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Volume 6, Chapter 14

Bridges Maintenance Plan

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1.0 PURPOSE

The purpose of this document is to provide guidelines and best practices to the Entity to manage the Bridges Maintenance Plan. In addition, its purpose extends to promote industry-accepted standards and minimum requirements for the maintenance, inspection, repair, rehabilitation, load ratings, and strengthening of existing bridge assets constructed of concrete, steel, and masonry.

While these minimum requirements apply to standard and typical bridge structures, they shall conform to specifications detailed in Section 4.0. The Entity shall modify the requirements specific to its maintenance needs.

2.0 SCOPE

- This document applies to the following five existing bridge structure types:
  - Bridges Over Roadway
  - Bridges Over Rail
  - Bridges Over Drainage Channel/Terrain
  - Bridges Over Pipelines
  - Pedestrian Bridges
- This document covers the Civil and Structural Engineering aspects of the asset.
- This document defines the Civil and Structural Engineering requirements for existing bridge assets through the following life cycle stages:
  - Maintenance
  - Inspection
  - Load Rating
  - Analytical Assessment
  - Repair and Rehabilitation
  - Strengthening
- The maintenance requirements provided herein, or cited by reference, are based on the American Association of State Highway and Transportation Officials (AASHTO), British Codes, industry standards, and best practices that should be embraced by the relevant Entity.
- This document provides the minimum technical requirements to be adopted by the Entity and/or Contractors to enable safety, quality, and cost-effectiveness in the maintenance, repair, and strengthening of bridge assets that meet the prerequisites and expectations of the relevant Entity.
- The Entity shall establish and develop set procedures for the continuous maintenance care and performance efficiency of the structural components for existing bridge structures.

3.0 DEFINITIONS

Term	Definition
Asset Register	Collection of information sources or schedule of components that form part of a built asset. Enables suppliers providing maintenance services to identify its engineering asset base and the associated safety, legal, and commercial risks over the lifecycle of the assets
Bridge	A structure built to carry road, railway, and pedestrians over a physical obstacle, such as a wadi, water, pipe, river or deep terrain
Bridge Management System (BMS)	A computerized tool that maintains all data for the bridge assets and allows informed decisions to be made regarding the management of these bridges
Confined Space	The space with limited access and egress
Design Life	The period during which the component/asset is expected by its designers to function within its specified parameters (i.e., the life expectancy). It is the length of time between placement into service of a single asset/component and the onset of wearing out / deterioration.
Detailed/ In-Depth Inspection	Close-up inspection of one or more members above or below the water level to identify any deficiencies not readily detectable using routine inspection procedures

Term	Definition
Emergency Maintenance	Maintenance activity on a bridge to rectify the danger to the public and restore bridge/components serviceability after an emergency event
Hidden Critical Elements	A member that cannot be observed throughout its extent from at least one side and is not protected by a material known to preserve the condition of the component/asset/part
Inspection	The evaluation of the condition of an asset(s) through a formally defined and controlled process. The process shall include all relevant information, site inspection surveys, and analytical assessments where required as stipulated in this document or any other standard
Load Rating/ Bridge Assessment	The bridge/components dead and live load carrying capacity
Maintenance	The undertaking of planned or unplanned actions, or both, including repairs, to ensure that the condition of the asset continues to meet the required standards over the service life of an asset.
Performance Deficiency	The bridge or element of the bridge which needs to be repaired or monitored
Planned Maintenance	A planned strategy of cost-effective treatments to an existing bridge and its systems/components that maintains the asset, prevents deterioration, and improves the functional condition (without substantially increasing structural capacity). It is performed to enhance or extend the functional life of an asset/component.
Rehabilitation	Restores the bridge and/or its components integrity to its former standard and structure. This potentially may result in a prolonged process of addressing the root cause.
Repair	Techniques used to restore the structural integrity and shape of bridge elements (i.e., carrying out works on damaged concrete or unsafe depressions)
Service Life	The total period during which the asset, element, or component remains in use. Regular maintenance can extend the service life of the asset.
Strengthening and Renewal	Corrective action to address life-expired assets or elements in accordance with the supplier's program for lifecycle management or a change in use, function or duty of the asset or element
Temporary Works	Site installations that do not form part of the permanent works
Visual Inspection	Close inspection of all parts of the structure carried out by raw human senses (i.e., vision, hearing, touch)
Acronyms	
AASHTO	The American Association of State Highway and Transportation Officials
ACR	Asset Condition Reporting
ARAMCO	Arabian American Oil Company
BIRM	Bridge Inspector's Reference Manual
BMS	Bridge Management System
CAPEX	Capital Expenditure - capital spent on bridge assets or bridge components for maintenance, improvement(s) or replacement(s)
CS	Condition State
DOT	US Department of Transportation
FHWA	The Federal Highway Administration
HSSE	Health, Safety, Security, and Environment
MOMRA	Kingdom of Saudi Arabia Ministry of Municipal and Rural Affairs
MOT	Saudi Ministry of Transportation
NBE	National Bridge Element
NBIS	National Bridge Inspection Standards
SAR	Saudi Railway Company
SO	Special Order

