINE	AUTHORISED	
OPG0159-10	0	DOCUMENTATION CONTROL GUIDELINE	AUTHORISED	
OPG0159-11	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-12	0	TURBO-GENERATOR & BOILER IN-SPECTION AND TEST PLANS GUIDELINE	AUTHORISED	
OPG0159-13	0	OPERATOR TRAINING GUIDELINE	AUTHORISED	
OPG0159-14	00	MAINTENANCE TRAINING	CANCELLED	Reserved for mainte-nance training but never published.
OPG0159-15	0	PERFORMANCE OPTIMISATION AND ON-SITE ENGINEERING GUIDELINE	AUTHORISED	
OPG0159-16	0	PLANNING OUTAGE AND INVEN-TORY MANAGEMENT GUIDELINE	AUTHORISED	
OPG0159-17	0	PROJECT R GUIDELINE	CANCELLED	Reserved for partner-ing but cancelled by Chris Brown
OPG0159-18	0	PROJECT R GUIDELINE	CANCELLED	Reserved for partner-ing but cancelled by Chris Brown
OPG0159-19	1	POWER STATION OWNWER MAN-UAL MANAGEMENT OF CONTROL AND INSTRUMENTATION ISSUES	CANCELLED	
OPG0159-20	0	QUALITY ASSURANCE GUIDELINE	AUTHORISED	
OPG0159-21	0	PROJECT R GUIDELINE	CANCELLED	Reserved for financial , but cancelled by Chris Brown
OPG0159-22	0	GENERATION ENVIRONMENTAL MANAGEMENT	UNDER RE-VIEW	Requested DMcC to advise review/revision completion date, 17

Reference	Rev	Title	Status	Comment
				Jan 2001.
OPG0159-23	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-24	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-25	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-26	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-27	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-28	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-29	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-30	1	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-31	1	POWER STATION OWNER MANUAL OPERATING FUNCTION - PLANT SECURITY LOCK OUT	AUTHORISED	
OPG0159-32	0	OPERATING DEPARTMENT OPERATING TECHNICAL SPECIFICATION GUIDELINE	CANCELLED	Replaced by rev 1
OPG0159-32	01	OPERATING DEPARTMENT OPERATING TECHNICAL SPECIFICATION GUIDELINE	AUTHORISED	
OPG0159-33	0	MAINTENANCE HISTORY GUIDELINE	CANCELLED	
OPG0159-33	1	MAINTENANCE HISTORY GUIDELINE	AUTHORISED	Requested Dave Mccann to provide a master document
OPG0159-34	0	ORGANIZATIONAL DEVELOPMENT GUIDELINE	AUTHORISED	
OPG0159-35	0	CONFIGURATION MANAGEMENT GUIDELINE	AUTHORISED	
OPG0159-36	0	PROJECT R GUIDELINE	CANCELLED	Reserved for occurrence management, but never published.
OPG0159-37	0	POWER STATION OWNER MANUAL	AUTHORISED	
OPG0159-A	02	POWER STATION OWNER"S MANUAL - VOLUME 1 (PARTS 1 TO 4)	CANCELLED	
OPG0159-B	00	POWER STATION OWNER"S MANUAL VOLUME 2 (PARTS 1 TO 3)	CANCELLED	Copies or individual docs/parts are available from OED.
OPG0159-C	00	POWER STATION OWNER"S MANUAL VOLUME 3 (PMF POLICIES)	CANCELLED	

Appendix 2 – NBI Rating Guideline

Bridge Safety Inspection
NBI RATING GUIDELINES

BIR #1. SURFACE (SI&A item 58A)

This item is to evaluate and rate the condition of the deck surface only. The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) if they are rating the structural deck surface or a protective wearing surface (i.e. thin epoxy, wood, bituminous or, latex overlay). Refer to SI&A item 108 "Wearing Surface / Protective System" for type of wearing surface. If there is no protective wearing surface, rate the condition of the surface of the structure deck.

A concrete or bituminous wearing surface should be inspected for spalling, cracking, scaling, and de-lamination. Timber wearing surfaces should be inspected for deterioration, splitting, and crushing. Rate and code the condition in accordance with the following ratings.

Concrete patches or concrete repaired areas that are sound and functioning properly should not be counted as deteriorated or deficient area. Concrete patches that are loose, delaminated, or generally in poor condition shall be counted as deteriorated or deficient area. Bituminous patches shall always be counted as deteriorated or deficient area

Code	Description
N	NOT APPLICABLE. Code N for culverts and other structures without decks, e.g., filled arch bridge.
9	NEW CONDITION. No noticeable or noteworthy deficiencies which affect the condition of the surface.
8	GOOD CONDITION. Minor cracking less than 1/32" wide (0.8mm) with no spalling, scaling or delamination.
7	GOOD CONDITION. Open cracks less than 1/16" wide (1.6mm) at a spacing of 10 ft or more, light shallow scaling allowed.
6	FAIR CONDITION. Surface has considerable number of open cracks greater than 1/16" wide (1.6mm) at a spacing of 5 ft or less. Surface area exhibits 2% or less of spalled or delaminated areas, including repaired areas. Medium scaling on the surface is 1/4" to 1/2" (6.4 mm to 13 mm) in depth.
5	FAIR CONDITION. Between 2% and 10% of the surface area is spalled or delaminated. There can be excessive cracking in the surface. Heavy scaling 1/2" to 1" in depth (13 mm to 26 mm) can be present.
4	POOR CONDITION. Large areas of the surface, 10 - 25% is spalled or delaminated.
3	SERIOUS CONDITION. More than 25% of the surface area is spalled.
2	CRITICAL CONDITION. Emergency surface repairs required by the crews.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #2 JOINTS

The joints to be rated in this item include expansion joint devices such as strip seals, compression seals, assembly joint seals, polymer block out joints, steel armor joints, pourable seals, and compression seals.

Joints such as cold joints, construction joints and other joints that do not have a seal will be coded in item #3 Other Joints. Code the joints for bridge decks that are continuous ("joint less bridges") and have allowance for expansion in the approach slabs, in item #3 Other Joints.

Code	Description
N	NOT APPLICABLE. Code N for jointless bridges, and structures without decks, ie sand filled arches and culverts.
9	NEW CONDITION. No noticeable or noteworthy deficiencies that would affect the operation, movement, or water tightness of the joints.
8	GOOD CONDITION. Condition same as in 9 above with possible minor accumulation of non-compressible and debris in the expansion opening.
7	GOOD CONDITION. Minor deterioration with shallow hairline cracks less than 1/32" (0.8 mm) within 2 ft. of the joint. No noticeable water leakage.
6	FAIR CONDITION. Minor deterioration with shallow hairline cracks greater than 1/32" (0.8 mm) and shallow spalls within 2 ft. of the joint. Device components maybe uneven, misaligned or the joint opening is closed. No noticeable water leakage.
5	FAIR CONDITION. Moderate deterioration of surrounding concrete including cracking and shallow spalling. Minor leakage due to adhesion failures of the seal and/or anchorage device (less than 5% of the length).
4	POOR CONDITION. Major deterioration of surrounding concrete including cracking and spalling to steel. Leaking along more than 5% of the seal and/or anchorage device.
3	SERIOUS CONDITION. Surrounding concrete is spalled below steel on top or bottom of deck with possible full-depth failures. Most of device is leaking or loose. Ride quality may be impacted.
2	CRITICAL CONDITION. Device and surrounding concrete is seriously deteriorated. Emergency repairs may be required for lane to remain open. Temporary joint support from underneath may be necessary.
1	IMMINENT FAILURE CONDITION. Lane closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #3 OTHER JOINTS

This item includes all other joints NOT in item #2 Joints. These are typically unsealed joints such as cold joints, construction joints, and expansion joints off of the bridge (i.e. "joint less bridges") in the approach slab.

Code	Description
N	NOT APPLICABLE. Code N for structures without decks, i.e. sand filled arches.
9	NEW CONDITION. No noticeable wear or leakage.
8	GOOD CONDITION. Condition same as in 9 above with possible minor accumulation of non-compressibles and debris in the tooled opening.
7	GOOD CONDITION. Minor deterioration with shallow hairline cracks less than 1/32" (0.8 mm) within 2 ft. of the joint. No noticeable water leakage.
6	FAIR CONDITION. Minor deterioration with shallow hairline cracks greater than 1/32" (0.8 mm) and shallow spalls within 2 ft. of the joint. No noticeable water leakage.
5	FAIR CONDITION. Moderate deterioration of surrounding concrete including cracking and shallow spalling. Minor leakage, along less than 5% of the length of the joint.
4	POOR CONDITION. Major deterioration of surrounding concrete including cracking and spalling to steel. Leaking along more than 5% of the length of the joint.
3	SERIOUS CONDITION. Surrounding concrete is spalled below steel on top or bottom of deck with possible full-depth failures. Most of joint is leaking. Ride quality may be impacted.
2	CRITICAL CONDITION. Joint and surrounding concrete is seriously deteriorated. Emergency repairs may be required for lane to remain open. Temporary joint support from underneath may be necessary.
1	IMMINENT FAILURE CONDITION. Lane closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #4 RAILING

This item is for the evaluation and rating of vehicular railing and pedestrian fencing on the supported spans of the bridge. Report the type of railing in the comment section and if the railing is constructed on only one side of the bridge, or if the bridge has a tie beam retrofit. Use SI&A item 36 A to D to report if the railing components meet the current standard. Report collision damage in the comment section and on the work recommendation list. Brush blocks are to be considered as part of the railing

Code	Description
N	NOT APPLICABLE. Code N for structures that do not have railings such as buried bridges and culverts that have guardrail off the shoulders.
9	NEW CONDITION. No noticeable wear, deterioration or collision damage.
8	GOOD CONDITION. Small and superficial wear, deterioration, or collision damage.
7	GOOD CONDITION. Minor deterioration with shallow hairline cracks in concrete components less than 1/32" (0.8 mm) or shallow scaling. Failure of paint or galvanizing coated steel is very small and in scattered locations. Collision damage limited to minor scrapes.
6	FAIR CONDITION. Minor deterioration with shallow hairline cracks in concrete components greater than 1/32" (0.8 mm) and shallow spalls or scaling limited to less than 2 % of the surface area.. Failure of the coating on steel components is limited to less than 2% of the surface area with no loss of section. Collision damage limited to minor scrapes.
5	FAIR CONDITION. Moderate deterioration with cracks in concrete components and spalls or scaling limited to less than 5 % of the surface area.. Failure of the coating on steel components is limited to less than 5% of the surface area with minor loss of section. Collision damage limited to minor scrapes or temporary repairs in place.
4	POOR CONDITION. Major deterioration with cracks in concrete components and spalls or scaling greater than 5 % of the surface area.. Failure of coating on steel components is greater than 5% of the surface area with some loss of section. Some collision damage but not affecting the performance of the railing. Temporary repairs may be in place.
3	SERIOUS CONDITION. Most of the railing components exhibit deterioration and/or loss of section. Collision damage and deterioration has not progressed to the point where the railing will fail if impacted.
2	CRITICAL CONDITION. Most of the railing components exhibit deterioration and/or loss of section. Collision damage and deterioration has progressed to the point where the railing may fail if impacted. Immediate repairs are called for.
1	IMMINENT FAILURE CONDITION. Lane or shoulder closed to traffic and temporary concrete barricades or thrie beam in place to keep the bridge open. Corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #5. SIDEWALKS or CURBS

This item is for the evaluation and rating of the surface of sidewalks and curbs on the supported spans only. The areas below the sidewalk are to be rated with the deck. The inspector must note in the comment field if the sidewalk is on only one side of the bridge. Brush blocks are to be rated as part of item #4, Railings

Code	Description
N	NOT APPLICABLE. Code N for structures without sidewalks or curbs.
9	NEW CONDITION. No noticeable or noteworthy deficiencies which affect the condition of the surface.
8	GOOD CONDITION. Minor cracking less than 1/32" wide (0.8mm) with no spalling, scaling, or delamination.
7	GOOD CONDITION. Open cracks less than 1/16" wide (1.6mm) at a spacing of 10 ft or more, light shallow scaling allowed.
6	FAIR CONDITION. Surface has considerable number of open cracks greater than 1/16" wide (1.6mm) at a spacing of 5 ft or less. Surface area exhibits 2% or less of spalled or delaminated areas, including repaired areas. Medium scaling on the surface is 1/4" to 1/2" (6.4 mm to 13 mm) in depth.
5	FAIR CONDITION. Between 2% and 10% of the surface area is spalled or delaminated. There can be excessive cracking in the surface. Heavy scaling 1/2" to 1" in depth (13 mm to 26 mm) can be present. This includes repaired areas and/or areas in need of corrective action.
4	POOR CONDITION. Large areas of the surface, 10 - 25% is spalled or delaminated. This includes repaired areas and/or areas in need of corrective action. Spalls and scaling are not deep enough to cause a trip hazard.
3	SERIOUS CONDITION. More than 25% of the surface area is spalled. This area includes repaired areas and/or areas in need of corrective action. Spalls and scaling are not deep enough to cause a trip hazard.
2	CRITICAL CONDITION. Emergency surface repairs required by the crews.
1	IMMINENT FAILURE CONDITION. Sidewalk is closed to pedestrians, but corrective action may put it back in service.
0	FAILED CONDITION. Bridge closed.

BIR #6. DECK BOTTOM SURFACE (SI&A item 58B)

This item is to evaluate and rate the condition of the deck bottom surface. The inspector must note in the comment field associated with this element (#6 on BSIR) if he/she is observing and rating the structural concrete of the deck bottom surface or the stay-in place forms. The bottom surface of a concrete deck should be inspected for cracking, scaling, spalling, leaching, delamination, and full or partial depth failures. If the deck has stay-in-place forms, rate the condition of the forms. Steel grid decks should be inspected for broken welds, broken grids section loss, and growth of filled grids from corrosion. Timber decks should be inspected for splitting, crushing, fastener failure, and deterioration from rot.

If the bottom surface of the deck cannot be observed because the superstructure obscures it, such as with side by side box beams or earth filled arch structures, code "N" and note in the comments why this item is not being rated. Also, code "N" for slab bridges, culverts, and when the underside is obscured because of false-decking or maintenance sheeting.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BSIR) the factors and quantities that influenced the judgment for the rating

BIR #6. DECK BOTTOM SURFACE (SI&A item 58B)

Code	Description
N	NOT APPLICABLE. Code N for culverts and other structures without decks, e.g., filled arch bridge, concrete slab, or when covered with false-decking or maintenance sheeting.
9	NEW CONDITION. No noticeable or noteworthy deficiencies which affect the condition of the bottom surface concrete or stay-in-place forms.
8	GOOD CONDITION. Minor cracking less than 1/32" wide (0.8mm) with no spalling, scaling, or delamination. No rust on stay-in-place forms.
7	GOOD CONDITION. Open cracks less than 1/16" wide (1.6mm) at a spacing of 10 ft or more, or light shallow scaling. No rust on stay-in-place forms.
6	FAIR CONDITION. The deck bottom surface has considerable number of open cracks greater than 1/16" wide (1.6mm) at a spacing of 5 ft or less. The bottom surface area exhibits 2% or less of spalled, delaminated, or heavily map cracked areas. Medium scaling on the surface is 1/4" to 1/2" (6.4 mm to 13 mm) in depth. Medium scaling on the surface is 1/4" to 1/2" (6.4 mm to 13 mm) in depth. Stay-in place forms have light surface or freckled rust over less than 2% of the total surface area.
5	FAIR CONDITION. The deck bottom surface area exhibits between 2% and 10% spalled, delaminated, or heavily map cracked areas. There can be excessive cracking in the surface. Heavy scaling 1/2" to 1" in depth (13 mm to 26 mm) can be present. Stay-in place forms have light surface or freckled rust between 2% and 10% of the total surface area.
4	POOR CONDITION. The deck bottom surface area exhibits between 10% and 25% spalled, delaminated, or heavily map cracked areas. Stay-in place forms have light to moderate corrosion over between 10% and 25% of the total surface area. Some small areas may have pulled away exposing the deck concrete.
3	SERIOUS CONDITION. The deck bottom surface is showing advanced deterioration that has seriously affected the primary structural components. Local failures are possible. The bottom surface area exhibits more than 25% spalled, delaminated, or heavily map cracked areas. Structural evaluation and/or load analysis may be necessary to determine if the structure can continue to function without restricted loading or structurally engineered temporary supports. There may be a need to increase the frequency of inspections. Stay-in place forms have moderate to severe corrosion over more than 25% of the total surface area. Some small areas may have pulled away exposing the deck concrete.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the deck will not support design loads and is therefore posted for reduced loads. Emergency deck repairs or shoring with structurally engineered temporary supports may be required by the crews. There may be a need to increase the frequency of inspections. Stay-in place forms have large areas of severe corrosion. Some areas may have pulled away exposing the deck concrete.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic due to the potential for deck failure, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed. Coordinate with S I & A item 41.