Term	Definition
STGO	Special Types General Order

Table 1 Definitions

4.0 REFERENCES

Maintenance, inspection, repair, load rating, rehabilitation and strengthening of all bridge structure components, elements and the asset itself shall be based upon the requirements of this section and on international highway and rail standards (i.e., to ensure interoperability, these shall be from Saudi Ministry of Transportation (MOT) and the American Association of State Highway and Transportation Officials (AASHTO), or those of the authority having jurisdiction over the structure such as Arabian American Oil Company (ARAMCO) and Saudi Railway Company (SAR), these shall be selectively applied based on the evaluation of individual requirements). Where the standards stipulated conditions conflict, the most stringent shall govern, unless otherwise noted herein and shall require the Entity's approval. The following are a listing of the adopted codes:

Codes and Standards

- AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2011, 2013, 2014, 2015, 2016 and 2018 Interim Revisions
- The American Association of State Highway and Transportation Officials (AASHTO), 2007" Maintenance Manual for Roadways and Bridges
- Kingdom of Saudi Arabia Ministry of Municipal and Rural Affairs (MOMRA), General Directorate of Operation and Maintenance (Bridges and Tunnels Maintenance Manual)
- Kingdom of Saudi Arabia Ministry of Communications/Transportation (MOT) General Specifications for Road and Bridge Construction (Part 5)
- US Department of Transportation (DOT), National Bridge Inspection Standards (NBIS)
- US Department of Transportation (DOT), Bridge Inspector's Reference Manual (BIRM)
- Joint Transportation Research Program: Indiana Department of Transportation (Technical Report FHWA/IN/JTRP-2015/22): Bridge Preservation Treatments and Best Practices (Appendix G)
- ACI Concrete Repair Manual - 3rd Edition
- ACI 562-19: Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary
- US Department of Transportation (DOT) Bridge Repair Manuals
- Institution of Civil Engineers, 2008, "ICE manual of bridge engineering," Second Edition, published by Thomas Telford Ltd. British
- New York State Department of Transportation, July 1997 "Fundamentals of Bridge Maintenance and Inspection"
- Guidelines for Evaluation and Repair of Damaged Steel Bridge Members – National Cooperative Highway Research Program Report 271
- AASHTO Standard Specifications for Highway Bridges, 17th Edition. American Association of State Highway and Transportation Officials (AASHTO), 2002
- AASHTO LRFD Bridge Design Specification, American Association of State Highway and Transportation Officials (AASHTO), 7th edition, 2014, with 2015 and 2016 Interim Revisions
- AASHTO Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges. American Association of State Highway, Federal Highway Association and Transportation Officials (AASHTO), with Current Interim Revisions
- American Association of State Highway and Transportation Officials (AASHTO)/National Steel Bridge Alliance (NSBA) Steel Bridge Collaboration Documents for Steel Bridges "AASHTO/NSBA."

Codes for the Assessment/Load Rating of Bridges

- AASHTO Manual for Bridge Evaluation, 2nd Edition (Section 6 – Load Rating), with 2011, 2013, 2014, 2015, 2016 and 2018 Interim Revisions
- BD 21/01: The Assessment of Highway Bridges and Structures
- BA 38/93: Assessment of the Fatigue Life of Corroded or Damaged Reinforcing Bars
- BA 39/93: Assessment of Reinforced Concrete Half-joints
- BD 48/93: The Assessment and Strengthening of Highway Bridge Supports
- BA 54/94: Load Testing for Bridge Assessment

- BA 55/06: The Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures
- BD 56/10: The Assessment of Steel Highway Bridges and Structures
- BD 56/96: The Assessment of Steel Highway Bridges and Structures
- BD 44/95: The Assessment of Concrete Highway Bridges and Structures
- BD 61/96: The Assessment of Composite Highway Bridges and Structures
- BD 86/07: The Assessment of Highway Bridges and Structures for the Effects of Special Types General Order (STGO) and Special Order (SO) Vehicles

The Entity/Contractor should also refer to the following relevant volumes/chapters/ sections of the National Manual of Assets and Facilities Management for further guidance while compiling the bridge structures maintenance plan.

- Refer to Volume 2: Asset Management
- Refer to Volume 3: Condition Assessment
- Refer to Volume 4: Financial Planning
- Refer to Volume 6: Maintenance Management (Chapter 4)
- Refer to Volume 7: Work Control
- Refer to Volume 10: Health, Safety, Security and Environment (HSSE)
- Refer to Volume 14: Emergency Management for Emergency Response Actions During Hazard Events

5.0 RESPONSIBILITIES

- All staff and suppliers carrying out operation and maintenance activities shall be qualified and competent.
- The Entity and the specialized Contractors/Operators shall have an organizational structure that delineates the responsibilities and competencies to oversee and monitor the operation and maintenance activities.
- In accordance with the published guidelines and standards for operation and maintenance of assets, the Entity and its specialized Contractors/Operators shall have a Competence Management System in place.
- The Entity and the specialized Contractors/Operators shall administer a robust continuous training program for developing and maintaining staff competence.

6.0 PROCESS

The Entity shall establish and develop set processes and procedures for continuous maintenance and performance efficiency for structural components of bridges. The comprehensive bridge maintenance plan shall employ actions and strategies (refer Figure 1) to maintain the service life of bridge assets, and the Entity shall consider the following as part of producing the plan:

- Development of the Bridge Maintenance Planning tool to assist Asset Managers and manage bridge assets.
- Effective planned maintenance program.
- Inspection schedule (initial, visual, detailed, special) and reporting.
- Effective corrective maintenance.
- Implementing best practices with regards to repair, rehabilitation, and replacement of bridge components.

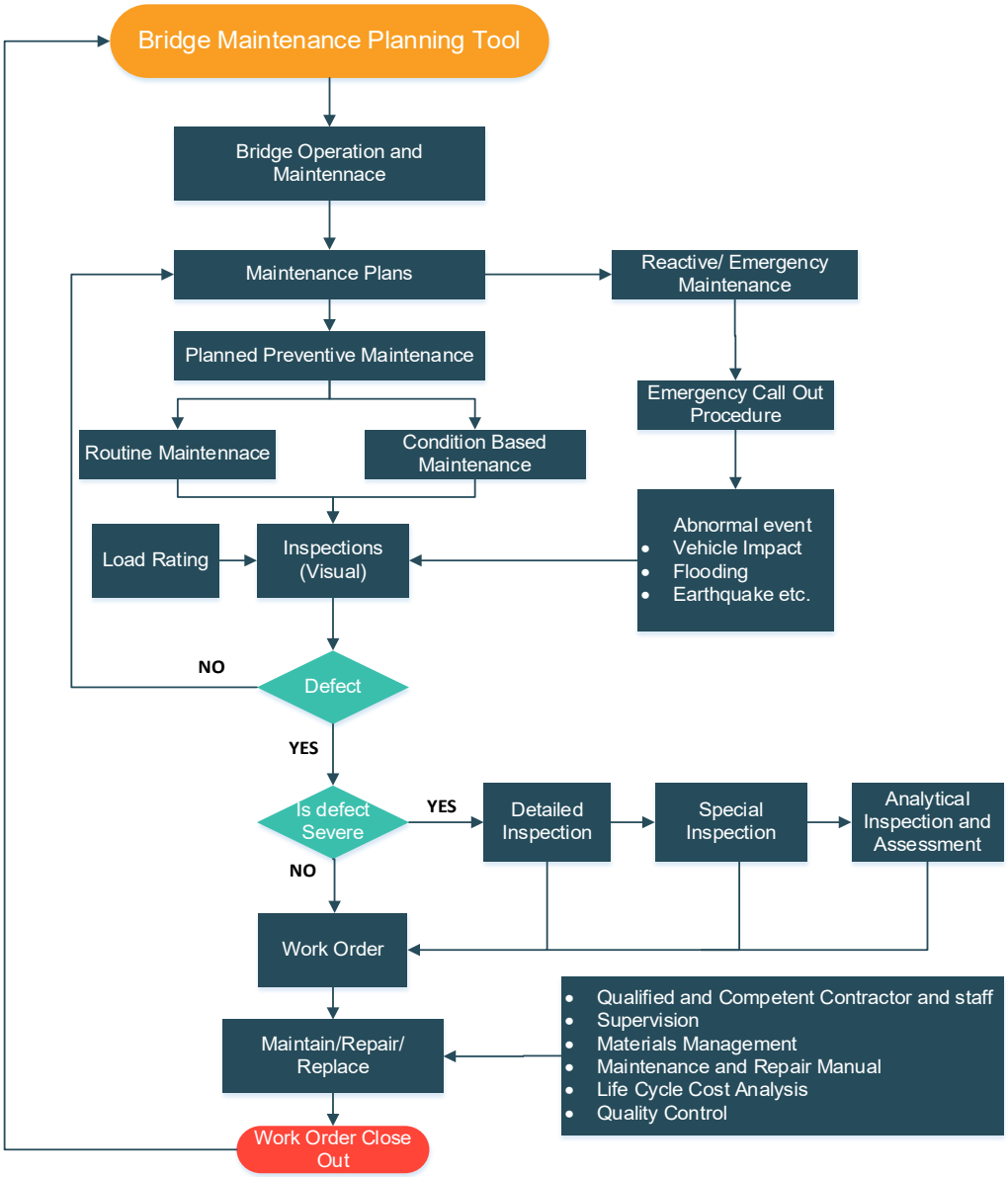

Figure 1: Bridge Operation and Maintenance Process

7.0 GENERAL REQUIREMENTS

- All staff and suppliers carrying out bridge/asset operations shall be qualified and competent.
- Health and safety aspects shall be considered throughout the maintenance, inspection, condition assessment, repairs/rehabilitation, and strengthening of existing bridge structures and strict measures taken of the applicable regulations. While carrying out maintenance and inspection activities, the following health and safety aspects shall be considered:
    - Working on highways
    - Confined space inspection
    - Encountering toxic mold
    - Working near/on railways
    - Diving operations for underwater inspections
    - Working at heights
- All activities, including the maintenance, inspection, repairs/rehabilitation, and strengthening of existing bridge structures, must comply with current environmental legislation, approved codes of practice, and authoritative guidance literature issued by relevant statutory bodies and Entities.
- During operational activities, including the maintenance, inspection, condition assessment, repairs/rehabilitation, strengthening, and load rating of existing bridge structures, the

Contractor/Entity shall consider the health and safety for customers and users (i.e., establishing safe access, egress and traffic management).