BIR #7. DECK (SI&A item 58)

This item is to evaluate and rate the overall condition of the deck. Rate and code the condition in accordance with the general condition ratings. Code "N" for culverts and other structures without decks, such as a filled arch bridge. Refer to SI&A item 108 "Wearing Surface / Protective System" for type of wearing surface.

A concrete deck should be inspected for cracking, scaling, spalling, leaching, potholing, delamination, and full or partial depth failures. Steel grid decks should be inspected for broken welds, broken grids section loss, and growth of filled grids from corrosion. Timber decks should be inspected for splitting, crushing, fastener failure, and deterioration from rot.

The condition of the wearing surface / protective coating system (BIR item #1. Surface), joints, expansion devices, curbs, sidewalks, parapets, fascias, bridge railing, and scuppers shall not be considered in the overall deck evaluation. However, their condition will be noted on the form in their respective items. If the structural deck is visible (i.e. there is no wearing surface / protective coating system) then the surface must be considered in the overall evaluation of the deck.

If the underside of the deck cannot be observed due to an adjacent box beam superstructure or stay-in-place forms, the inspector is to evaluate and rate the deck from observations on the surface of the deck and note in the comment field any limitations this may cause.

Structurally engineered temporary supports may allow unrestricted loading of the bridge, however a load rating analysis must be completed without the addition of the supports and the coding of SI & A item 103 changed to a "T". Contact Bridge Management Unit when this is necessary.

When determining the overall percent deterioration of the deck and both structural surfaces are visible, the quantity of deteriorated top surface area should be added to the quantity of deck bottom surface area and the summation is divided by the combined top and bottom surface areas.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating.

Bridge Safety Inspection
NBI RATING GUIDELINES

BIR #8. DRAINAGE

This item is for noting poor drainage characteristics on the bridge deck. There is no rating scale. The inspector can note in the comments if there is ponding of water on the surface or debris build up on the deck or in the drains that is preventing water from getting to the drains. The deck drains and the area adjacent to the deck drains are to be considered in the evaluation of item 6 Deck (SI & A # 58).

BIR #9. STRINGER (SI & A Item 59, Superstructure)

This item describes the physical condition of all structural members below the deck and above the pier cap, trusses (deck & through trusses) and, suspension cables and suspenders. Evaluate and rate the condition in accordance with the general condition ratings. Code N for all culverts.

All structural members should be inspected for visible signs of distress which may include cracking, deterioration, section loss, and malfunction and misalignment of bearings or pin and hanger assemblies. The condition of BIR Items 9, 10, and 11 (Paint, Section Loss and Bearings) may negatively influence the rating if they are in poor condition. However, they should not offset or improve the rating for stringers that are in poor condition. Such as a structure where the stringers are in poor condition at a rating of 4, would not be increased to 5 because the bearings are rated 8.

On bridges where the deck is integral with the superstructure, the superstructure condition rating may be affected by the deck condition. The resultant superstructure condition rating may be lower than the deck condition rating in the situation where the girders have deteriorated or been damaged.

Fracture critical components should receive careful attention because failure could lead to collapse of a span or the bridge. Fatigue prone details should receive close observation because they could lead to failure of a given element.

Structurally engineered temporary supports may allow unrestricted loading of the bridge, however a load rating analysis must be completed without the addition of the supports and the coding of SI & A item 103 changed to a “T”. Contact Bridge Management Unit when this is necessary.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating.

BIR #10. PAINT (SI & A item 59A)

This item is to evaluate and rate the condition of the paint only. The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the type of paint or coating system (such as weathering steel or galvanized beams) and the year that the paint was applied.

The condition of the coating system may have influence on the rating of item # 8 Stringer (SI & A # 59) al

Code	Description
N	NOT APPLICABLE. Code N for concrete super-structures, A-588 Weathering Steel super-structures, and galvanized beams.
9	NEW CONDITION. No deficiencies in the coating which will affect its long term performance.
8	GOOD CONDITION. Minor weathering of the coating and/or dirt contamination.
7	GOOD CONDITION. Minor pinhead size failures of the coating in scattered locations or on sharp edges.
6	FAIR CONDITION. Minor coating failures in scattered locations with a total area of less than 1%.
5	FAIR CONDITION. Moderate coating failures between 1% and 5% of the surface area. If areas of paint failure are concentrated under open joints, consideration may be given to zone painting.
4	POOR CONDITION. Large areas of coating failures, between 5% and 15% of the total surface. If areas of paint failure are concentrated under open joints, consideration may be given to zone painting. Otherwise, schedule for complete repainting when coating failure has progressed beyond 15%.
3	SERIOUS CONDITION. More than 15% of the coating has failed. Structure should be scheduled for complete repaint.
2	CRITICAL CONDITION. More than 50% of the coating has failed. Structure should be scheduled for complete repaint.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #11. SECTION LOSS UNDER JOINTS (SI&A Item 59B)

This item is used only for steel structures and is intended to identify and track those structures with a tendency for deterioration under the joints. Evaluate and rate the area 5 ft. on each side of the joint. This item is separate from item # 8 Stringer (SIA-59) and all deterioration in this location must be also taken into account when rating item #8. Code N for all bridges with concrete super-structures.

Code	Description
N	Non-applicable (Concrete superstructure, etc.)
3	No loss of paint protection, corrosion, or evidence of loss of section due to corrosion.
2	Rusty beam ends or minor section loss. Less than 10% section loss.
1	10% or greater section loss.
0	Holes(s) in steel. May be temporarily supported.

BIR #12. BEARINGS (SI&A item 59C)

This item describes the physical condition of bearings. Evaluate and rate the condition in accordance with the general condition ratings. Code N for culverts, delta frame designs and bridges designed with the superstructure integral with the substructure.

This item is separate from BIR item # 8 Stringer (SIA-59), however deterioration in this location may be also taken into account when rating item #8. The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the type of bearings on the bridge and the factors and quantities that influenced the judgment for the rating

Code	Description
N	NOT APPLICABLE. Code N for culverts.
9	NEW CONDITION. No deficiencies in any bearing components that will affect the long term performance.
8	GOOD CONDITION. All protective coatings are sound and functioning but with minor weathering of the coating and/or dirt contamination on bearing components.
7	GOOD CONDITION. Minor coating failures in scattered locations on steel bearing components. All bearing components function as designed.
6	FAIR CONDITION. Minor deterioration affecting non-structural components. Some protective coating failures. Minor misalignment or loss of bearing support. All bearing components function as designed.
5	FAIR CONDITION. Moderate deterioration affecting bearing components. Minor misalignment, section loss or, loss of bearing in low or no stress areas.
4	POOR CONDITION. Considerable deterioration affecting bearing components with section loss up to 10% in scattered and isolated areas, misalignment, and/or loss of bearing. All members continue to function as designed.
3	SERIOUS CONDITION. Considerable deterioration affecting bearing components with section loss up to 25% in scattered and isolated areas. Structural and/or load analysis may be necessary to determine if the structure can continue to function without restricted loading.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the structure will not support design loads and must be posted for reduced loads.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #13. ABUTMENTS (SI&A Item 60, Substructure)

This item describes the physical condition of abutments, piles, fenders, footings or other substructure components in proximity of the abutments and below the bearings. The final rating for SI & A #60 will be the lower of this rating and the rating for BIR #14. Piers. Evaluate and rate the condition in accordance with the general condition ratings. The substructure rating is independent of the deck and superstructure. Code N for all culverts.

All structural members should be inspected for visible signs of distress which may include cracking, deterioration, section loss, settlement, misalignment, scour, collision damage and corrosion. The rating given by Item 113 - Scour Critical Bridges, may have a significant effect on this item if scour has substantially affected the overall condition of the substructure. The location, size and, depth of any scour must be noted in the comments.

Integral - abutment wing walls to the first construction or expansion joint shall be included in the evaluation. For non-integral superstructure and substructure units, the substructure shall be considered as the portion below the bearings. For structures where the substructure and superstructure are integral, the substructure shall be considered as the portion below the superstructure.

Structurally engineered temporary supports may allow unrestricted loading of the bridge, however a load rating analysis must be completed without the addition of the supports and the coding of SI & A item 103 changed to a “T”. Contact Bridge Management Unit when this is necessary.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating

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BIR #13. ABUTMENTS (SI&A Item 60, Substructure)

Code	Description
N	NOT APPLICABLE. Code N for culverts.
9	NEW CONDITION. No deficiencies in any of the structural components that will affect the long term performance.
8	GOOD CONDITION. All structural components are sound and functioning as designed. There may be superficial cracking or weathering of protective coatings and/or dirt contamination on structural components.
7	GOOD CONDITION. All members retain full section properties and function as designed. There may be minor cracking in structural components.
6	FAIR CONDITION. All members retain full section properties and function as designed. There may be some deterioration affecting structural members such as minor cracking, scaling, small scattered spalls, or shallow scour. Some protective coating failures.
5	FAIR CONDITION. Moderate deterioration affecting structural members such as cracking, scaling, scattered spalls, minor settlement or shallow scour. Minor section loss in low or no stress areas. All members continue to function as designed.
4	POOR CONDITION. Considerable deterioration affecting structural members such as cracking, scaling, scattered spalls, partial settlement or, scour. . All members continue to function as designed.
3	SERIOUS CONDITION. Considerable deterioration affecting structural members. Structural evaluation, hydraulic, and/or load analysis may be necessary to determine if the structure can continue to function without restricted loading, structurally engineered supports, or immediate repairs. There may be a need to increase the frequency of inspections.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the structure will not support design loads and therefore is posted for reduced loads. Emergency repairs or shoring with structurally engineered temporary supports may be required by the crews. There may be a need to increase the frequency of inspections.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic due to abutment failure, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed. Coordinate with S I & A item 41

BIR #14. PIERS (SI&A item 60, Substructure)

This item describes the physical condition of Piers, pier caps, crash walls, footings or other substructure components in proximity of the piers and below the bearings. The final rating for SI & A #60 will be the lower of this rating and the rating for BIR #13. Abutments. Evaluate and rate the condition in accordance with the general condition ratings. The substructure rating is independent of the deck and superstructure. Code N for all culverts.

All structural members should be inspected for visible signs of distress which may include cracking, deterioration, section loss, settlement, misalignment, scour, collision damage and corrosion. The rating given by Item 113 - Scour Critical Bridges, may have a significant effect on this item if scour has substantially affected the overall condition of the substructure. For structures where the substructure and superstructure are integral, the substructure shall be considered as the portion below the superstructure.

Structurally engineered temporary supports may allow unrestricted loading of the bridge, however a load rating analysis must be completed without the addition of the supports and the coding of SI & A item 103 changed to a "T". Contact Bridge Management Unit when this is necessary.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating. The location, size and, depth of any scour must be noted in the comments

BIR #14. PIERS (SI&A item 60, Substructure)

Code	Description
N	NOT APPLICABLE. Code N for culverts.
9	NEW CONDITION. No deficiencies in any of the structural components that will affect the long term performance.
8	GOOD CONDITION. All structural components are sound and functioning as designed. There may be superficial cracking or weathering of protective coatings and/or dirt contamination on structural components.
7	GOOD CONDITION. All members retain full section properties and function as designed. There may be minor cracking in structural components.
6	FAIR CONDITION. All members retain full section properties and function as designed. There may be some deterioration affecting structural members such as minor cracking, scaling, small scattered spalls, or shallow scour. Some protective coating failures.
5	FAIR CONDITION. Moderate deterioration affecting structural members such as cracking, scaling, scattered spalls, minor settlement or shallow scour. Minor section loss in low or no stress areas. All members continue to function as designed.
4	POOR CONDITION. Considerable deterioration affecting structural members such as cracking, scaling, scattered spalls, partial settlement or, scour. . All members continue to function as designed.
3	SERIOUS CONDITION. Considerable deterioration affecting structural members. Structural evaluation, hydraulic, and/or load analysis may be necessary to determine if the structure can continue to function without restricted loading, immediate repairs, or structurally engineered temporary supports. There may be a need to increase the frequency of inspections.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the structure will not support design loads and is therefore posted for reduced loads. Emergency repairs or shoring with structurally engineered temporary supports may be required by the crews. There may be a need to increase the frequency of inspections.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic due to pier failure, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed. Coordinate with S I & A item 41

BIR #15. SLOPE PROTECTION

This item describes the physical condition of the slope protection ahead of and on the sides of the abutments. This rating could have impact on the evaluation and the rating assigned to BIR #13. Abutments. Evaluate and rate the condition in accordance with the general condition ratings. The substructure rating is independent of the deck and superstructure. Code N for all culverts.

All structural members should be inspected for visible signs of distress which may include cracking, deterioration, settlement, misalignment, and scour. Report the location, size and, depth of any scour at the toe of the slope in the comments.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating.

Code	Description
N	NOT APPLICABLE. Code N for culverts.
9	NEW CONDITION. No deficiencies in any of the primary components that will affect the long term performance.
8	GOOD CONDITION. All primary components are sound and functioning as designed. There may be superficial cracking and/or dirt contamination on primary components.
7	GOOD CONDITION. All members retain full section properties and function as designed. There may be minor deterioration and/or cracking of primary components.
6	FAIR CONDITION. All members retain full section properties and function as designed. There may be some deterioration affecting primary members such as minor cracking, shallow settlement, scaling, small scattered spalls, or shallow scour.
5	FAIR CONDITION. Moderate deterioration affecting primary members such as cracking, scaling, scattered spalls, minor settlement or shallow scour. All members continue to function as designed.
4	POOR CONDITION. Considerable deterioration affecting primary members such as cracking, scaling, scattered spalls, partial settlement or, scour. All members continue to function as designed.
3	SERIOUS CONDITION. Considerable deterioration affecting primary members. Structural or hydraulic analysis may be necessary to determine if the structure can continue to function without restricted loading or immediate repairs.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the structure will not support design loads and must be posted for reduced loads.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #16. APPROACH

This item is to evaluate and rate the overall condition of the road approach pavement. It includes the roadway area from the bridge seat at the abutments to 40 feet away from the bridge or to the first joint. Rate and code the condition in accordance with the general condition ratings. Code N for culverts and other structures without decks, such as a filled arch bridge where the pavement is carried across the structure on grade.

The concrete or asphalt pavement should be inspected and evaluated for settlement, cracking, scaling, spalling, potholing, and delamination. The approach should allow for a smooth transition to the bridge deck.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating

Code	Description
N	NOT APPLICABLE. Code N for culverts and other structures without decks, e.g., filled arch bridge.
9	NEW CONDITION. No noticeable or noteworthy deficiencies which affect the condition of the approach pavement.
8	GOOD CONDITION. Minor cracking less than 1/32" wide (0.8mm) with no spalling, scaling or delamination on the approach pavement.
7	GOOD CONDITION. Open cracks less than 1/16" wide (1.6mm) at a spacing of 10 ft or more, light shallow scaling allowed in the surface. Approach pavement will function as designed.
6	FAIR CONDITION. Deterioration of the approach pavement, including repaired areas, is 2% or less of the total area. There may be a considerable number of open cracks greater than 1/16" wide (1.6mm) at a spacing of 5 ft or less in the approach pavement. Medium scaling on the surface is 1/4" to 1/2" (6.4 mm to 13 mm) in depth. Settlement is minor. Approach pavement will function as designed.
5	FAIR CONDITION. Deterioration of the approach pavement, including repaired areas, is between 2% and 10% of the surface area. There can be excessive cracking in the surface. Heavy scaling 1/2" to 1" in depth (13 mm to 26 mm) can be present. Settlement is less than 3/4 inches at the bridge seat. Approach pavement will function as designed.
4	POOR CONDITION. Deterioration on the approach pavement, including repaired areas, is between 10 - 25% . Settlement is more than 3/4 inches at the bridge seat. Approach pavement will function as designed.
3	SERIOUS CONDITION. Deterioration in the approach pavement, including repaired areas, is more than 25% of the surface area. Urgent surface repairs may be required by the crews.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the approach pavement will not function as designed. Emergency surface repairs may be required by the crews.
1	IMMINENT FAILURE CONDITION. Bridge is closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #17. APPROACH SHOULDERS AND SIDEWALKS

This item is to evaluate and rate the overall condition of the approach shoulders, sidewalks, and curbs and gutter. It includes those shoulders etcetera, that are carried across the structure on grade. Rate and code the condition in accordance with the general condition ratings.

The concrete or asphalt pavement should be inspected and evaluated for settlement, cracking, scaling, spalling, potholing, and delamination. Gravel shoulders should have adequate slope and drainage.

The inspector must note in the comment field on the Bridge Safety Inspection Report (BIR) the factors and quantities that influenced the judgment for the rating.

Code	Description
N	NOT APPLICABLE. Code N if the bridge has no approach shoulders or sidewalks.
9	NEW CONDITION. No noticeable or noteworthy deficiencies which affect the condition of the approach shoulders or sidewalks.
8	GOOD CONDITION. Small and superficial deterioration or wear on the approach shoulders or sidewalks.
7	GOOD CONDITION. Minor deterioration or wear on the approach shoulders or sidewalks. All components will function as designed.
6	FAIR CONDITION. Some deterioration or wear on the approach shoulders or sidewalks. Settlement is minor. All components will function as designed.
5	FAIR CONDITION. Moderate deterioration or wear on the approach shoulders or sidewalks. Settlement is less than 3/4 inches at the bridge seat. All components will function as designed.
4	POOR CONDITION. Considerable deterioration or wear on the approach shoulders or sidewalks. Settlement is more than 3/4 inches at the bridge seat. All components will function as designed.
3	SERIOUS CONDITION. Serious deterioration or wear on the approach shoulders or sidewalks. Urgent surface repairs may be required by the crews.
2	CRITICAL CONDITION. Deterioration has progressed to the point where the approach shoulders and sidewalks will not function as designed. Emergency repairs may be required by the crews.
1	IMMINENT FAILURE CONDITION. Shoulder or sidewalks are closed to traffic, but corrective action may put the bridge back in service.
0	FAILED CONDITION. Bridge closed.

BIR #18. APPROACH SLOPES

This item is for noting poor characteristics or situations associated with the road approach slopes. There is no rating scale. The inspector can note in the comments if there are washouts, erosion that can affect the guardrail supports or the road shoulders. Evidence of scour of the slopes should be reported on the BIR under item 12 ABUTMENTS.

BIR #19. UTILITIES

This item is for noting poor characteristics of utilities attached to and affecting the bridge. There is no rating scale. The inspector can note in the comment field the situations observed.

BIR #20. CHANNEL (SI&A item 61 - Channel and Channel Protection)

This item describes the physical conditions associated with the flow of water through a bridge such as stream stability and the condition of the channel, riprap, slope protection or stream control devices including spur dikes. The inspector should be particularly concerned with visible signs of excessive water velocity which may affect undermining of slope protection, erosion of banks, and realignment of the stream which may result in immediate or potential problems. Scour, accumulation of drift and debris on the superstructure and substructure should be noted on the inspection form (in BIR items 12 "Abutment" and /or BIR item 13 "Pier") but not included in the condition rating of this element

Code	Description
N	NOT APPLICABLE. Code N when the bridge is not over a waterway (channel).
9	NEW CONDITION. No noticeable or noteworthy deficiencies affect the condition of the channel.
8	GOOD CONDITION. Banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable condition.
7	GOOD CONDITION. Bank protection is in need of minor repairs. River control devices and embankment protection have a little minor damage. Banks and/or channel, have minor amounts of drift.
6	FAIR CONDITION. Bank is beginning to slump. River control devices and embankment protection have widespread minor damage. Minor stream bed movement is evident. Debris is restricting the channel slightly.
5	FAIR CONDITION. Bank protection is being eroded. River control devices and/or embankment have major damage. Trees and brush restrict the channel.
4	POOR CONDITION. Bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the channel.
3	SERIOUS CONDITION. Bank protection has failed. River control devices have been destroyed. Streambed, aggradation, degradation or lateral movement has changed the channel to threaten the bridge and/or approach roadway now.
2	CRITICAL CONDITION. The channel has changed to the extent the bridge is near a state of collapse.
1	IMMINENT FAILURE CONDITION. Bridge closed because of channel failure. Corrective action may put back in service.
0	FAILED CONDITION. Bridge closed because of channel failure. Replacement necessary.

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BIR #21. DRAINAGE CULVERTS

This item is for noting damage or poor drainage characteristics in the approach drains. There is no rating scale. The inspector can note in the comments if there is ponding of water at the casting due to build up of debris or erosion of approach fill into the manhole.

Appendix 3 – OSIM Tables and Inspection Forms

Table 2.1: Element List and Condition State Cross Reference Table

Element Group	Element Name[6,7,8]	Unit for Quantity[1,2,3,4]	Applicable Condition State Table Number [5]
Abutments	Abutment walls	Sq.m.	4.5, 4.11, 4.19
	Ballast walls	Sq.m.	4.5, 4.11, 4.19
	Bearings	Each	4.2
	Wingwalls	Sq.m.	4.5, 4.11, 4.19
Accessories (Attachments and Signs)	Bridge Mounted Sign Supports[9]	Each	4.12
	Electrical[9]	Each	4.12
	Noise Barriers	m[10]	4.12
	Other	Each	4.12
	Signs	Each	4.12
	Utilities	Each	4.12
Approaches	Approach slabs	Sq.m.	4.5, 4.6
	Barriers[9]	m[10]	4.17,4.19
	Curb and Gutters	m.	4.5
	Drainage System	Each	4.7
	Sidewalk/Curbs	Sq.m.	4.5
	Wearing surface	Sq.m.	4.1, 4.5, 4.6
Barriers	Barrier/Parapet Walls	Sq.m.	4.5
	Hand Railings	m[10]	4.17
	Posts	Each	4.5, 4.16, 4.19
	Railing Systems	m[10]	4.17, 4.19
Beams/Main Longitudinal Elements	Diaphragms	Each (Sq.m if Concrete)	4.5, 4.15, 4.16, 4.19
	Floor beams	Sq.m.	4.5, 4.16, 4.19
	Girders	Sq.m.	4.5, 4.15, 4.16, 4.19
	Inside boxes (sides & bottom)	Sq.m.	4.5 , 4.15
	Stringers	Each	4.5 , 4.16, 4.19
Bracing	Bracing	Each	4.15, 4.16, 4.19
Coatings	Railing Systems / Hand Railings	Sq.m.	4.3
	Structural Steel	Sq.m.	4.4
Culverts	Barrels	Sq.m.	4.5, 4.14
	Inlet Components	Sq.m.	4.5
	Outlet Components	Sq.m.	4.5
Decks	Deck Top	Sq.m.	4.5, 4.6, 4.19
	Drainage System	Each	4.7
	Soffit – Inside Boxes	Sq.m.	4.5
	Soffit – Thick slab	Sq.m.	4.5
	Soffit – Thin Slab	Sq.m.	4.5, 4.19
	Wearing Surface	Sq.m.	4.1
Embankments & Streams	Embankments	Each	4.8
	Slope protection	Each	4.13
	Streams and Waterways	All	4.18
Foundations	Foundation (below ground level)	N/A	Rate performance only.
Joints	Armouring/retaining devices	m.	4.9
	Concrete end dams	Sq.m	4.5
	Seals/sealants	Each	4.10
Piers	Bearings	Each	4.2

Element Group	Element Name[6,7,8]	Unit for Quantity[1,2,3,4]	Applicable Condition State Table Number [5]
	Caps	Sq.m.	4.5, 4.11, 4.16, 4.19
	Shafts/columns/Pile Bents	Sq.m.	4.5, 4.11, 4.16, 4.19
Retaining walls	Barrier Systems on walls	Sq.m.	4.5, 4.17, 4.19
	Railing Systems	m[10]	4.17, 4.19
	Drainage Systems	All	4.7
	Walls	Sq.m.	4.5
Sidewalks/curbs	Curbs	Sq.m.	4.5
	Sidewalks and medians	Sq.m.	4.5
Trusses/Arches	Bottom chords	Sq.m.	4.5, 4.16, 4.19
	Connections	Each	4.16, 4.19
	Top chords	Sq.m.	4.5, 4.16, 4.19
	Verticals/diagonals	Sq.m.	4.5, 4.16, 4.19

Notes:
1 – For "All", place the entire component (100%) in one condition state.
2 – For "Each", give the number of occurrences of the component in each state.
3 – For cracks in concrete, estimate repair area (4m of crack = 1 sq. m of repair).
4 – For cracks in steel, estimate required repair area.
5 – Tables given are typical for element. Use appropriate table for applicable material. (See Section 4).
6 – Sub-elements (End/Middle) to be used for the following elements at expansion joint locations: Deck Top, Girders, Inside Boxes
Sub-elements (End/Intermediate) to be used for the following elements at expansion joint locations:: Floor Beams, Stringers, Bracing and Diaphragms
Sub-elements (End/Interior/Exterior) to be used for Soffits
Sub-elements (Interior/Exterior) to be used for Barrier/Parapet Walls
7 – For an explanation of which bridge components are included in each element, see Table 3.1.
8 – Similar element types should be grouped together (e.g. I-girders, x-frames, etc.)
9 - Optional element. Not required for MTO use.
10- For these elements that are inspected by linear metre, a defect in the post shall be assumed to affect the tributary area for that post.

Table 2.2: Element List for Each Bridge Type*

Element Group	Element Name	Sub-element	Slab on I-girder (Steel)	Slab on I-girder (Concrete)	Slab on Box-girder (steel)	Slab on Box-girder (concrete)	Post-tensioned deck (rect. voids)	Post-tensioned deck (circ. voids)	Solid Slab	Truss	Culvert	Rigid Frame
Abutments	Abutment walls		X	X	X	X	X	X	X	X		X
	Ballast walls		X	X	X	X	X	X	X	X		
	Bearings		X	X	X	X	X	X	X	X		
	Wingwalls		X	X	X	X	X	X	X	X	X	X
Accessories (Attachments and Signs)	Bridge Mounted Sign Supports		?	?	?	?	?	?	?	?	?	?
	Electrical		?	?	?	?	?	?	?	?	?	?
	Noise Barriers		?	?	?	?	?	?	?	?	?	?
	Other		?	?	?	?	?	?	?	?	?	?
	Signs		?	?	?	?	?	?	?	?	?	?
	Utilities		?	?	?	?	?	?	?	?	?	?
Approaches	Approach slabs		X	X	X	X	X	X	X	X		X
	Barriers		?	?	?	?	?	?	?	?	?	?
	Curb and gutters		?	?	?	?	?	?	?	?	?	?
	Drainage System		X	X	X	X	X	X	X	X	?	X
	Sidewalk/Curb		?	?	?	?	?	?	?	?	?	?
	Wearing surface		X	X	X	X	X	X	X	X	?	X
Barriers	Barrier/Parapet Walls	Interior/ Exterior (for faces of barrier)	X or	X or	X or	X or	X or	X or	X or	X or	X or	X or
	Hand Railings		?	?	?	?	?	?	?	?	?	?
	Posts		?	?	?	?	?	?	?	?	?	?
	Railing Systems		X	X	X	X	X	X	X	X	X	X
Beams / Main Longitudinal Elements (MLE's)	Diaphragms											
		End	X	X	X	X						
		Intermediate	X	?	X	?						
	Floor beams	End								X		
		Intermediate								X		
	Girders		X or	X or	X or	X or						
		End / Middle	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)						
	Inside boxes				X or	X or	X or					

Element Group	Element Name	Sub-element	Slab on I-girder (Steel)	Slab on I-girder (Concrete)	Slab on Box-girder (steel)	Slab on Box-girder (concrete)	Post-tensioned deck (rect. voids)	Post-tensioned deck (circ. voids)	Solid Slab	Truss	Culvert	Rigid Frame
		End/Middle			X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)					
	Stringers	End								X		
		Intermediate								X		
	Bracing	End								X		
		Intermediate								X		
Coatings	Barrier Systems / Hand Railings		?	?	?	?	?	?	?	?	?	?
	Structural Steel		X (Not applicable for ACR steel) or		X (Not applicable for ACR steel) or					X (Not applicable for ACR steel) or	X (Not applicable for ACR steel) or	
		End/Middle	X (only with exp. Joints)		X (only with exp. Joints)					X (only with exp. Joints)	X (only with exp. Joints)	
Culverts	Barrels										X	
	Inlet Components										X	
	Outlet Components										X	
Decks	Deck Top		X	X	X	X	X	X	X	X		X
	Drainage System		?	?	?	?	?	?	?	?		?
	Soffit – Inside Boxes				X or	X or	X or					
		End / Middle			X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)					
	Soffit – Thick slab (Post-tensioned decks and Rigid Frames)											X
		End					X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)			
		Exterior					X	X	X			X
		Interior					X	X	X			X
	Soffit – Thin Slab (Slab on I or Box Girders)	End	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)	X (only with exp. Joints)				X (only with exp. Joints)		
		Exterior	X	X	X	X				?		
		Interior	X	X	X	X				X		

Element Group	Element Name	Sub-element	Slab on I-girder (Steel)	Slab on I-girder (Concrete)	Slab on Box-girder (steel)	Slab on Box-girder (concrete)	Post-tensioned deck (rect. voids)	Post-tensioned deck (circ. voids)	Solid Slab	Truss	Culvert	Rigid Frame
	Wearing Surface		X	X	X	X	X	X	X	X	X	X
Embankments and Streams	Embankments		X	X	X	X	X	X	X	X	X	X
	Slope protection		X	X	X	X	X	X	X	X	X	X
	Streams and Waterways		? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	? (only for water crossing)	X	? (only for water crossing)
Foundations	Foundation (below ground level)		X	X	X	X	X	X	X	X	X	X
Joints	Armouring / retaining devices		?	?	?	?	?	?	?	X		
	Concrete end dams		?	?	?	?	?	?	?	X		
	Seals / sealants		?	?	?	?	?	?	?	X		
Piers (only for multi-span structures)	Bearings		X	X	X	X	?	?	?	X		
	Caps		?	?	?	?	?	?	?	?		?
	Shafts/Columns/Pile Bents		X	X	X	X	X	X	X	X	X	X
Retaining walls	Barrier Systems on Walls	Interior / Exterior (for faces of barrier)	?	?	?	?	?	?	?	?	?	?
	Walls		?	?	?	?	?	?	?	?	?	?
Sidewalks/curbs	Curbs		?	?	?	?	?	?	?	?		?
	Sidewalks and medians		?	?	?	?	?	?	?	?		?
Trusses/Arches	Bottom Chords									X		
	Connections									X		
	Top chords									X		
	Verticals / Diagonals									X		

Notes:

* = It should be noted that this list is for guidance only. The actual element list should be customised to suit the structure being inspected.

X = Element Required

X or = Element or subsequent element must be chosen (only 1 of the choices needs to be selected) e.g. Barrier /parapet wall or Railing System

? = May be applicable if component exists (e.g. Exp. Joint)

Table 3.1: Procedures for Computing Element Dimensions and Quantities

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
Abutments	Abutment walls		N/A	average width of abutment from wing wall to wing wall	Average top of bearing seat elevation – average top of ground elevation + bearing seat width + visible part of footing	# of abutments (2 max.)	width x height x count	Includes bearing seat width and top of footing (if visible).
	Ballast walls		N/A	average width wing wall to wing wall	For Decks without exp. Joints Average underside of deck soffit elevation – average bearing seat elevation For Decks with exp. joints Top of deck elevation – average bearing seat elevation	# of ballast walls	width x height x count	Quantity includes entire ballast wall even if some areas are not visible due to diaphragms.
	Bearings		N/A	N/A	N/A	Total # of bearings at abutments	count (Units are Each)	
	Wingwalls		average length of wing walls (from 6 bearing to end of approach)	N/A	Average height	# of wingwalls	length x height x count	
Accessories (Attachments and Signs)	Bridge Mounted Sign Supports		N/A	N/A	N/A	# of Accessories	Count (Each)	
	Electrical		N/A	N/A	N/A	# of Accessories	Count (Each)	
	Noise Barriers		Average length (including approach)	N/A	Height	# walls (typ. 2)	Count x Length (m)	
	Other		N/A	N/A	N/A	# of Accessories	Count (Each)	
	Signs		N/A	N/A	N/A	# of Accessories	Count (Each)	
	Utilities		N/A	N/A	N/A	# of Accessories	Count (Each)	

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
Approaches[6]	Approach slabs		Approach slab length	curb to curb width	Thickness	# of approaches	count x width x length	
	Barrier		Length of Barrier					
	Curb and gutters		avg. length of approach slab	N/A	Min. height of curb	# of curbs (2 per abutment maximum)	count x length (units are m)	
	Drainage System		N/A	N/A	N/A	N/A	Count (typ.) Units are Each	General drainage at each corner of the bridge.
	Sidewalk/Curb		avg. Length of approach slab	avg. width of sidewalk	Min. height of sidewalk curb	# of sidewalks	count x length x (width + height)	
	Wearing surface		Approach slab length	curb to curb width	Thickness	# of approaches	count x width x length	
Barriers	Barrier/Parapet Walls	Interior / Exterior (for faces of barrier)	total length including approaches (to end of approach slabs) for one side	Thickness at top	Barrier height	# of sides (typically 2)	length x height* x count	Sub-elements must be used and interior and exterior of barrier/parapet must be rated separately. * - include barrier top with interior. This element is also used for concrete end posts.
	Hand Railings		total length of railing on top of barrier (includes approaches) on one side	N/A	N/A	# of sides	count x length (units are m)	This element is to be used for railings on top of barrier/parapet walls.
	Posts		Length dimension of a post along length of bridge	width of post in transverse direction	Height of posts	# of posts	Count (units are Each)	This element is to be used for the post component of open type railing systems. (Posts of Wood, Steel, Concrete, etc).
	Railing Systems		length of 1 steel panel	N/A	Height of barrier	# of panels	length x count (units are m)	This element is to be used for open type of railing systems (steel railing, flex beam, etc)