- Maintain inherent structural integrity (to prevent complete or partial collapse) during the maintenance, inspection, condition assessment, repairs/rehabilitation, strengthening, renewal, the load rating of existing bridge structures.
- Provide appropriate access and egress for all planned uses (including maintenance), and for reasonably anticipated emergency uses. Ensure safe access/egress by passengers, the general public, employees, and emergency services in planned & reasonably expected emergency scenarios.
- Safeguard the health and safety of users, employees, inspectors, and members of the general public.
- Temporary Works required for the maintenance, inspection, condition assessment, repairs/rehabilitation, strengthening, and renewal works shall be entirely compatible with the continuing safe and reliable operations of adjacent facilities.
- Any loads which Temporary Works impose on existing assets shall be allowed for in the design.
- Existing assets required to sustain loads imposed by the Temporary Works associated with maintenance, inspection, condition assessment, repairs/rehabilitation, strengthening, and renewal works shall be validated for integrity. If required, additional support shall be designed.

8.0 BRIDGE GROUPS

The principles, guidelines, and requirements specified under this document shall apply to the transportation structure groups defined in Table 1. This document provides concept maintenance for structures that would be required to carry highways over existing roadways/railways, wadi, waterways, and various types of terrain. Additional structures covered under this document include pedestrian bridges.

Group	Structure Designation	Configuration	Structure type
1	Bridge Over Roadway	Roadway Over Roadway	Pre-stressed/Reinforced Concrete/Steel/ Composite structure
2	Bridge Over Rail	Roadway Over Railway Track	Pre-stressed/three-sided/arch reinforced concrete structure/reinforced concrete structure
3	Bridge Over Drainage Channel/Terrain	Roadway Over Drainage Channel/ Terrain	Pre-stressed/Reinforced Concrete/Steel-Concrete Composite structure
4	Bridge Over Pipelines	Roadway Over Pipelines	Three-sided/arch reinforced concrete culvert structures
5	Pedestrian Bridges	Footway bridges	Pre-stressed/Reinforced Concrete/Steel structure

Table 1: Applicable Structures

Note:
Bridge assets in the Kingdom of Saudi Arabia are mostly constructed from concrete; this is the preferred material.

9.0 BRIDGE MANAGEMENT SYSTEM

The life cycle approach of a bridge structure is based on informed decision making during the design, construction, inspection, monitoring, maintenance, and replacement stages. Regular inspection and planned maintenance are vital phases to preserve the bridge in a serviceable condition and prolong its design and service life.

The Entity should develop a tool such as a Bridge Management System (BMS) to assist Asset Managers oversee their bridge assets (Refer Figure 2). The BMS should provide detailed guidelines for appropriate asset management practices, processes, and activities specific to the bridge assets. When implemented, these will aid in efficiently managing the physical and operational attributes of the structure to prolong its life, while maintaining defined levels of service. The detailed requirements for a comprehensive Asset Management system are given in Volume 2 of the National Assets and Facilities Manual. The Entity should consider the criteria detailed in Volume 2 (Asset Management) to develop its Bridge Management System (BMS) or a similar tool to manage its bridge assets.

The Bridge Management System (BMS) should be developed by the Entity and should contain the following key aspects:

- Program management
- Bridge inquiry
- Bridge inventory
- Inspections (Bridge and Elements Condition data, Planned and Completed work items, Photographs, Drawings, and reports)
- Load Rating
- Annual Average Daily Traffic (AADT) and Heavy Vehicles
- Assets Risk Analysis/Matrix
- Decision making, evaluation & strategic review of asset maintenance needs (do nothing, rehabilitation, replace)
- Provides a system to develop optimum works programs and capture the cost of works against the bridge assets
- Cost-benefit analysis
- Schedule and deliver works