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
Beams / Main Longitudinal Elements (MLE's)	Diaphragms		girder spacing or for cross or "K" bracing: total length of all bracing members measured along the length of the member	average width of flanges	Depth of section	# of individual diaphragm segments	Count (Units are Each) or For concrete use length x count x (height x 2 + width)	All Diaphragms on bridges with no expansion joints. To be used if all diaphragms are of the similar type and the deck does not have expansion joints. End sub-elements are not required. (See Figure 3.1b)
		End[1]	girder spacing or for cross or "K" bracing: total length of all bracing members measured along the length of the member	average width of flanges	Depth of section	# of individual diaphragm segments	Count (Units are Each) or For concrete use length x count x (height x 2 + width)	Diaphragms at support locations with expansion joints (piers, abutments). Similar diaphragm types should be grouped together. End sub-elements are required. (See Figure 3.1b)
		Intermediate	girder spacing or for cross or "K" bracing: total length of all bracing members measured along the length of the member	average width of flanges	Depth of section	# of individual members (braces)	Count (Units are Each) or For concrete use length x count x (height x 2 + width)	All diaphragms in the span(s).
	Floor beams		curb to curb width	average width of flanges (simple avg.)	Girder depth (flange to flange)	# of beams	length x count x (height x 2 + width x 3)	All floor beams. To be used if all floor beams are of the same type and the deck does not have expansion joints. (See Figure 3.1c)
		End	curb to curb width	average width of flanges (simple avg.)	Girder depth (flange to flange)	# of beams	length x count x (height x 2 + width x 3)	End floor beams at expansion joint locations. (See Figure 3.1c)
		Intermediate	curb to curb width	average width of flanges (simple avg.)	Girder depth (flange to flange)	# of beams	length x count x (height x 2 + width x 3)	Intermediate floor beams (See Figure 3.1c)

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
		(For Modular Bridges)	Length of stringer sets	Spacing of stringer sets	Stringer depth	# stringer set wide x # stringer sets long	count (Units are Each)	Stringer sets often span over a transom. Ramp at bridge ends is an approach slab and not a stringer.
		End	floor beam spacing	average width of flanges	Depth	# of stringers	count (Units are Each)	Stringers in end panel at exp. joint locations (See Figure 3.1c)
		Intermediate	floor beam spacing	average width of flanges	Depth	# of stringers	Count (Units are Each)	Stringers in intermediate panels
Bracing	Bracing		average length of 1 bracing member	N/A	N/A	# of bracing members	Count (Units are Each)	All Bracings - includes bracing between trusses and lateral bracing between floor system in horizontal plane - vertical plane is considered a diaphragm element (See Figure 3.1b)
		End	average length of 1 bracing member	N/A	N/A	# of bracing members	Count (Units are Each)	Bracings in end panel. (See Figure 3.1b)
		Intermediate	average length of 1 bracing member	N/A	N/A	# of bracing members	Count (Units are Each)	Bracings in Intermediate panel (See Figure 3.1b)
Coatings	Barrier Systems / Hand Railings		N/A	N/A	N/A	N/A	Use Area of corresponding Barrier System element	If the element units are not sq. m., obtain appropriate area.
	Structural Steel		N/A	N/A	N/A	N/A	Use Area of corresponding element such as girder, floor beams etc.	For all structural steel.
		End	N/A	N/A	N/A	N/A	Use Area of corresponding sub-element such as end of girder, end floor beams etc.	To be used if the corresponding element used "End" elements.

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
		Middle	N/A	N/A	N/A	N/A	Use Area of corresponding sub-element such as middle of girder, end floor beams etc.	To be used if the corresponding element used "Middle" elements
Culverts[5]	Barrels		total length of culvert	Average cell width	Height of cell	# of cells	total interior surface area for one cell x # of cells	Interior surface area includes soffit, walls and bottom slab of culvert if present
	Inlet Components		N/A	N/A	N/A	1	area of all inlet components	Includes all components. (head walls, cut-off walls, aprons, etc)
	Outlet Components		N/A	N/A	N/A	1	area of all outlet components	Includes all components. (head walls, cut-off walls, aprons, etc)
Decks	Deck Top		sum of span lengths + sum of overhangs[3]	overall width (out-to-out)	Deck thickness minimum	N/A	length x width	(See Figure 3.2b)
	Drainage System		N/A	N/A	N/A	N/A	Count (units are Each)	Includes all components such as drains, drain pipes, connecting pipes, etc. Can also be per side of bridge
	Soffit – Inside Boxes		sum of span lengths + sum of overhangs[3]	Sum of distance between top flanges inside of boxes (steel or concrete)	N/A	N/A	length x width	The entire soffit length inside the boxes. To be used for decks without expansion joints (See Figure 3.2c)
		End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	Sum of distance between top flanges of boxes (steel or concrete)	N/A	N/A	length x width	For decks with expansion joints (See Figure 3.2c)
		Middle	Sum of span lengths + sum of overhangs – sum of "Ends"	Sum of distance between top flanges of boxes (steel or concrete)	N/A	N/A	length x width	To be used in areas away from expansion joints in conjunction with the "end" element. (See Figure 3.2c).

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
	Soffit – Thick slab (Post-tensioned decks and Rigid Frames)	End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	overall width + fascias	N/A	N/A	length x width	For decks with expansion joints
		Exterior	Sum of span lengths + sum of overhangs – sum of "Ends"	fascias + cantilevers[4]	N/A	N/A	length x width	For Rigid frames, span lengths are from faces of abutments and piers and the cantilever is assumed to be 1m as shown in Figure 3.4. When End elements are used, the length will be reduced by the sum of the End elements. (See Figure 3.2c)
		Interior	Sum of span lengths + sum of overhangs – sum of "Ends"	overall width – cantilevers[4]	N/A	N/A	length x width	For Rigid frames, span lengths are from faces of abutments and piers. When End elements are used, the length will be reduced by the sum of the End elements. (See Figure 3.2c)
	Soffit – Thin Slab (Slab on I or Box Girders)	End	Range 1 to 3 m, with default of 2m. Inspector has option to choose a length between 1 to 3 m.	fascias + exterior cantilevers to flanges + sum of distances between flanges (for boxes use outside of box top flanges only)	N/A	N/A	length x width	For decks with expansion joints
		Exterior	Sum of span lengths + sum of overhangs – sum of "Ends"	fascias + exterior cantilevers to flanges	N/A	N/A	length x width	When End elements are used, the length will be reduced by the sum of the End elements.

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
		Interior	Sum of span lengths + sum of overhangs – sum of "Ends"	sum of distances between flanges (for boxes use outside of box top flanges only)	N/A	N/A	length x width	When End elements are used, the length will be reduced by the sum of the End elements.
	Wearing Surface		Sum of span lengths + Sum of overhangs	Roadway width (curb to curb)	Thickness of wearing surface from drawings	N/A	length x width	
Embankments & Streams	Embankments		N/A	N/A	N/A	N/A	Units are Each	A typical abutment has 3 embankments (1 at front face and 2 side slopes).
	Slope protection		N/A	N/A	N/A	N/A	Units are Each	A typical abutment has 3 slopes (1 at front face and 2 side slopes).
	Streams and Waterways		N/A	N/A	N/A	N/A	Units are All	
Foundations	Foundation (below ground level)		N/A	N/A	N/A	N/A	N/A	Foundation is considered to be anything below ground. This element is rated for performance only and not material condition. If top of footing is visible, it should be rated under the Abutment wall or Pier Shaft element.
Joints	Armouring / retaining devices		Overall width (out-to-out) for 1 armouring	N/A	N/A	# of armourings (Typically, 2 per joint x # of joints)	count x length (units are m)	For multi-seal joints, the total length shall include the armouring, separator beams, support beams, etc.
	Concrete end dams		Curb to curb width	width of one side only	N/A	# of end dams (2 per joint x # of joints)	length x width x count	
	Seals / sealants		Overall width of bridge (for 1 seal)	N/A	N/A	# of seals	count (units are Each)	
Piers	Bearings		N/A	N/A	N/A	Total # of bearings at piers	count (Units are Each)	

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
	Caps		Thickness or length of caps parallel to length of bridge	width of cap	Depth or height of cap	# of caps	count x 2 x [(width x height) + (length x height) + (length x width)]	
	Shafts/Columns/Pile Bents		*For Rectangular Shaft or Column:* Thickness parallel to bridge length *For Round Columns , Pipe Piles or Timber Piles:* Diameter *For H-Pile Bents:* web heights	**For rectangular Shaft or Column:** avg. width of shaft or column *For Round Columns , Pipe Piles or Timber Piles:* Diameter *For H-Piles:* flange width	Bearing seat elevation or elevation at bottom of pier cap - top of ground elevation (if under water use stream bed elevation)+ bearing seat width+visible part of footing	# of shafts or # of columns or # of piles	**For Rectangular Shafts or Columns:** 2 x (length + width) x height x count **For Round Columns, Pipe Piles or Timber Piles:** B x width x height x count **For H Piles:** *count x height x (2 x length + 4 x width)*	Note: similar shapes should be combined as an element Includes bearing seat width and top of footing (if visible).
Retaining walls	Barrier Systems on Walls	Interior / Exterior (for faces of barrier)	total length including approaches (to end of approach slabs) for one side	N/A	Barrier height	# of sides (typically 2)	length x height x count	Sub-elements must be used and interior and exterior of barrier/parapet must be rated separately.
	Walls		average length of wall	N/A	Average height of wall	# of walls	length x height x count	
Sidewalks/curbs	Curbs		total length of bridge excluding approaches	avg. width of all curbs	Maximum height (need to verify in field because of resurfacing)	# of curbs	length x (width + height) x count	See Figure 3.3 for definition of sidewalk / median and curb
	Sidewalks and medians		total length of bridge excluding approaches	avg. width of all sidewalks / medians	Maximum height (need to verify in field because of resurfacing)	# of sidewalks / medians	length x (width + height) x count	See Figure 3.3 for definition of sidewalk / median and curb

Element Group	Element Name	Sub-element	Length (m)	Width (m)	Height (m)	Count	Quantity (Sq.m)[1]	Comments
Trusses/Arches	Bottom Chords		total length of top chord (all panels)	average flange width	Depth of section	# of chords/side = 2 usually	*For I Sections:* quantity = count x length x(height x 2 + 4 x width) *For T or L Sections:* quantity = count x length x (height x 2 + 2 x width)	
	Connections		N/A	N/A	N/A	# of connections	Count (Units are Each)	Main truss connections[7]
	Top chords		total length of top chord (all panels)	average flange width	Depth of section	# of chords/side = 2 usually	*For I Sections:* quantity = count x length x (height x 2 + 4 x width) *For T or L Sections:* quantity = count x length x (height x 2 + 2 x width)	
	Verticals / Diagonals		average length of diagonals	average flange width	Depth of section	# of verticals / diagonals for all sides	*For I Sections:* quantity = count x length x (height x 2 + 4 x width) *For T or L Sections:* quantity = count x length x (height x 2 + 2 x width)	

Notes: ***1*** *– Default units are sq.m unless noted otherwise.* ***2*** *– End elements are to be used at all expansion joint locations*

3 *– Overhang = Distance from centre of Bearing to end of deck (See Figure 3.1a, 3.2a)* ***4*** *– For definition of Cantilever, See Figure 3.4*

5 *– Culverts include soil-steel structures.*

6 *– The length of the "approach" should be taken as the length of the approach slab or the length to the end of the wingwalls (whichever is greater). For modular bridges, the ramps are taken as approaches.*

7 *– For Modular bridges, a separate connection occurs for the top and bottom chord, but all panels wide plus chord reinforcement is part of 1 connection.*

Table 4.1: Asphalt Wearing Surface

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No Observed Material Defects	Light cracking	Medium cracking	Severe to very severe cracking
	Light ravelling	Medium ravelling	Severe and very severe ravelling
			All areas with loss of bond
	Light Potholes	Medium Potholes	Severe and very severe potholes
	Light wheel track rutting	Medium wheel track rutting	Severe and very severe wheel track rutting
	Light Rippling	Medium Rippling	Severe and Very Severe Rippling
	Light Flushing	Medium Flushing	Severe and very severe flushing

For all calculations, the actual area shall be determined for areas containing numerous cracks (i.e. alligator cracks, radial cracks). For isolated cracks, 4 m of crack length is to equal to 1 square metre of defect repair area.

Table 4.2: Bearings

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No Observed Material Defects	Hairline cracks in elastomeric pads	Narrow to medium cracks in elastomeric pads	Very wide cracks in elastomeric pads and/or steel plates debonded
	Light bulging or shear deformations in elastomeric pads, or light local deformation of roller/rocker plates	Medium bulging or shear deformations in elastomeric pads, or medium local deformation of roller/rocker plates	Severe bulging or shear deformations in elastomeric pads, or severe local deformation of roller/rocker plates
	Light scoring/scratches in TFE or stainless steel	Medium scoring/scratches in TFE or stainless steel	Severe scoring/scratches or rips and tears in TFE or stainless steel
	Light Corrosion	Medium Corrosion	Severe and very severe corrosion and or cracks in steel
	Anchor bolts slightly bent	Anchor bolts severely bent and cracked	Anchor bolts are broken
	Guide bars and thrust plates slightly worn	Guide bars and thrust plates moderately worn	Guide bars and thrust plates severely worn and/or loose or missing nuts
	Up to 5% of bonded sliding surface is debonded	5% to 20% of bonded sliding surface is debonded	Over 20% of bonded sliding surface is debonded
			Internally confined compression material is squeezing or squeezed out

Table 4.3: Coating* – Steel Railings

Excellent Condition	Good Condition	Fair Condition	Poor Condition
RUST CONDITION** RATING CATEGORY 1	RUST CONDITION RATING CATEGORY 2	RUST CONDITION RATING CATEGORY 3	RUST CONDITION RATING CATEGORY 4 or higher

Table 4.4: Coating* - Structural Steel Substructures And Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No Observed Material Defects	Chalking	Checking, cracking, alligatoring	
		Intercoat delamination, peeling (top coat only)	Undercutting, blisters, peeling (prime coat), underfilm corrosion
		Signs of chemical attack	
	Overspray, runs, sags, pinholing	Bridging, edge defects, shadows	
RUST CONDITION** RATING CATEGORY 1	RUST CONDITION** RATING CATEGORY 2	RUST CONDITION** RATING CATEGORY 3	RUST CONDITION** RATING CATEGORY 4 or higher
		Coating Condition Survey is required if the combined area in the Fair and Poor Condition States is greater than 25% and the area in the Poor Condition State is less than 10% ***	

* Galvanized elements are included under the "Coating" category

** Rust Condition Ratings based on ASTM D 610 sketches are shown in Figure 4.1.

*** In order to consider overcoating as a viable rehabilitation option, a detailed condition survey should be triggered before deterioration is too widespread. If the percentage in Poor Condition exceeds 10%, overcoating is not a feasible treatment and a coating condition survey is not required.

Table 4.5: Concrete – Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light scaling	Medium scaling	Severe to very severe scaling, erosion and disintegration
	Rust stains on concrete due to corroding rebar chairs	Rust stains on concrete due to corroding reinforcing steel	Medium to very severe corrosion of reinforcing steel
	Surface carbonation (Reaction with CO_2, associated discolouration, shrinkage and cracks)	Surface defects such as stratification, segregation, cold joints, abrasion, wear, slippery surfaces, wet areas and surface deposits (except on soffits).	
	Light honeycombing and pop-outs	Medium honeycombing and pop-outs	Severe to very severe honeycombing and pop-outs
	Hairline and Narrow cracks	Medium cracks	All wide cracks
	Light alkali-aggregate reaction	Medium alkali-aggregate reaction	Severe and very severe alkali-aggregate reaction
		Stable relative displacement between precast units. Leaking between precast units.	Active relative displacement between precast units
			All delaminated and spalled areas
		Active wet areas on soffit without cracks	Active wet areas or leachate deposits on soffit with associated cracks
			Condition Survey if area of deterioration in this state >10% for substructures
			Deck Condition Survey if area of deterioration in this state >10% for superstructures

Notes:

(1) For all calculations, the actual area shall be determined for areas containing numerous cracks (i.e. pattern cracks, map cracks). For isolated cracks, 4 m of crack length is to equal to 1 square metre of defect repair area.

(2) If shear cracks are found at girder ends, an evaluation should be done. If cracks are wide, the inspector should mark "URGENT" for the timeframe of the evaluation. As with other potentially unsafe conditions, the bridge owner should be notified if these cracks are noticed.