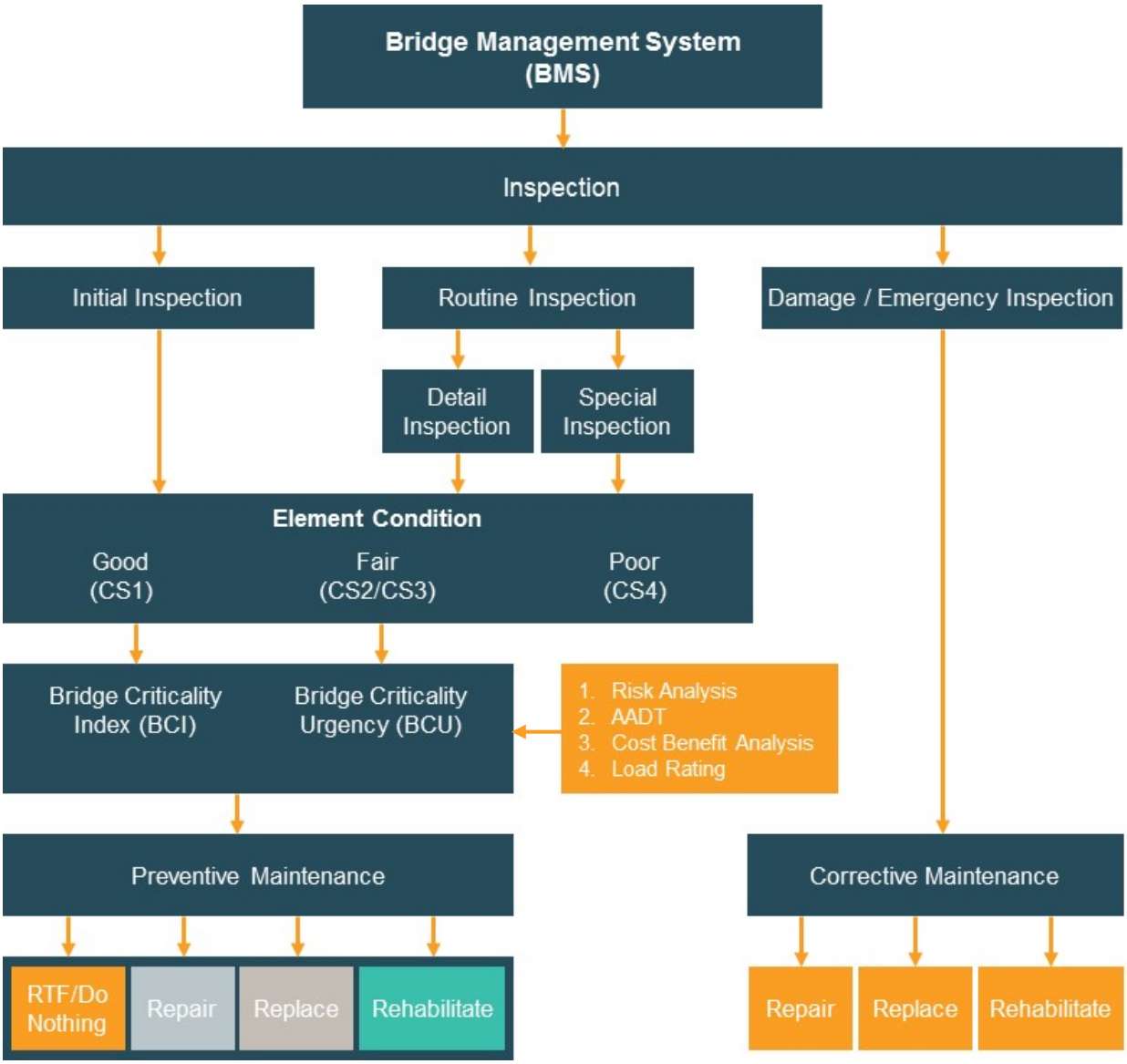

Figure 2: Bridge Management System

10.0 BRIDGE MAINTENANCE

10.1 General

- Maintenance work shall be undertaken to ensure assets perform within design life parameters.
- Assets that fail to perform within specified parameters shall have restricted operations imposed or be withdrawn from service.

10.2 Maintenance work

- Maintenance work shall be planned or remedial (including repairs to damage and defects). Maintenance work shall be based on the principles of the lifecycle of the asset management process. During the life of the asset, if service repairs and connections are required for which provisions were not anticipated during the design and construction phase, a process shall be formed to control cutting, grinding, drilling, repairing and supporting from existing structures (in accordance with applicable standards and codes mentioned in Section 4.0).
- Maintenance action shall be based on:
    - Inspection (refer to Section 11.0)
    - Bridge assessment/Load Rating/Analytical Assessment (refer Section 14.0)

10.3 Planned Maintenance

The Entity/Contractor shall schedule and conduct Planned Maintenance activities regularly in order to prevent element deficiencies of a bridge. These activities are essential and should not alter the condition rating of the element or structure. The Entity shall consider Planned Maintenance (PM) actions for the long-term benefits of a bridge.

- Planned Maintenance: Preventive and Predictive (PM, PdM)
- Unplanned Maintenance: Corrective and Emergency (CM, EM)

This document focuses primarily on Planned Maintenance, other maintenance types are described within NMA & FM, Volume 6 Chapter 3 – Descriptions and Definitions (EOM-ZM0-PR-000002).

Planned Maintenance should sustain components of the bridge and prevent the development of a structural deficiency. Planned Maintenance activities are classified into two groups - Scheduled and Response:

- Scheduled - The Entity/Contractor should conduct operations on a scheduled interval basis.
- Response – The Entity/Contractor should conduct activities that shall be identified through the inspection process.

The activity schedule mentioned in Attachment 1 shall be scheduled and completed regularly as part of the Planned Maintenance plan by the relevant Entity. The list (Attachment 1) is not exhaustive and represents a collection of typical activities. The relevant Entity/Contractor shall also develop a program and set of activities and intervals to develop its PM plan and where appropriate in accordance with the manufacturer's specifications. The reference included in Attachment 1 provides the best practice to execute the Planned Maintenance activity.

10.4 Reactive/Emergency Maintenance

- The Entity/Contractor shall develop an Emergency Maintenance Plan to accommodate unscheduled and unplanned repairs (i.e., vehicle impacts or fires or to mitigate the consequences of other extreme events that may arise during the assets life).
- This is usually reported through a service call when a component or a system has been malfunctioning or is not fit for purpose.
- This should be recorded against the asset number to allow historical data to be collated and is essential for demonstrating the possible allocation of CAPEX funds if required.
- The consequent inspection after the service call can result in the following two actions:
    - If the problem is affecting the service life of the structure and posing a threat to users, then emergency response and corrective action are required immediately.
    - If the problem is not critical, then a routine planned maintenance response may be adequate.
    - In both cases, the Entity should undertake a review of the current maintenance regime in place and, if necessary, adjust to meet the present conditions.
- The response can include the significant repair/rehabilitation of the asset or component to protect life and property or moderate/major repair requiring qualified and skilled labor.

The Entity should also refer to the requirements detailed in the National Manual of Assets and Facilities Management Volume 14 – Emergency Management for further details regarding emergency response procedures.

11.0 INSPECTION

The Inspection provides the necessary inputs for the Bridge Management System (BMS) or a similar asset management tool. The Entity shall develop a comprehensive bridge inspection program according to the needs of its bridge assets.

11.1 General

- Inspections of bridge assets shall be performed for the following purposes:

  - Confirmation that assets are safe for desired operations.
  - Provide necessary information for the managed maintenance of assets.
  - Provide the necessary information to assess the condition of the assets in a consistent and accurate manner.
  - Provide information enabling the asset register to be maintained as an accurate record of the physical features of the assets.
  - Provide all the necessary physical information on assets to meet the requirements for the Asset Condition Reporting (ACR) process.
  - Identify defects, causes, and effects of damage, deterioration, and vulnerable structures.
- The asset register shall be reviewed, and the records updated as part of the reporting process.
- Inspection reports and related forms shall be retained for the life of the asset.
- The Inspection shall not commence unless the Inspector has reviewed previous examination reports, asset registers, and asset files to establish its previous condition and likely hazards. This should include attributes, residual risks (i.e., hidden critical elements or falling elements), and any partial inspection information.
- The Inspector must be fully aware of access arrangements to prevent delays.

11.2 Types of Inspection

Types of inspections:

- General/Visual Inspection
- Detail/In-depth Inspection
- Special Inspection
- Inspection for Analytical Assessment
- Damage/Defect Advice Inspection

11.3 General/Visual Inspection

In accordance with the National Bridge Inspection Standards (NBIS) using the US Department of Transportation (DOT) Bridge Inspector's Reference Manual (BIRM) and Manual for Bridge Element Inspection, the Entity shall inspect bridge structures every two years and shall develop a comprehensive bridge inspection program according to the specific needs of its bridge asset(s).

11.3.1 Purpose:

- The Entity/Contractor shall carry out visual inspections with the following considerations and objectives:
  - Verify the general serviceability of the structure.
  - Identify any emerging problems.
  - Ensure public safety for bridges.
  - Identify deficiencies to include into the Asset Management Program/BMS that would initiate maintenance activities and/or rehabilitation/replacement of structures.
- General inspections shall be performed, and visual checks recorded for accessible assets.
- Any deterioration in condition or visible developments of defects during General inspections shall be notified.
- General inspections shall be conducted efficiently to detect and report any visual changes since the previous review, and evidence of circumstances that may impact on the condition of the asset before the next scheduled inspection.

11.3.2 Planning for Visual Inspection

The Entity/Contractor shall ensure that the Inspector is suitably competent to perform the inspection. The Inspector shall provide all relevant documentation and inspection/safety equipment in order to complete the required activities.

The following documents are required on-site for this level of inspection:

- Manual for Bridge Element Inspection, AASHTO 2015

- Bridge Inspection Manual
- Inspection Forms
- Bridge Drawings
- Workplace Health and Safety Plan
- Structural Inventory Verification Forms

All staff involved in bridge inspections must be familiar with their responsibilities under the Workplace Health and Safety Act. The safety plans should be reviewed by the inspection crew and significant hazards identified before the commencement of an activity.

The traffic control procedures shall be covered under generic road/rail maintenance safety plans. The hazards of operating within the lateral confines imposed by bridge barriers are significantly different from the risks posed while operating on the "open" road. Safety equipment shall include signage (for traffic management purposes) and, where appropriate, other safety equipment relevant to routine maintenance activities.

11.3.3 Preparing for Visual Inspection

Before commencing inspections, the Inspectors shall ensure that they have all relevant documentation, locations, inspection equipment, safety equipment, and the appropriate arrangements with relevant road/ governmental/other authorities for temporary access. Safety plans and permits must be prepared and approved by the relevant Entity before commencing inspection activities.

11.3.4 Performing Visual Inspection

The inspector's duties include:

- Maintaining the proper structure orientation
- Element numbering system
- Developing an inspection sequence
- Following proper inspection procedures

The bridge Inspector shall collect the following information:

- The general terminology used to label bridge components
- Measurements of the dimensions of all elements
- Photographs
- Defects shall be defined in terms of their location, orientation, area, depth, residual section, rate of deterioration, and severity (condition state), The inspection forms shall appropriately be described, measured, photographed, and sketched to illustrate their nature, extent, and severity.
- The drawings shall be annotated with photos of severe defects and highlighted.
- The criticality, maintenance needs, and performance deficiencies of each element shall be noted in the inspection forms, as shown in Figure 3 or similar categorization developed by the Entity.