Table 4.6: Concrete - Top of Deck Beneath Asphalt Wearing Surface

Based on Visual Inspection of Asphalt			
Excellent Condition	**Good Condition**	**Fair Condition**	**Poor Condition**
No Asphalt Defects.	Top-Down Asphalt Defects	Bottom-Up Asphalt Defects	
		Local protrusions in asphalt.	All Potholes in asphalt.
	Light and medium isolated cracks in asphalt.	Wide isolated cracks in asphalt. (Cracks include: longitudinal cracks, above location of voids, edge of beam flanges, joint between precast units, construction joints, etc., or transverse cracks)	
			All Pattern cracking in asphalt (e.g. map, alligator, radial, edge cracking).
	All Bond Defects (e.g. rippling, loss of bond) in asphalt.		
	All Surface Defects (e.g. ravelling, flushing, slippery surface) in asphalt.		
	All Surface Distortions (wheel track rutting) in asphalt.		
			Condition survey if the area of deterioration in this state >10% if not already done.

Notes:

(1) For all calculations, the actual area shall be determined for areas containing numerous cracks (i.e. alligator cracks, radial cracks). For isolated cracks, 4 m of crack length is to equal to 1 square metre of defect repair area.

(2) If a bridge has been recently repaved without rehabilitating the deck, the inspector must estimate the condition of the concrete deck using other means. This would include using previous inspection information, the age of the waterproofing, deck condition survey data, etc.

Table 4.7: Drainage System

Excellent Condition	**Good Condition**	**Fair Condition**	**Poor Condition**
No observed material defects	Up to 20% of individual drainage system has loose or deteriorated components, connections or fasteners	20% to 60% of individual drainage system has loose or deteriorated components, connections or fasteners	More than 60% of individual drainage system has loose or deteriorated components, connections or fasteners
			Broken pipe components resulting in water draining onto substructure

Table 4.8: Embankments

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Up to 10% loss of material for embankments not directly supporting foundations; or, up to 5% loss for embankments directly supporting foundations	10% - 30% loss of material for embankments not directly supporting foundations; or 5% to 15% loss for embankments directly supporting foundations; or, loss of material to the top of foundations	More than 30% loss of material for embankments not directly supporting foundations; or, more than 15% loss for embankments directly supporting foundations; or, loss of material to the bottom of foundations

Table 4.9: Expansion Joint – Armouring and Retaining Devices

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light Corrosion*	Medium Corrosion*	Severe Corrosion* Bolts, anchors, armouring, clamping devices or welds are loose, broken or missing.

* As defined in Table 4.16.

Table 4.10: Expansion Joint – Seals/Sealants

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Abrasions in seal with no perforations	Loss of resiliency of seal but no perforations	Cracks, tears or holes in the seal
			Seal has debonded
			Seal is allowing leakage on the substructure. Sealant debonded, pulled out or settled.

Table 4.11: Masonry Construction

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Hairline and narrow cracks	Medium cracks	Wide cracks
		Leaching of lime based mortar	
	Light splitting, spalling and disintegration	Medium splitting, spalling and disintegration	Severe and very severe splitting, spalling and disintegration
	Light loss of pointing mortar	Medium loss of pointing mortar	Severe and very severe loss of pointing mortar and stones

Table 4.12: Accessories (Attachments and Signs)

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed defects	Not a standard sign	Not located according to standards	Illegible
			Gives misleading, wrong or inaccurate information
			Sign is missing
	Light material defects	Medium material defects. Loose, damaged or bent components on attachment	Severe and very severe material defects. Broken or missing components on attachment

Table 4.13: Slope Protection

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Loss or deterioration of less than 20% of slope protection material	Loss or deterioration of 20% to 60% of slope protection material	Loss or deterioration of more than 60% of slope protection material

Table 4.14: Soil-Steel Structures*

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects		Medium Cusping or Crimping of corrugations (less than 10 mm in height)	Severe Cusping or Crimping of corrugations (greater than 10 mm in height)
		Medium Global Deformation (less than 10% of culvert diameter)	Severe Global Deformation (greater than 10% of culvert diameter or with reverse curvature)
		Bolt tilting	Cracks
	Light Corrosion (surface rust).	Medium Corrosion (Shallow pitting and corrosion scale over surface – less than 10% section loss)	Severe Corrosion (Deep pitting and corrosion scale over surface – greater than 10% section loss)

* - Unit of measure for soil-steel structures is m^2. The area of defect should be recorded for Severe Corrosion (excluding corrosion with perforations), as well as for the Excellent, Good and Fair Condition States. For all other portions in the Poor Condition State (cusping, crimping, deformations, cracks and corrosion with perforations) the area shall be taken to include the entire circumference. This is due to the importance of soil-steel interaction and continuity of the radial corrugations of steel where such a defect at one point on the culvert will affect the entire circumference.

Table 4.15: Steel – Atmospheric Corrosion Resistant Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects with smooth uniform rust layer (patina)	Early signs of patina flaking and no section loss	Flaking and delamination of Patina up to 10% section loss	More than 10% section loss
			All cracks
			Permanent deformations
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies
			Evaluation and condition survey* if > 10% in this state.

* Involves measuring thickness of critical members to determine section loss as it varies across the element.

Table 4.16: Steel or Aluminum – Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light corrosion – no section loss	Medium corrosion - up to 10% section loss	Severe and very severe corrosion – more than 10% section loss
			All cracks (immediate action is required -estimate repair area)
			Permanent deformations
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies
			Evaluation and condition survey* if > 10% in this state.

* Involves measuring thickness of critical members to determine section loss as it varies across the element.

Table 4.17: Steel or Aluminum - Railings

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light corrosion – no section loss	Medium corrosion - up to 10% section loss	Severe and very severe corrosion – more than 10% section loss
	Slight loss of cable tension or slight slippage of cable anchors and splices	Moderate loss of cable tension or slight slippage of cable anchors and splices	Significant loss of cable tension or slight slippage of cable anchors and splices
			Broken cable strands/supports
			Collision or vandalism damage/missing sections
			Permanent deformations
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies

Table 4.18: Streams and Waterways

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	A few locations of scour or degradation of the stream bed or stream banks but not exposing the foundations	Numerous locations of scour or degradation of the stream bed or stream banks to the top of the previously covered foundations	Scour or degradation of the stream bed or stream banks to the bottom of previously covered foundations
	Slight scour at inlet or outlet of culverts and soil-steel structures	Moderate scour at the inlet or outlet of culverts and soil-steel structures	Extensive scour around the inlet or outlet of culverts and soil-steel structures with loss of embankment fill
	Stream alignment shifted but not encroaching against components previously not subject to stream flow	Stream alignment shifted and encroaching close to components not previously subject to stream flow	Stream alignment shifted with stream flow directly against most of a component not previously subject to stream
	A few locations of aggradation not affecting the stream flow at the structure	Medium aggradation having a significant effect on the stream flow at the structure	Extensive aggradation very severely affecting the stream flow at the structure)

Table 4.19: Wood – Substructures and Superstructures

Excellent Condition	Good Condition	Fair Condition	Poor Condition
No observed material defects	Light checks and shakes.*	Medium checks and shakes.*	Severe and very severe checks, and shakes and all splits.*
	Light weathering	Medium weathering	Severe and very severe weathering
	Light rot or decay	Medium rot or decay	Severe and very severe rot or decay.
	Light insect damage	Medium Insect Damage	Severe and very severe insect damage
	Light abrasion and wear	Medium Abrasion and wear	Severe and very severe abrasion and wear
	Light cracking, splintering, crushing and shattering	Medium cracking, splintering, crushing and shattering	Severe and very severe cracking, splintering, crushing and shattering
	Light fire and chemical damage	Medium fire and chemical damage	Severe and very severe fire and chemical damage
	Light connection deficiencies	Medium connection deficiencies	Severe connection deficiencies
			Condition survey if area of deterioration in this state > 10%

* - These naturally occurring cracks in the wood, caused by shrinkage, are not as severe as overload cracking or splintering since wood fibres exist to bridge the crack and reduce the impact on the member capacity. The actual area containing the defect shall be determined for areas containing numerous defects. For isolated cracks, 8 m of crack length is equal to 1 square metre of defect for checks, shakes and splits; while 4 m of crack length is equal to 1 square metre of defect for cracking, splintering, crushing and shattering. The length of cracks, shakes, splits, etc. shall be measured on all surfaces.

Table 5.1: Suspected Performance Deficiencies

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
1	Load Carrying Capacity	Girder, Deck Top, Railing System, etc (Note – deficiencies in most elements can trigger a strength evaluation)	• Material defects leading to loss of strength, or which are indicative of inadequate strength of the component (eg.20% section loss at mid-span of girder) • Detrimental modifications made subsequent to construction; • Strong evidence of under design for current loads.	• Strength evaluation • Monitoring of deformations (displacements or rotations) or cracks.
2	Excessive Deformations	Railing System, Deck Top, Truss Chord, Abutment Wall, Bearings, etc	• Severely bent members • Overloading, either single or repetitive occurrence, resulting in permanent deformations of the deck or deck components. • Permanent deformations, especially in compression components • Unanticipated or excessive vibration or deflection of components, connections or joints under live loads • Unexpected noise from components or connections due to vehicles moving across the structure. • Mis-alignment, lateral deformation, warping, etc. of components; • Inability of the abutment to withstand lateral earth pressures, as indicated by long, medium horizontal cracks in abutments; • Deformation of the roof slab, floor slab or walls of culverts. • Deformation of soil-steel structures such as flattening or peaking of the soffit or buckling of the shoulders or haunches; • Up-lift at ends of soil-steel structures • Movements causing distress in a bearing or it's components, or in other structure components;	• Strength evaluation • Monitoring of deformations (displacements or rotations)
3	Continuing settlement	Foundation	• Loss of strength or support for applied loads due to material defects; • Loss of material supporting foundations due to scour or erosion • Consolidation or failure of underlying soil resulting in cracking or movement of foundations, abutments or piers • Loss of contact between piles and pile cap or pier cap; • Changes in the inclination of piles. • Rotational movement of pile caps and loss of full contact with piles.	• Regular Monitoring of settlement, pier and abutment elevations and crack widths • Strength evaluation • Geotechnical investigation • Underwater investigation
4	Continuing Movements	Abutment Wall, Pier, Deck Top, Bearings, etc	• Out of plumb of abutment walls, piles, piers or other components supported on them;	• Regular monitoring and measurement of movements, inclinations,

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
			• Tilting or bulging of Retained Soil System (RSS) walls • Unusual or unexpected substructure movements occurring during the passage of heavy vehicles over the bridge; • Tapering or misalignment of cracks and joints in foundations, abutments, piers or other components supported on them; • Sudden drops or kinks in the structure profile over piers or abutment walls when sighting along railings or beam lines; • Abnormally large or small openings or misalignment of deck expansion joints at abutments and piers; • Abnormal displacements or inclinations of bearings; • Abnormally large or small clearance between ballast wall and superstructure; • Cracks in abutment wall and ballast wall • Shift in alignment from original position;	crack widths, etc. • Underwater investigation • Geotechnical investigation
5	Seized Bearings	Bearings	• Binding or jamming of expansion or rotational components due to corrosion, lack of lubrication or damage to sliding surfaces;	• Strength evaluation to account for change in articulation • Lubricate Bearings (Maintenance Operation)
6	Bearing not uniformly loaded/unstable	Elastomeric Bearing, Rocker Bearing, etc	• Non-uniform contact of bearing surfaces with each other or with bearing seat • Excessive inclinations of bearings	• Regular monitoring of bearing movements
7	Jammed expansion Joint	Armouring/ retaining devices	• Inadequate joint gap to accommodate anticipated further movement; • Surfacing materials have jammed in the joints during resurfacing of deck; • Design or construction problems not allowing proper movement of multi-seal joints.	• Regular monitoring of deck movements • Clean out gap (Maintenance operation)
8	Pedestrian/ vehicular hazard	Armouring/ retaining devices, Sidewalk	• Vertical or horizontal misalignment across the joint; • Severe material defects (e.g. Spalling) • Horizontal, vertical or rotational displacements in curbs and sidewalks as they are hazardous to pedestrian and vehicular safety, and present obstructions to snow plows. • Inadequate curb height, or loss of curb height for sidewalks due to the placement of an additional layer of wearing surface or deck overlay	• Remove obstruction (Maintenance operation) • Review Code requirements for curb height
9	Rough Riding Surface	Wearing Surface, Approach slabs	• Rough approaches, settlement or consolidation of approach embankments, or deterioration of the approach slabs or ramps, resulting in vehicles "bouncing"	• Smooth out asphalt at approach (Maintenance operation) • Strength evaluation

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
			onto the bridge. In addition to applying excessive dynamic loading to the bridge, this may also result in difficulty in maintaining vehicle control • Depressions and cracks in the roadway pavement above culverts and soil-steel structures;	
10	Surface Ponding	Sidewalk, Wearing surface	• Water ponding on sidewalks/wearing surface, as it presents a safety hazard, especially if allowed to freeze;	• Fill in depression with asphalt (Maintenance Operation)
11	Deck Drainage	Drainage System	• Deck drains not provided where necessary, or have inadequate size of opening; • Deck drains and drainage systems improperly constructed with inadequate slopes or sharp directional changes; • Drainage system plugged or partially plugged and not allowing for free and unobstructed flow of water; • Drainage outlets discharging directly onto structure components or roadways below the deck; • Drainage outlets discharging directly onto embankment without proper provision for collecting, channelling and controlling of discharge with splashpads, spillways or gutters; • Inadequate provision for drainage at the structure approaches.	• Review deck drainage requirements
12	Slippery Surfaces	Deck Top	• Loss in riding comfort and potential loss of vehicle control due to defects in the component material; • Loss of protection to underlying surfaces due to defects in the wearing surface materials;	• Resurface problem area (Maintenance Operation)
13	Flooding/ Channel Blockage	Streams & Waterways	• **The inspector should look for the following evidence of high water levels, inadequate opening at the structure and adverse affects on other components of the structure:** • Bending or buckling of the lower chord of steel trusses in the downstream direction by ice or heavy debris; • Ice scars and damage to substructures; • Coarse debris, such as branches and small trees, caught or wedged under the superstructure; • Fine debris, such as grass and twigs, on fences, trees, embankments, structures, etc.; • Wash lines on bare soil slopes; • Mud or silt deposited on embankments;	• Determine historical frequency of flooding and recorded water levels and compare to current high water elevation • Monitor water elevations throughout year • Perform hydrology study

	Suspected Performance Deficiency	Element Name (Examples)	Description of Deficiency	Possible Follow-up Action
			• Marks and stains on structures.	
14	Undermining of Foundation	Streams & Waterways or Foundation	• Loss of material supporting foundations due to scour or erosion.	Underwater Investigation
15	Unstable Embankments	Embankments	• Settlement of embankment, slope protections or approach roadway; • Sliding failure of the toe or slopes of the embankment; • Surface or deep seated slips; • Loss of embankment material from under foundations.	Geotechnical investigation
16	Other			

Table 6.1: Maintenance Needs

	Maintenance Need	Description
1	Lift and Swing Bridge Maintenance	The operation, maintenance and repair activities that are unique to lift and swing bridge structures, including all mechanical equipment and electrical devices such as signals, flashers, lighting, navigation lights, etc., but not including work defined by other structural maintenance operations.
2	Bridge Cleaning	The cleaning of bridge components including: 1) Washing of bearings, bearing seats, truss members, etc. 2) Sweeping of bridge decks, curbs and gutters. 3) Removal of debris from expansion joints. 4) Debris pick-up or minor removal of aggregate. 5) Cleaning of catch-basins, man-holes and deck drains.
3	Bridge Railing System Maintenance	The painting, repair and/or replacement of metal handrails, railing systems and posts, as well as touch-up painting activities.
4	Painting Steel Bridge Structures	The preparation (sandblasting, etc.) and painting of structural steel. Includes handrails when performed as part of an overall bridge painting operation.
5	Bridge Deck Joint Repair	The repair and/or replacement of expansion and/or fixed deck joints and end dams.
6	Bridge Bearing Maintenance	The adjustment, repair and/or replacement of bridge bearings. Includes all work directly associated with bridge bearings.
7	Repair to Structural Steel	The repair of all structural steel, including repair or replacement of steel components, bolts and fasteners.
8	Repair of Bridge Concrete	The repair of all concrete components of the structure, such as localized areas on exposed decks or concrete end dams, curbs, pedestrian walks, concrete handrail posts, parapet walls, abutments and piers, except when the repair is more directly associated with one of the other defined bridge maintenance operations or the quantity of repair is excessive for a maintenance operation.
9	Repair of Bridge Timber	The repair of all bridge timber, including the repair of timber decks on steel bridges.
10	Bailey Bridges – Installation, Maintenance and Removal	The installation, removal, repair and maintenance work that is unique to Bailey Bridges, but not including work defined by other structural maintenance operations.
11	Animal/Pest Control	The installation and maintenance of animal/pest control devices under bridge structures such as pigeon-proofing.
12	Bridge Surface Repair	The repair of bridge surfaces such as pothole patching.
13	Erosion Control at Bridges	Operations performed to prevent or repair damage due to erosion, such as scour at abutments and around piers, and washouts on slopes. Includes removal of obstructions to water flow, clearing of vegetation growth, etc.
14	Concrete Sealing	The sealing or treatment of bridge concrete surfaces with approved materials, as well as the preparation of surfaces prior to treatment.
15	Rout and Seal – Concrete and Asphalt Pavement on Bridge Decks	The routing of joints and/or cracks in concrete and asphalt pavement and the filling of same with joint fillers or rubberized asphaltic sealing compounds.
16	Bridge Deck Drainage	The repair, maintenance and replacement/ extension of deck drains. Includes steaming and calcium application to unthaw.
17	Scaling (Loose Concrete or ACR Steel)	The removal of loose delaminated concrete or delaminated patina of ACR steel girders that pose a risk as a falling hazard.
18	Other Maintenance	A maintenance activity that does not fit into any other category.