Suspected Performance Deficiencies (PD)

00 – None	06 – Bearings not uniformly loaded/unstable	12 – Slippery surface	**RW Timing**
01 – Load carrying capacity	07 – Jammed expansion joint	13 – Flooding/channel blockage	<1 Year
02 – Excessive deformations (deflections & rotation)	08 – Pedestrian/vehicular hazard	14 – Undermining of foundation	1 – 5 Years
03 – Continuing settlements	09 – Rough riding surface	15 – Unstable embarkments	6 – 10 Years
04 – Continuing movements	10 – Surface ponding	16 – Other	None
05 – Seized bearings	11 – Deck drainage		Urgent

Maintenance Needs (MN)

01 – Animal/Pest Control	07 – Bridge Surface Repair	13 – Repair of Bridge Concrete	**MN Timing**
02 – Bridge Bearing Maintenance	08 – Concrete Sealing	14 – Repair to Structural Steel	1 Year
03 – Bridge Cleaning	09 – Electrical Maintenance	15 – Rout and Seal	2 Years
04 – Bridge Deck Drainage	10 – Erosion Control at Bridges	16 – Scaling (Loose Concrete or ACR Steel)	Now
05 – Bridge Deck joint Repair	11 – Other Maintenance		
06 – Bridge Railing System Maintenance	12 – Painting Steel Bridge Structure		

Figure 3: Performance Deficiency and Maintenance Needs table

- The Inspector shall identify items that need maintenance and/or repairs.
- The Inspector shall identify each item to ensure public safety and maximize the longevity of the bridge.
- The Entity shall develop and implement an inspection form as referenced in Attachment 2 to assist Inspectors in performing required activities related to bridge assets. The checklist (Attachment 2) is not exhaustive and represents a collection of typical inspection activities.

11.3.5 Reporting of Visual Inspection

The Entity/Contractor shall complete the comprehensive technical Visual Inspection reports. The reports shall be prepared and reviewed by qualified and competent engineers and should include the following, but not limited to:

- Cover page
- Structure inventory and appraisal data
- Map coordinates displaying the location of the structure
- As-built drawings (if available) or sketches
- Record of the location, extent, and severity of all defects
- Bridge element condition tables, quantities, charts, illustrations and diagrams as necessary
- Relevant recorded observations, measurements, and readings of monitoring points
- Element condition tables, charts, sketches, and diagrams (as required)
- Identify when a further investigation or an additional examination is needed, and recommend the scope of necessary work. Buried or revealed hidden parts should be reported.
- Photographs (general and defect)
- Recommend essential/remedial maintenance actions/requirements including the extent and priority level
- Provide details of any emergency actions required for the bridge
- Confirm that the inspection has been completed
- List any significant defects which have occurred or deteriorated
- Changes which have occurred since the last inspection should be listed and reported
- Identify whether there is a requirement for further investigations or action
- General inspections shall be reported and approved by the Entity

11.4 Detailed/In-Depth Inspection

11.4.1 Purpose:

- The Entity/Contractor should carry out Detailed/In-Depth Inspection of the bridge when the general/visual inspection yields unsatisfactory results; at this stage, ascertaining the safe live load capacity is prudent.

11.4.2 Scope:

The Entity/Contractor shall perform extensive inspections by qualified and competent personnel; this may include physical testing and/or structural analysis to assess the following:

- Close examination of all inspection items and/or critical elements of the asset. This is performed to provide visual confirmation on conditions necessary for the management of the assets.
- Detailed inspections shall bring to notice deterioration in condition or visible development of defects and appraise the effects on the asset.
- Current structural condition, behavior, and capacity.
- Rate of deterioration and residual life expectancy.
- Asset management strategies.
- Non-destructive field tests.
- Detailed inspection of all relevant bridge components, i.e., measurements, testing, and analysis as necessary to supplement the visual inspection).
- Determination of material properties and structural behavior.
- Identification of components that are limiting the performance of the structure due to their current condition and capacity or are likely to deteriorate within the next few years.

- Identification of the probable causes and projected rate of deterioration and the effects of the continued decline on the performance, durability, and residual life of the structure.
- Identification of factors that will influence the dynamic load allowance to be utilized in load ratings. These factors include the geometry and quality of the bridge approaches, surface discontinuities at deck joints, and the dynamic response of the bridge.
- Examination of the hydraulic performance of the structure, including any signs of siltation, scour, debris impact or build-up, bank or embankment erosion, and tree & vegetation encroachment.

The Entity/contractor should identify specific tests required for each bridge, depending on the element's condition. The in-depth inspections should include, but not be limited to, the following listed criteria:

- Half-cell potentials of uncoated reinforcing steel in concrete
- Pulse velocity through concrete
- Schmidt hammer
- Core test
- Carbonation
- Sulfate, chloride and cement content
- Crack assessment

Detailed inspections shall be reported, consisting of, but not limited to:

- Detailed Inspection Cover sheet, signed by the inspectors and checkers
- Contents sheet
- Asset specific form
- Any additional information required
- Executive summary
- Introduction and purpose
- Structure description
- Site Visits details and findings
- Structural analysis, calculations, and findings
- Test results and findings
- Summary
- Conclusions
- Recommendations

11.5 Special Inspection

The purpose of a Special Inspection is to provide detailed information on a part, area, or defect that is causing concern, or inspection of which is beyond the requirements of the general/In-Depth inspection regime. Special Inspections are scheduled at the discretion of the bridge owner and utilized to monitor a known or suspected deficiency. The inspection types that best fit this definition are the following:

- Provide additional or frequent information on assets necessary for management purposes.
- The requirement for a close inspection of a particular area or defect causing concern.
- Where inspections detailed in 10.3 and 10.4 does not provide enough information or as instructed by the Entity.
- Special Inspections shall be reported with all findings and conclusions (approved by the Entity).
- Deck surveys to measure the number of spalls and delamination.
- Interior box girder inspections, due to the presence of permit-entry confined spaces.
- Concrete corrosion/Cathodic protection system inspection.
- Concrete segmental bridge inspection due to the complexity of the structure.
- Bridge clearance measurements for the routing of over-sized vehicles.
- Load ratings and bridge post regulations.
- Scour monitoring.
- Underwater bridge inspection procedures.
- Fracture critical inspections.