Table 7.1: List of Materials

MATERIAL			
Aluminum	Corrugated steel	Mass concrete	Steel
Asphalt	Gravel	Plastic	Weathering steel
Cast Iron	Hybrid	Precast concrete	Wood
Cast-in-place concrete	Masonry	Retained soil system	Other

Table 7.2: Examples of Environmental Exposure

Severe	Moderate	Benign
Exposed Concrete Deck	Concrete Deck with waterproofing	
	Exterior Soffit	Interior Soffit
Railings and inside face of Barrier Walls	Outside face of barrier wall	
Abutment in splash zone	Abutment at expansion joint	Abutment with no joint (integral abutment)
Pier in splash zone	Pier at expansion joint	Pier with no joint (where deck continuous)
	End Portion of Beams (at joints)	Remainder of Beams
Joints		

Ontario Structure Inspection Manual – Inspection Form **MTO Site Number:** ____

Inventory Data:

Structure Name			
Main Hwy/Road #	On ☐ Under ☐	Crossing Type:	☐ Navig. Water ☐ Non-Navig. Water ☐ Rail ☐ Road ☐ Ped. ☐ Other
Hwy/Road Name			
Structure Location			
Latitude		Longitude	
Owner(s)		Heritage Designation:	☐ Not Cons. ☐ Cons./not App. ☐ List/not Desig. ☐ Desig./not List ☐ Desig. & List
MTO Region		Road Class:	Freeway ☐ Arterial ☐ Collector ☐ Local ☐
MTO District		Posted Speed	No. of Lanes
Old County		AADT	% Trucks
Geographic Twp.		Inspection Route Sequence	
Structure Type		Interchange Number	
Total Deck Length	(m)	Interchange Structure Number	
Overall Str. Width	(m)	Min. Vertical Clearance	(m)
Total Deck Area	(sq.m)	Special Routes:	☐ Transit ☐ Truck ☐ School ☐ Bicycle
Roadway Width	(m)	Detour Length Around Bridge	(km)
Skew Angle	(Degrees)	Direction of Structure	
No. of Spans		Fill on Structure	(m)
Span Lengths			(m)

Historical Data:

Year Built		Year of Last Major Rehab.	
Last OSIM Inspection		Last Evaluation	
Last Enhanced OSIM Inspection		Current Load Limit	/ / (tonnes)
Enhanced Access Equipment (ladder, boat, lift, etc.)		Load Limit By-Law #	
Last Underwater Inspection		By-Law Expiry Date	
Last Condition Survey			

Rehab History: (Date/description)

Scheduled Improvements:			
Regional Priority Number		Programmed Work Year	
Nature of Program Work:			

Appraisal Indices:		**Comments**
Fatigue		
Seismic		
Scour		
Flood		
Geometrics		
Barrier		
Curb		
Load Capacity		

Ontario Structure Inspection Manual – Inspection Form **MTO Site Number:** ☐

Field Inspection Information:			
Date of Inspection:		Type of Inspection:	☐ OSIM ☐ Enhanced OSIM
Inspector:			
Others in Party:			
Access Equipment Used:			
Weather:			
Temperature:			

Additional Investigations Required:	Priority		
	None	Normal	Urgent
Material Condition Survey			
Detailed Deck Condition Survey:			
Non-destructive Delamination Survey of Asphalt-Covered Deck:			
Concrete Substructure Condition Survey:			
Detailed Coating Condition Survey:			
Detailed Timber Investigation			
Post-Tensioned Strand Investigation			
Underwater Investigation:			
Fatigue Investigation:			
Seismic Investigation:			
Structure Evaluation:			
Monitoring			
Monitoring of Deformations, Settlements and Movements:			
Monitoring Crack Widths:			
Investigation Notes:			

Overall Structure Notes:	
Recommended Work on Structure:	☐ None ☐ Minor Rehab. ☐ Major Rehab. ☐ Replace
Timing of Recommended Work:	☐ 1 to 5 years ☐ 6 to 10 years
Overall Comments:	
Date of Next Inspection:	

Suspected Performance Deficiencies

01 Load carrying capacity
02 Excessive deformations (deflections & rotations)
03 Continuing settlement
04 Continuing movements
05 Seized bearings
06 Bearing not uniformly loaded/unstable
07 Jammed expansion joint
08 Pedestrian/vehicular hazard
09 Rough riding surface
10 Surface ponding
11 Deck drainage
12 Slippery surfaces
13 Flooding/channel blockage
14 Undermining of foundation
15 Unstable embankments
16 Other

Maintenance Needs

01 Lift and Swing Bridge Maintenance
02 Bridge Cleaning
03 Bridge Handrail Maintenance
04 Painting Steel Bridge Structures
05 Bridge Deck Joint Repair
06 Bridge Bearing Maintenance
07 Repair to Structural Steel
08 Repair of Bridge Concrete
09 Repair of Bridge Timber
10 Bailey bridges - Maintenance
11 Animal/Pest Control
12 Bridge Surface Repair
13 Erosion Control at Bridges
14 Concrete Sealing
15 Rout and Seal
16 Bridge Deck Drainage
17 Scaling (Loose Concrete or ACR Steel)
18 Other

Element Data

Element Group:		Length:				
Element Name:		Width:				
Location:		Height:				
Material:		Count:				
Element Type:		Total Quantity:				
Environment:	Benign / Moderate / Severe	Limited Inspection ☐				
Protection System:						Perform. Deficiencies
Condition Data:	Units	Exc.	Good	Fair	Poor*	
	m^2 / m / each / % / all					
Comments:						
Recommended Work:	☐ Rehab ☐ Replace ☐ 1-5 years ☐ 6-10 years	Maintenance Needs:				
		☐ Urgent ☐ 1 year ☐ 2 year				

Element Group:		Length:				
Element Name:		Width:				
Location:		Height:				
Material:		Count:				
Element Type:		Total Quantity:				
Environment:	Benign / Moderate / Severe	Limited Inspection ☐				
Protection System:						Perform. Deficiencies
Condition Data:	Units	Exc.	Good	Fair	Poor*	
	m^2 / m / each / % / all					
Comments:						
Recommended Work:	☐ Rehab ☐ Replace ☐ 1-5 years ☐ 6-10 years	Maintenance Needs:				
		☐ Urgent ☐ 1 year ☐ 2 year				

Element Group:		Length:				
Element Name:		Width:				
Location:		Height:				
Material:		Count:				
Element Type:		Total Quantity:				
Environment:	Benign / Moderate / Severe	Limited Inspection ☐				
Protection System:						Perform. Deficiencies
Condition Data:	Units	Exc.	Good	Fair	Poor*	
	m^2 / m / each / % / all					
Comments:						
Recommended Work:	☐ Rehab ☐ Replace ☐ 1-5 years ☐ 6-10 years	Maintenance Needs:				
		☐ Urgent ☐ 1 year ☐ 2 year				

* A quantity must be estimated using the appropriate unit (e.g. m^2). Percent should not be used.

Appendix 4 – DER Rating Tables

Table 4 Number of Inspection Items per Structure Type

Structure Type	Number of Inspection
Bridge - General	21
Bridge - Arch	21
Bridge - Cable	21
Bridge Cellular	14
Major Culvert	14
Lesser Culvert	5
Retaining Wall	7
Gantry	8
Road Tunnel	8

Table 5 Inspection Items and Sub-items for Bridge (General, Arch and Cable)

Inspection Item		Number of Sub-items		
		Bridge - General	Bridge – Arch	Bridge – Cable
	General Items:			
1	Approach embankments	No. of abutments	No. of abutments	No. of abutments
2	Guardrails	No sub-items	No sub-items	No sub-items
3	Waterway	No sub-items	No sub-items	No sub-items
4	Approach embankment protec-tion work	No. of abutments	No. of abutments	No. of abutments
5	Abutment foundations	No. of abutments	No. of abutments	No. of abutments
6	Abutments	No. of abutments	No. of abutments	No. of abutments
7	Wing/retaining walls	No. of abutments	No. of abutments	No. of abutments
8	Surfacing	No sub-items	No sub-items	No sub-items
9	Superstructure drainage	No sub-items	No sub-items	No sub-items
10	Kerbs/sidewalks	No sub-items	No sub-items	No sub-items
11	Parapets/handrails	No sub-items	No sub-items	No sub-items
	Support Items:			
12	Pier protection works	No of Piers	No of Piers plus No of Springings	No of Piers plus No of pylons
13	Pier foundations	No of Piers	No of Piers plus No of Springings	No of Piers plus No of pylons
14	Piers & column	No of Piers	No of Piers plus No of Springings	No of Piers plus No of pylons
15	Bearings	No of Piers plus No of Abutments	No of Piers plus No of Abutments plus No of Springings	No of Piers plus No of Abutments plus No of pylons
16	Support drainage	No of Piers plus No of Abutments	No of Piers plus No of Abutments	No of Piers plus No of Abutments

Inspection Item		Number of Sub-items		
		Bridge - General	**Bridge – Arch**	**Bridge – Cable**
			plus No of Springings	plus No of pylons
17	Expansion joints	No of Piers plus No of Abutments	No of Piers plus No of Abutments plus No of Springings	No of Piers plus No of Abutments plus No of pylons
	Span Items:			
18	Longitudinal members in the deck	No of Spans	No of Spans plus No of Arches	No of Spans plus No of Cable Groups*
19	Transverse members in the deck	No of Spans	No of Spans plus No of Arches	No of Spans
20	Deck slab	No of Spans	No of Spans plus No of Arches	No of Span
	Miscellaneous Item:			
21	Items not covered under Items 1 to 20	No sub-items	No sub-items	No sub-items
*A Cable Group is defined as the cables supporting a span of a cable type bridge or the cables extended to an anchorage point or anchorage chamber behind a bridge abutment where no span is supported. Examples of Cable Groups are the main suspension cables and hangers supporting a span of a suspension bridge, the stay cables supporting a span of a cable stayed bridge or the hangers supporting a span of an arch bridge				

Table 6 Inspection Items and Sub-items for Bridge (Cellular) and Major Culvert

Inspection Item		Number of Sub-items
	General Items:	
1	Apron slabs & cut off walls	No. of embankments
2	Wing / return / head walls	No. of embankments
3	Scour protection works (in river)	No. of embankments
4	Embankments	No. of embankments
5	Waterway	No sub-items
6	Road slabs	No sub-items
7	Roadway joints	No sub-items
8	Guardrails	No sub-items
9	Parapets/handrails	No sub-items
	Cell Items:	
10	Walls	No. of Cells
11	Top slab	No. of Cells
12	Invert slab	No. of Cells
13	Cell displacement	No. of Cells
	Miscellaneous Item:	
14	Items not covered under items 1 to 13	No. of sub-items

Table 7 Inspection Items and Sub-items for Lesser Culvert

Inspection Item		Number of Sub-items
	General Items:	
1	Inlet Works	No sub-items
2	Outlet Works	No sub-items
3	Barrel(s)	No sub-items
4	Waterway	No sub-items
5	Embankments	No sub-items

Table 8 Inspection Items and Sub-items for Retaining Wall

Inspection Item		Number of Sub-items
	General Items:	
1	External Drainage	No sub-items
2	Slope Protection	No sub-items
	Wall Items:	
3	Walls	No sub-items
4	Joints	No sub-items
5	Internal Drainage	No sub-items
6	Foundation	No sub-items
	Miscellaneous Item:	
7	Items not covered under items 1 to 6	No. of sub-items

Table 9 Inspection Items and Sub-items for Gantry

Inspection Item		Number of Sub-items
	General Items:	
1	Guardrails	No sub-items
	Gantry Items:	
2	Foundations	No. of columns
3	HD Bolts and Base Plates	No. of columns
4	Vertical Members	No. of columns
5	Horizontal Members	No. of spans
6	Sign Face	No. of signs
7	Sign Fasteners	No. of signs
	Miscellaneous Item:	
8	Items not covered under items 1 to 7	No. of sub-items

Table 10 Inspection Items and Sub-items for Road Tunnel

Inspection Item		Number of Sub-items
	Portal Items:	
1	Guardrails	No. of portals
2	Slope Protection	No. of portals
3	Rock Fall Protection	No. of portals
	General Items:	
4	Drainage	No. of sub-items
5	Road Surface	No. of sub-items
	Tunnel Bore Items	
6	Lining	No. of panels
7	Joints	No. of panels
	Miscellaneous Item:	
8	Operational Services (See A. 5.8)	No. of operational services
9	Items not covered under items 1 to 8	No. of sub-items

Bridge (General)

Item 1 Approach Embankment Defect		
Defect	Observations	D
Scour or erosion of embankment	Scour or erosion is shallow. There is no possibility of local collapse.	1
	Scour or erosion is shallow. Sides appear stable. There is a small possibility of local collapse.	2
	Scour or erosion is deep. There is a possibility of local collapse.	3
	Scour or erosion is deep. Sides are vertical or overhanging. Sides appear unstable. There is a real possibility of local collapse, which would endanger the roadway.	4
Settlement of approach fill	Settlement is not more than 50 mm.	1
	Settlement is greater than 50 mm but smaller than 100 mm.	2
	Settlement is more than 50 mm but smaller than 100mm. There is an abrupt step of the same magnitude in the riding surface at the abutment screen (bearing sill) wall.	3
	Settlement is greater than 100 mm. There is an abrupt step of the same magnitude in the riding surface at the abutment bearing sill wall.	4
Kerbs, berms and/or down chutes	Kerbs, berms or down chutes are ineffective due to the collection of debris and/or vegetation or due to minor damage.	1
	Kerbs, berms or down chutes are moderately damaged.	2
	The damage on kerbs, berms or down chutes has reached a warning state.	3
	Kerbs, berms or down chutes are severely damage	4
Trees and vegetation	Trees and vegetation can be detrimental to the integrity of the approach embankment as well as contribute to reduced site distances etc.	
	Minor	1
	Moderate	2
	Warning	3
	Severe	4

Bridge (General)

Item 2 Guardrail Defects		
Defect	Observations	D
Defective guardrail	Guardrails are not attached to the bridge parapet end blocks.	4
	Guardrails are poorly attached to the bridge parapet end blocks.	2-3
	Guardrail posts are cracked or broken.	1-2
	Guardrail posts are missing.	2-3
	Bolts/nuts are loose.	1-2
	Nuts are missing.	1-2
	Wood spacer blocks are misaligned.	1-2
	Wood spacer blocks are missing.	2-3
	Guardrails are damaged, bent or broken.	1-4
	Guardrails are corroded.	2-3
	Laps need to be reversed.	4

Bridge (General)

Item 3 Waterway Defects		
Defect	Observations	D
Flood debris accumulation	Loose debris accumulating on piers or bridge decks.	1
	Debris accumulation in the form of small branches on piers or on bridge decks.	2
	Debris accumulation in the form of large branches or small trees on piers or on bridge decks.	3
	Debris accumulation in the form of large trees on piers or on bridge decks	4
Siltation	Siltation reduces the flood capacity of the bridge	
	Moderate	2
	Warning	3
	Severe	4
Vegetation growth within the waterway	Reeds, bushes and trees growing within the bridge waterway reducing the flood capacity of the bridge	
	Minor (Reeds and bushes)	1
	Moderate (Reeds and bushes)	2
	Warning (Bushes and trees)	3
	Severe (Bushes and trees)	4

Bridge (General)

Item 4 Approach Embankment Protection Works		
Defect	Observations	D
Defective embankment protection works.	Embankment protection materials can comprise: - Gabion mattresses and/or boxes Stone pitching Grouted stone pitching Interlocking concrete paving blocks Concrete edge beams and channels Concrete slabs Precast concrete retaining blocks Geocells Interlocking cellular concrete grass blocks General defects include: -	
	Vegetation growth within the protection works can damage the protection works and is aesthetically a problem	1-3
	Portions of the protection works are missing or have been damaged; they may have been removed by vandals or have eroded away	2-3
	Protection works were never provided or have been completely removed. In river bridges the abutment stability may be compromised.	3-4
Scour or erosion of embankment	Scour or erosion is shallow. There is no possibility of local collapse	1
	Scour or erosion is shallow. Sides appear stable. There is a small possibility of local collapse	2
	Scour or erosion is deep. There is a possibility of local collapse.	3
	Scour or erosion is deep. Sides are vertical or overhanging. Sides appear unstable. There is a real possibility of local collapse, which would endanger the roadway	4

Bridge (General)

Item 5 Abutment Foundation Defects		
Defect	Observations	D
Shrinkage and restraint cracks including AAR (Crack should be cleaned. Its width and if possible its depth ascertained)	Crack is of the order of 0.3 mm with no signs of water leakage or corrosion of reinforcement.	1
	Crack is greater than 0.3 mm but smaller or equal to 0.6 mm with no signs of water leakage or corrosion of reinforcement.	2
	Crack is of the order of 0.6 mm and there are signs of water passing through crack and evidence of corrosion of reinforcement.	3
	Crack is greater than 0.6 mm	4
Shear cracks (Crack should be cleaned. Its width and if possible its depth ascertained)	Crack is visible of the order of 0.1 to 0.2 mm and there are no signs of water leakage or corrosion of reinforcement.	1
	Crack is greater than 0.2 mm but smaller or equal to 0.4 mm with no signs of water leakage or corrosion of reinforcement.	2
	Crack is greater than 0.4 mm with no signs of water leakage or corrosion of reinforcement.	3
	Crack is greater than 0.5 mm and there are signs of water passing through crack and/or evidence of corrosion of reinforcement.	4
	Crack is of the order of 0.3 mm with no signs of water leakage or corrosion of reinforcement.	1

Item 5 Abutment Foundation Defects		
Bending cracks (Crack should be cleaned. Its width and if possible its depth ascertained)	Crack is greater than 0.3 mm but smaller or equal to 0.6 mm with no signs of water leakage or corrosion of reinforcement.	2
	Crack is of the order of 0.6 mm and there are signs of water passing through crack and evidence of corrosion of reinforcement.	3
	Crack is greater than 0.6 mm	4
Honeycombing (If possible, areas of honeycombed concrete must be removed to expose full extent of damage)	Honeycombing is shallow and reinforcement is not visible.	1
	Honeycombing is shallow. Reinforcement is partly exposed. No signs of corrosion.	2
	Reinforcement is fully exposed, with some signs of corrosion; or reinforcement is partly exposed and corroded. Prestress duct is partly exposed.	3
	Reinforcement is exposed and corroded. Prestress duct is exposed.	4
Scour of foundations	Local scour at pier foundation is shallow. Scour has not exposed base of foundation.	1
	Local scour at pier foundation is shallow. Scour has partly exposed base of foundation or piles of piled foundation.	2
	Local scour at pier founded on piles has exposed the piles. Scour has exposed erodible founding material of a spread footing on a small portion of the perimeter of footing.	3
	Scour has exposed erodible founding material of a spread footing which might cause the footing to collapse or settle	4

Bridge (General)

Item 6 Abutment Defects		
Defect	Observations	D
Spalling (All loose concrete must be broken away to expose extent of spall)	Spalling is shallow and reinforcement is not visible.	1
	Spalling is shallow. Reinforcement is partly exposed. Minor signs of corrosion. Thus spalling not attributable to corrosion	2
	Reinforcement is partially or fully exposed and corrosion is a problem.	3
	Reinforcement is exposed and significantly corroded. Prestress duct is exposed. Section loss.	4
Shrinkage and restraint cracks including AAR (Crack should be cleaned. Its width and if possible its depth ascertained)	Crack is of the order of 0.3 mm with no signs of water leakage or corrosion of reinforcement.	1
	Crack is greater than 0.3 mm but smaller or equal to 0.6 mm with no signs of water leakage or corrosion of reinforcement.	2
	Crack is of the order of 0.6 mm and there are signs of water passing through crack and evidence of corrosion of reinforcement.	3
	Crack is greater than 0.6 mm	4

Bridge (General)

Item 7 Wing/Retaining Wall Defects		
Defect	Observations	D
Shrinkage and restraint cracks including AAR (Crack should be cleaned. Its width and if possible its depth ascertained)	Crack is of the order of 0.3 mm with no signs of water leakage or corrosion of reinforcement.	1
	Crack is greater than 0.3 mm but smaller or equal to 0.6 mm with no signs of water leakage or corrosion of reinforcement	2
	Crack is of the order of 0.6 mm and there are signs of water passing through crack and evidence of corrosion of reinforcement.	3
	Crack is greater than 0.6 mm	4
Spalling (All loose concrete must be broken away to expose extent of spall)	Spalling is shallow and reinforcement is not visible	1
	Spalling is shallow. Reinforcement is partly exposed. Minor signs of corrosion. Thus spalling not attributable to corrosion.	2
	Reinforcement is partially or fully exposed and corrosion is a problem.	3
	Reinforcement is exposed and significantly corroded. Section loss.	4

Bridge (General)

Item 8 Surfacing Defects for Bridges and Culverts		
The surfacing area that should be assessed with this inspection item includes only the surfacing area on the bridge deck (between abutment expansion joints) or directly above a culvert. The surfacing area on the approaches or road below the bridge/culvert is not included		
Defect	Observations	D
Cracking	This could be an indication of failure of the surfacing material, or indicates excessive movement or deterioration of the underlying deck. With time, crumbling of the surfacing material along the edges of the cracks takes place and the ingress of water may lead to loss of adhesion between the surfacing and the deck.	
	The defects in the surfacing will not likely cause an accident on the bridge	1-2
	The defects in the surfacing could likely cause an accident on the bridge.	3-4
Excessive deformation	This will take place due to the combined effects of traffic and warm weather or due to loss of adhesion at the interface with the deck or waterproofing membrane. When the deformation becomes excessive, it impairs riding quality and in turn can substantially increase the dynamic loading and vibration from moving vehicles.	
	The defects in the surfacing will not likely cause an accident on the bridge	1-2
	The defects in the surfacing could likely cause an accident on the bridge	3-4
Loss of skid resistance	Because of polishing under traffic, the surfacing will become more slippery with time and re-treatment of the surface will be required to restore the resistance to skidding. The standard of this resistance on bridges should be high because of the likely serious consequences of skidding accidents on bridges	

Item 8 Surfacing Defects for Bridges and Culverts		
	The defects in the surfacing will not likely cause an accident on the bridge	1-2
	The defects in the surfacing could likely cause an accident on the bridge	3-4

Bridge (General)

Item 9 Superstructure Drainage Defects		
Drainage is an important item for inspection, since trapped, ponded, flowing or splashing water can cause damage to the bridge over a long period and represent a safety hazard to traffic. The main defects include the following: a. Water stains on beams, slabs, piers and abutments may indicate inadequate drainage systems or leaking expansion joints. b. Blocked or inadequate drainage gullies and pipes. c. Drain outlets should be checked to ensure that water is not discharged where it may be detrimental to other components of the structure or on traffic below the bridge. d. The accumulation of debris in drainage systems. e. Wind blowing drainage water on structure. f. Drainage gullies/scuppers should be able to drain water from the deck surface. Resurfacing operations may restrict or block the water flow. g. In voided decks, drain pipes should be provided to remove water from the lowest points of voids.		
Defect	Observations	D
Drain is partly silted up	Water flow is restricted but drain is still functional.	1
Drain is in the order of 50% blocked.	Water flow is restricted.	2
Drain is almost completely blocked.	Water flow severely restricted	3
Drain is completely blocked up or not provided where required.	No water flow can take place. Ponding may occur causing aquaplaning at high speed	4
Drain pipes not protruding past deck soffit.	Result in streaking and staining of deck. Cyclical wet and dry conditions may aggravate concrete deterioration and result in cracking and spalling, especially where ASR is present in the concrete	2-4

Bridge (General)

Item 10 Kerb/Sidewalk Defects		
The surfacing area that should be assessed with this inspection item includes only the surfacing area on the bridge deck (between abutment expansion joints) or directly above a culvert. The surfacing area on the approaches or road below the bridge/culvert is not included		
Defect	Observations	D
Spalling (All loose concrete must be broken away to expose extent of spall)	Spalling is shallow and reinforcement is not visible.	1
	Spalling is shallow. Reinforcement is partly exposed. Minor signs of corrosion. Thus spalling not attributable to corrosion.	2
	Reinforcement is partially or fully exposed and corrosion is a problem.	3
	Reinforcement is exposed and significantly corroded. Prestress duct is exposed. Section loss.	4
Lack of cover to reinforcement	There are sporadic signs of slight discolouration of concrete face indicating start of reinforcement corrosion due to lack of cover.	1
	There are clear signs of discolouration of concrete face along length of reinforcement bar with small cracks.	2
	Cracks are visible along the length of the reinforcement but with more significant cracks.	3
	Local spalling and extensive cracking and staining due to corrosion of reinforcement	4
Sidewalk surface defect	Sidewalk surfacing, paving blocks or pre-cast planks are slightly uneven. Pedestrians may trip over uneven surface if they are not careful.	1
	Sidewalk surfacing, paving blocks or pre-cast planks are moderately uneven. Pedestrians will trip over uneven surface.	2
	Sidewalk surfacing, paving blocks or pre-cast planks has subsided or broken. Pedestrians have to walk around subsided areas or in the roadway	3
	Sidewalk surfacing, paving blocks or pre-cast planks, including manhole covers in surface are missing. Condition of sidewalk poses a hazard to pedestrians and may result in serious injury	4

Appendix 5 – STRUMAN Bridge and Structures Management System

STRUMAN: Bridge and Structures Management							***Version 4.02 (20120918)***
BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
01. Approach Em-bankment	NA,SA,EA, WA,BA	01.116. Repair concrete side drain/gutter/down chute	m	500	Y	-	M210.06.a
		01.155. Earth backfill	m^3	200	Y	-	M170.01.d.l
		01.156. Gabion (mattress and boxes)	m^3	1000	Y	-	M520.03.a
		01.157. Mass concrete backfill	m^3	1800		61.08.d	-
		01.158. Rock backfill	m^3	600		61.08.a	-
		01.201. Clean downchutes/sidedrains	m	50	Y	-	M250.01
		01.357. Replace kerbs or berms	m	200	Y	-	M280.04.a
		01.358. Replace cover slab and lids	No	500	Y	-	M210.04.a
		01.359. Replace sidedrains/gutter/downchutes	m	500	Y	-	M280.02.b
		01.362. Replace inlet/outlet structures	No	3000	Y	-	M210.03.a
		01.363. Install kerbs or berms	m	200	Y	-	M280.04.a
		01.402. Clear bush	m^2	40	Y	-	M630.01.a
		01.404. Remove trees (girth < 500mm)	No	200	Y	-	M630.02.a
		01.405. Remove trees (girth > 500mm)	No	500	Y	-	M630.02.b
		01.504. Repair settlement (asphalt fill)	m^3	3500	Y	-	M110.03.d.iiii
		01.953. Ad-hoc item (describe under Remarks)	No	1000		-	-

STRUMAN: Bridge and Structures Management							*Version 4.02 (20120918)*
BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
02. Guardrail	AL,NA, SA,EA,WA, BA, Si, AS	02.451. Attach guardrail to end block	No.	300	Y	-	M9104
		02.452. Cut bolts for pedestrian safety	No.	50	Y	-	M9104
		02.455. New guardrail (single and double)	m	300	Y	-	M440.01
		02.463. Repair guardrail (realign, bolt replacement, etc)	m	100	Y	-	M440.11
		02.466. Replace bolts and washers	No	20	Y	-	M9104
		02.467. Replace posts (steel or timber)	No	200	Y	-	M440.08.d
		02.468. Replace reflectors	No	50	Y	-	M440.08d.l
		02.469. Reverse laps in guardrails	No	100	Y	-	M440.11
		02.953. Ad-hoc item (describe under Remarks)	No	1000	Y	-	-
03. Waterway	AL,Pi,AP,Si, AS	03. 151. Backfill scour damage (earth)	m^3	200	Y	-	M170.01.d.l
		03. 152. Backfill scour damage (mass concrete)	m^3	1800		61.08.d	-
		03. 153. Backfill scour damage (rock)	m^3	600		61.08.a	-
		03. 156. Gabion (mattresses and boxes)	m^3	1000	Y	-	M520.03.a
		03. 207. Clear debris	m^3	100	Y	-	M260.01
		03. 209. Clear siltation	m^3	100	Y	-	M260.01
		03.404. Remove trees (girth <500 mm)	No	200	Y	-	M630.02.a
		03.405. Remove trees (girth > 500 mm)	No	500	Y	-	M630.02.b

STRUMAN: Bridge and Structures Management							*Version 4.02 (20120918)*
BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		03.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
04. Approach Embankment Protection Works	NA, SA, EA,WA, BA	04. 155. Earth backfill	m^3	200	Y	-	M170.01.d.l
		04. 156. Gabion (mattresses and boxes)	m^3	1000	Y	-	M520.03.a
		04. 157. Mass concrete backfill	m^3	1800		61.08.d	-
		04. 158. Rock backfill	m^3	600		61.08.a	-
		04. 159. Stone pitching	m^2	300	Y	-	M510.01.b
		04. 160. Interlocking blocks	m^2	300	Y	-	M510.01.b
		04.401. Apply weed killer/ant poison and remove growth.	m^2	30	Y	-	M510.07.a,b
		04.403. Grassing	m^2	30	Y	-	M650.07.a
		04.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
05. Abutment Foundations	NA, SA, EA,WA, BA	05. 101. Apply protective coating	m^2	200		126.02	-
		05. 102. Apply silanes	m^2	150		126.02	-
		05. 106. Construct earth berms for access	m^3	400		61.51	-
		05. 108. Cut back reinforcement (tie roads) and make good	No	50		122.02	-
		05. 118. Repair spall (including honeycombing)	L	100		123.03	-

STRUMAN: Bridge and Structures Management							*Version 4.02 (20120918)*
BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		05. 120. Seal cracks	m	200		124.05	-
		05. 155. Earth backfill	m^3	200	Y		M170.01.d.l
		05. 156. Gabion (mattresses and boxes)	m^3	1000	Y	-	M520.03.a
		05. 157. Mass concrete backfill	m^3	1800	Y	61.08.d	-
		05. 158. Rock backfill	m^3	600	Y	61.08.d	-
		05. 161. Underpinning (describe under Remarks)	No	1000		-	-
		05. 953. Ad-hoc item (describe under Remarks)	No	1000		-	-
06. Abutments	NA, SA,EA, WA, BA	06. 101. Apply protective coating	m^2	200		126.02	-
		06. 102. Apply silanes	m^2	150		126.02	-
		06. 103. Clean concrete surface	m^2	50		126.01	-
		06. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		06. 105. Concrete (mass)	m^3	4000		64.01,62.01,63.01	-
		06. 108. Cut back reinforcement (tie rods) and make good	No	50		122.02	-
		06. 114. Reconstruct backwall (re-instate gap)	m^3	10000		64.01,63.01,62.01	-
		06. 115. Repair anchor heads	No	6000		128.12	-
		06. 118. Repair spall (including honeycombing)	L	100		123.03	-
		06. 120. Seal cracks	m	200		124.05	-

BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		06. 122. Stabilise wall with ground/rock anchors	m^2	1000		75.01-75.08	-
		06. 154. Construct masonry wall	m^2	1000		128.05	-
		06.202. Clean drainage	m	50	Y	-	M250.01
		06.207. Clean debris	m^3	100	Y	-	M260.01
		06.309. Reinstate expansion gap	m	5000		66.29	-
		06.311. Remove/repair cladding/bearing protection plates	m	100	Y	-	M9104
		06.314. Replace joint sealant	m	100	Y	66.08.b	-
		06.355. Repair weep holes	No	150		128.02	-
		06.618. Service and repair gully doors/manholes	No	1500	Y	-	M9104
		06.653. Access-using scaffold (>10m)	No	1000		121.01	-
		06.654. Access-using scaffold (<10m)	No	500		121.01	-
		06.702. Traffic accommodation-Low (< 10 000 vpd)	LS	90000		15.01,15.03	-
		06.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		06.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		06.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
07. Wing/Retaining Walls	NA, SA, EA,WA, BA	07. 101. Apply protective coating	m^2	200		126.02	-
		07. 102. Apply silanes	m^2	150		126.02	-

STRUMAN: Bridge and Structures Management							*Version 4.02 (20120918)*
BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		07. 103. Clean concrete surface	m^2	50		126.01	-
		07. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		07. 105. Concrete (mass)	m^3	4000		64.01,62.01,63.01	-
		07. 108. Cut back reinforcement (tie rods)and make good	No	50		122.02	-
		07. 118. Repair spall (including honeycombing)	L	100		123.03	-
		07. 120. Seal cracks	m	200		124.05	-
		07. 122. Stabilise wall with ground/rock anchors	m^2	1000		75.01-75.08	-
		07. 155. Earth backfill	m^3	200	Y	-	M170.01.d.l
		07. 156. Gabion (mattresses and boxes)	m^3	1000	Y	-	M520.03.a
		07. 157. Mass concrete backfill	m^3	1800		61.08.d	-
		07. 158. Rock backfill	m^3	600		61.08.a	-
		07. 161. Underpinning (describe under Remarks)	No	10000		-	-
		07. 207. Clear debris	m^3	100	Y	-	M260.01
		07.309. Reinstate expansion gap	m	5000		66.29	-
		07.314. Replace joint sealant	m	100	Y	66.08.b	-
		07.355. Repair weep holes	No	150		128.02	-
		07.607. Monitor (movements, rotations, etc) (5 year period)	No	10000		129.05	
		07.653. Access-using scaffold (>10m)	No	1000		121.01	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		07.654. Access-using scaffold (<10m)	No	500		121.01	-
		07.702. Traffic accommodation-Low (< 10 000 vpd)	LS	90000		15.01,15.03	-
		07.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		07.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		07.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
08. Surfacing	AL,NA, SA, EA,WA, BA,Si, AS	08. 117. Repair concrete topping	m^3	2500		123.01	-
		08. 207. Clear debris	m^3	100	Y	-	M260.01
		08.209. Clear siltation	m^3	100	Y	-	M260.01
		08.501. Crack seal (asphalt)	m	20	Y	-	M132.01,a,b,c
		08.502. Resurface or patch	m^2	300	Y	-	M110.03.d..l
		08.505. Shape surfacing at scuppers	No	300	Y	-	M123.01.a
		08.702. Traffic accommodation-Low (< 10 000 vpd)	LS	90000		15.01,15.03	-
		08.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		08.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		08.953. Ad-hoc item (describe under Remarks)	No	1000		-	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
09. Superstructure Drainage	Si,AS	09. 206. Clear channel	m	50	Y	-	M250.01
		09. 208. Clear scuppers	No	50		128.02	-
		09. 351. Construct new scuppers	No	500		128.06	-
		09. 353. Extended scupper below deck soffit	No	300		128.08	-
		09. 354. Repair scuppers	No	200		128.09	-
		09. 361. Replace grid inlet	No	400		128.10	-
		09. 365. Seal leaking pipes	No	250		128.11	-
		09. 653. Access-using scaffold (> 10m)	No	1000		121.01	-
		09.654. Access-using scaffold (< 10m)	No	500		121.01	-
		09.702. Traffic accommodation-Low (< 10 000 vpd)	LS	90000		15.01,15.03	-
		09.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		09.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		09.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
10.Kerbs/sidewalks	AL,NA, SA, EA,WA, BA,Si,AS	10. 101. Apply protective coating	m^2	200		126.02	-
		10. 102. Apply silanes	m^2	150		126.02	-
		10. 118. Repair spall (including honeycombing)	L	100		123.03	-

STRUMAN: Bridge and Structures Management							*Version 4.02 (20120918)*
BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		10. 120. Seal cracks	m	200		124.05	-
		10. 207. Clear debris	m^3	100	Y	-	M260.01
		10. 314. Replace joint sealant	m	100	Y	66.08.b	-
		10. 357. Replace kerbs or berms	m	200	Y	-	M280.04.a
		10. 363. Install kerbs or berms	m	200	Y	-	M280.04.a
		10. 366. Install/replace concrete channel	m	150			
		10. 568. Replace service duct cover	No	200		67.01	-
		10. 609. Provide sidewalk	m^2	500	Y	-	M280.02.c
		10.614. Repair sidewalk surface (blocks, screed etc)	m^2	300	Y	-	M280.02.c
		10.702. Traffic accommodation-Low (< 10 000 vpd)	LS	90000		15.01,15.03	-
		10.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		10.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		10.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
11. Parapet	Si,AS	11. 101. Apply protective coating	m^2	200		126.02	-
		11. 102. Apply silanes	m^2	150		126.02	-
		11. 103. Clean concrete surface	m^2	50		126.01	-
		11. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		11. 113. Concrete (precast)	m^3	6000		66.02	-
		11. 118. Repair spall (including honeycombing)	L	100		123.03	-
		11. 120. Seal cracks	m	200		124.05	-
		11.309. Reinstate expansion gap	m	5000		66.29	-
		11. 314. Replace joint sealant	m	100	Y	66.08.b	-
		11. 453. Install full height pedestrian balustrade	m	2000		66.32	-
		11. 454. New endblocks	No	8000		66.17	-
		11. 456. New pedestrian parapet	m	3300		66.15,63.01	
		11. 457. New traffic barrier (Concrete F-Shape/NJ)	m	5000		66.15,63.01.	-
		11. 458. New/repair steel railing	m	1200		66.16.67.01.b	-
		11.459. Paint steel rails	m^2	300		84.01.a	-
		11. 462.Realign handrails	m	100		66.33	-
		11. 464. Repair/replace guardrail fixings	No	200	Y	-	M9104
		11.465. Repair/replace handrail posts	No	750		128.04	-
		11.569. Replace service duct cover	No	200		67.01	-
		11. 651.Access-using hanging basket for outer surface	No	5000		121.01	-
		11.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		11.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		11.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		11.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
12.Pier Protection Works	Pi,AP	12. 156. Gabion (mattresses and boxes)	m^3	1000	Y	-	M520.03.a
		12. 157. Mass concrete backfill	m^3	1800		61.08.d	-
		12. 158. Rock backfill	m^3	600		61.08.a	-
		12. 460. Provide guardrail protection	m	300	Y	-	M440.01
		12. 461. Provide F-shape NJ barrier protection	m	5000		66.15	-
		12.702. Traffic accommodation-Low (< 10 000 vpd)	LS	90000		15.01,15.03	-
		12.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		12.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		12.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
13. Pier Founda-tion	Pi,AP	13. 101. Apply protective coating	m^2	200		126.02	-
		13. 102. Apply silanes	m^2	150		126.02	-
		13. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		13. 105. Concrete (mass)	m^3	4000		64.01,62.01,63.01	-
		13. 106. Construct earth berms for access	m^3	400		61.51	-

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Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		13. 118. Repair spall (including honeycombing)	L	100		123.03	-
		13. 120. Seal cracks	m	200		124.05	-
		13. 155. Earth backfill	m^3	200	Y	-	M170.01.d.l
		13. 156. Gabion (mattresses and boxes)	m^3	1000	Y	-	M520.03.a
		13. 157. Mass concrete backfill	m^3	1800		61.08.d	-
		13. 158. Rock backfill	m^3	600		61.08.a	-
		13.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		13.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		13.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		13.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
14. Piers & Co-lumns	Pi,AP	14. 101. Apply protective coating	m^2	200		126.02	-
		14. 102. Apply silanes	m^2	150		126.02	-
		14.103. Clean concrete surface	m^2	50		126.01	-
		14. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		14. 108. Cut back reinforcement (tie rods)and make good	No	50		122.02	-
		14. 118. Repair spall (including honeycombing)	L	100		123.03	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		14. 120. Seal cracks	m	200		124.05	-
		14. 207. Clear debris	m^3	100	Y	-	M260.01
		14. 310. Remove cladding – bearing plates	m	30	Y	-	M9104
		14.653. Access-using scaffold (>10m)	No	1000		121.01	-
		14.654. Access-using scaffold (<10m)	No	500		121.01	-
		14.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		14.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		14.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		14.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
15. Bearings	AL,NA,SA, EA,WA,BA, Pi,AP	15. 251. Jacking – complicated (provide jack support work)	No	20000		12X01,02	-
		15.252. Jacking – simple (flat jacks)	No	10000		12X02	-
		15. 253. Refurbish (corrosion protection, anchor bolts, etc)	No	3000		128.07	-
		15. 254. Repair bearing plinth	No	500		123.02.a	-
		15. 255. Replace-elastomeric	No	2000		66.09.10	-
		15. 256. Replace-mechanical	No	30000		66.09.10	-
		15. 257.Re-seat	No	1000		128.07	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		15. 258. Service bearing (clear obstructions, etc)	No	500	Y	-	M9104
		15.653. Access-using scaffold (>10m)	No	1000		121.01	-
		15.654. Access-using scaffold (<10m)	No	500		121.01	-
		15.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		15.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		15.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		15.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
16. Support Drainage	AL,NA,SA, EA,WA,BA, Pi,AP	16.205. Clear blocked drainage	No	50	Y	-	M250.01
		16.360. Replace drainage	m	100		66.19	-
		16.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
17. Expension Joints	AL,NA,SA, EA,WA,BA, Pi,AP	17. 203. Clean joint of loose material.	m	50		128.01	-
		17. 301. Install silicon/bituminous seal	m	200		-	-
		17.302. Joint cover plates (replace and refit)	No	1400		66.27	-
		17. 304. New 40mm claw	m	4000		66.03.a,66.27,66.	-

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Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		17. 305. New 80mm claw	m	6000		66.03.a,66.27,66	
		17. 306. New asphalt plug joint	m	3000		66.03.a,66.27,66	-
		17. 307. New multi element joint	m	30000		66.03.a,66.27,66	-
		17. 308. Refurbish (paint, etc) metal claw/rail	m	100		84.01.b	-
		17. 312. Repair concrete at joint up-turns	L	200		123.03	-
		17. 313. Repair concrete nosing	m	2000		66.30	-
		17.315. Replace glands of claw joint	m	800		66.04.a	M280.06
		17.316. Replace pressfit seal with silicone	m	500		66.08	-
		17.317. Service multi-element joint	m	2000		66.31	-
		17.602. Bolts to cover plates	No	100	Y	-	M9104
		17.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		17.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		17.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		17.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
18. Longitudinal Members	Si,AS	18. 101. Apply protective coating	m^2	200		126.02	-
		18. 102. Apply silanes	m^2	150		126.02	-
		18.103. Clean concrete surface	m^2	50		126.01	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		18. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		18. 108. Cut back reinforcement (tie rods) and make good	No	50		122.02	-
		18.110. Jacking – complicated (provide jack support work)	No	6000		12X01,02	-
		18.111. Jacking – simple (flat jacks)	No	3000		12X02	-
		18. 118. Repair spall (including honeycombing)	L	100		123.03	-
		18. 120. Seal cracks	m	200		124.05	-
		18. 123. Strengthening (using plates, carbon fibre, etc)	m^2	10000		127.01-127.06	-
		18. 352. Drill drainage holes	No	50		128.06	-
		18. 520. Cable anchorage refurbishment for cables up to 100 mm diameter	No	10000		-	-
		18. 521. Cable anchorage refurbishment for cables 100 mm to 200 mm diameter	No	12000		-	-
		18. 522. Cable anchorage refurbishment for cables greater than 200 mm diameter.	No	20000		-	-
		18. 523. Cable replacement up to 100 mm diameter.	m	5000		-	-
		18. 524. Cable replacement 100 mm to 200 mm diameter.	m	10000		-	-
		18. 525. Cable replacement greater 200 mm diameter.	m	15000		-	-
		18. 526. Access to pylon head for repair (crane or other means)	Sum	50000		-	-
		18. 527. Install vandalism tubes to cables	No	25000		-	-

BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		18. 528. Additional (corrosion) protection for cables (painting, wrapping or sheathing a cable)	m	10000		-	-
		18. 576. Structural steel- re-torque bolts	No	50	Y	-	-
		18.653. Access-using scaffold (>10m)	No	1000		121.01	-
		18.654. Access-using scaffold (<10m)	No	500		121.01	-
		18.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		18.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		18.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		18.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
19. Transverse l Members	Si,AS	19. 101. Apply protective coating	m^2	200		126.02	-
		19. 102. Apply silanes	m^2	150		126.02	-
		19.103. Clean concrete surface	m^2	50		126.01	-
		19. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		19. 108. Cut back reinforcement (tie rods)and make good	No	50		122.02	-
		19.110. Jacking – complicated (provide jack support work)	No	6000		12X.01,02	-
		19.111. Jacking – simple (flat jacks)	No	3000		12X.02	-
		19. 118. Repair spall (including honeycombing)	L	100		123.03	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		19. 120. Seal cracks	m	200		124.05	-
		19. 123. Strengthening (using plates, carbon fibre, etc)	m^2	10000		127.01-127.06	-
		19. 352. Drill drainage holes	No	50		128.06	-
		19. 553. Corrosion protection to steel cables	m	300		84.01	-
		19.653. Access-using scaffold (>10m)	No	1000		121.01	-
		19.654. Access-using scaffold (<10m)	No	500		121.01	-
		19.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		19.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		19.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		19.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
20. Decks and Slabs	Si,AS	20. 101. Apply protective coating	m^2	200		126.02	-
		20. 102. Apply silanes	m^2	150		126.02	-
		20.103. Clean concrete surface	m^2	50		126.01	-
		20. 104. Concrete (reinforced)	m^3	4000		64.01,62.01,63.01	-
		20. 108. Cut back reinforcement (tie rods)and make good	No	50		122.02	-
		20.110. Jacking – complicated (provide jack support work)	No	6000		12X.01,02	-

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		20.111. Jacking – simple (flat jacks)	No	3000		12X.02	-
		20. 118. Repair spall (including honeycombing)	L	100		123.03	-
		20. 120. Seal cracks	m	200		124.05	-
		20. 123. Strengthening (using plates, carbon fibre, etc)	m^2	10000		127.01-127.06	-
		20. 125. Waterproofing of top surface	m^2	1000		42.41	-
		20. 207. Clear debris	m^3	100	Y	-	M260.01
		20. 352. Drill drainage holes.	m^3	50		128.06	-
		20. 551. Paint steelwork	m^2	300		-	-
		20. 553. Corrosion protection to steel cables	m	300		84.01	-
		20. 556. Structural steel – remove all rivets and replace with bolts	No	300			
		20.557. Structural steel – remove all rivets and replace	No	300			
		20.558. Structural steel – replace bolts, washers etc	No	50	Y	-	M9104
		20.559. Structural steel – replace bottom boom	t	30000		-	
		20.560. Structural steel – replace channel	t	30000	Y	-	M280.02.c
		20.561. Structural steel – replace diagonals	t	30000			
		20.562. Structural steel – replace and post	t	30000			
		20.563. Structural steel – replace main long member	t	30000			
		20.564. Structural steel – replace main transverse member	t	30000			

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		20.565. Structural steel – replace portal bracing	t	30000			
		20.566. Structural steel – replace secondary long member	t	30000			
		20.567. Structural steel – replace secondary transverse member	t	30000			
		20.571. Structural steel – replace stringers	t	30000			
		20.572. Structural steel – replace top boom	t	30000			
		20.573. Structural steel – replace top plate of cross girder	t	30000			
		20.574. Structural steel – replace verticals	t	30000			
		20.575. Structural steel – replace wind bracing	t	30000			
		20.577. Structural steel – sand blast to white metal	m^2	200			
		20.578. Structural steel – strengthen bottom boom	t	30000			
		20. 579. Structural steel- strengthen diagonals	t	30000			
		20. 580. Structural steel- strengthen end post	t	30000			
		20.581. Structural steel- strengthen main long member	t	30000			
		20. 582. Structural steel- strengthen main trans member	t	30000			
		20. 583. Structural steel- strengthen portal bracing	t	30000			
		20. 584. Structural steel- strengthen secondary long member	t	30000			
		20. 585. Structural steel- strengthen secondary trans member	t	30000			

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		20. 586. Structural steel- strengthen stringers	t	30000			
		20. 587. Structural steel- strengthen the web of cross girder	t	30000			
		20. 588. Structural steel- strengthen top boom	t	30000			
		20. 589. Structural steel- strengthen verticals	t	30000			
		20. 590. Structural steel- strengthen wind bracing	t	30000			
		20.653. Access-using scaffold (>10m)	No	1000		121.01	-
		20.654. Access-using scaffold (<10m)	No	500		121.01	-
		20.702. Traffic accommodation-Low (< 11 000 vpd)	LS	90000		15.01,15.03	-
		20.703. Traffic accommodation-Medium (10 000 - 40 000 vpd)	LS	110000		15.01,15.03	-
		20.704. Traffic accommodation-High (> 40 000 vpd)	LS	140000		15.01,15.03	-
		20.953. Ad-hoc item (describe under Remarks)	No	1000		-	-
21. Miscellaneous Items	AL,NA,SA, EA,WA,BA, Pi,AP,Si,AS	21. 119. Repair support plinths	L	50		123.03	-
		21. 554. Corrosion protection to masts	m^2	1000		67.03.a	-
		21.570. Replace cover plates on street lights	No	300		67.01	-
		21.601. Bolts (miscellaneous)	No	50	Y	-	M9104
		21.604. Install clearance sign	No	1000	Y	-	M410.01.a

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BRIDGE			**Inspection Remedial Activity List**				
Item	Position	Activity Description	Unit	Rate	Routine	Standard Payment No.	Routine Payment No.
		21.606. Install fencing	m	600	Y	-	M310.02.a
		21.610. Rebuild/repair access chamber	No	6000	Y	-	M210.03.a
		21.612. Remove people using structure as habitat	LS	30000	Y	-	M9104
		21.613. Repair service hangers (lighting etc)	No	4000		67.01	-
		21.615. Repair sign gantries	No	30000		67.01,67.02,67.03	-
		21.616. Repair signpost connections	No	300	Y	-	M9104
		21.617. Replace road signs	m^2	1600	Y	-	M410.01.a
		21.619. Service structure lights	No	150	Y	-	M9104
		21.620. Install structure number plate	No	1000		66.18.a	-
		21.953. Ad-hoc item (describe under Remarks)	No	1000		-	-