11.6 Inspection for Analytical Assessment

- An Inspection for Analytical Assessment shall provide the physical information pertaining to an asset (essential for evaluation purposes).
- A thorough examination of all inspection items and/or critical elements of the asset, performed within proximity to determine section sizes and the extent of deterioration, or other features that impact the ability of the asset to perform its required obligations.
- The inspection shall cover the condition of the individual components and the structure as an entity, observing signs of distress and associated root causes. The report shall be documented on the inspection form relevant to the structure being inspected.
- The inspection for the Analytical Assessment shall be undertaken by the individual carrying out the bridge assessment/load rating.
- Inspections for Analytical Assessments shall provide information on the loading applied to the assets and factors relevant to the asset's structural resistance.
- Inspection information shall be provided under the following general headings:
    - Confirmation of information contained in drawings and documents
    - Accurate estimates of dead and superimposed dead loads, including surcharge loadings
    - Structural dimensions and load dispositions
    - Details of finishes and fixings
    - Service ducts and services
    - Clearance dimensions
    - Sufficient to determine imposed loading and structural clearances
    - Structural condition and evidence of physical deformation
    - Evidence of foundation deterioration
    - Performance of bearings and expansion joints

11.7 Damage/Defect Advice Inspection

- Defect Advice Inspections shall be performed following notification or a report of an incident that causes damage to an asset or has the potential to adversely affect the ability of the asset to perform its required function.
- Information shall be collected for reporting incidents being investigated and to identify the immediate root causes.
- Sufficient information shall be collected to ensure the safety of the asset before the instigation of an assessment.

11.8 Inspection Frequency

- The Entity/contractor inspection frequencies should be based on risk (i.e., structure developing a fault sufficient to interrupt the user service either by partial or complete bridge closure).
- The frequency of asset inspections shall be undertaken as defined in Section 11.3.
- The process of inspection type selection should be as defined in Figure 1 and Section 11.0.
- The Entity may request assistance in creating/conducting a structural inspection regime for assets. Where appropriate, inspection frequencies should be as similar to Section 11.0 or as agreed with the Entity.

12.0 BRIDGE REPAIRS

Bridge Repairs are frequently required due to inadequate maintenance, excessive loading, change in use, in code of practice, and/or exposure to adverse environmental conditions. Regular rehabilitation and repair of existing bridges is an efficient and economical procedure; this maintains the serviceability of the current bridge inventory.

- The Entity shall perform repair services of all bridge structure components, elements, and assets in accordance with manufacturer's specifications and Section 4.0.
- The manufacturer's recommendations or original specifications should be consulted in each instance.
- The Entity should develop a comprehensive bridge maintenance manual to detail the specifications, procedures, and requirements for bridge repairs and rehabilitation.
- Maintenance repair specifications included in Section 4 are for informational purposes only. They are not intended to be used for actual repairs. Any other use of this document shall be the responsibility of the design engineer. Repair details and specifications are distinct for each bridge

and vary with the defect type, bridge type, material, and location. This document may be used only as a reference.
- The Entity/bridge owner reviews and approves all drawings and specifications related to repairs of existing bridge structures and structural systems.

12.1 Concrete Repairs

Effective repair of concrete structures entails understanding the causes of deterioration and assessment of the repair technique. Concrete Repairs should be based on the evaluation and tests of the existing structure. Corrosion of steel reinforcements is the most common reason for repairing concrete structures. The following should be considered:

- Reinforcement steel covering
- Carbonization depth – the depth of carbon penetration into the concrete
- The area contaminated with chlorides
- Details of the concrete mixture
- Concrete age
- The environmental factors that have caused the contamination and related condition

The test program and its outcomes will lead to understanding the extent of the existing defect and the cause of deterioration.

Concrete Repair may be required for several reasons other than reinforcement steel corrosion. Among these are damages resulting from fire, in which case the same general strategy will be adopted in the repair.

Concrete repairs to the existing bridges shall be carried out in accordance with the detailed requirements highlighted in codes and references of section 4.0 and the following ACI documents:

- 546R-14: Guide to Concrete Repair.
- 562-19: Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary.

The requirements detailed in the codes and references in section 4.0 and above documents encompass the following key aspects in the repair and rehabilitation of existing concrete bridge structures:

- General requirements for concrete repair
- Evaluation/condition assessment requirements for concrete repair
- Structural analysis for concrete repair
- Design, implementation, execution, durability, and quality assurance requirements for concrete repair

12.2 Steel Repairs

Steel repairs to the existing bridges should be carried out in accordance with manufacturer requirements and specifications and the specific requisites highlighted in codes and references of section 4.0.

The requirements detailed in section 4.0 encompass the following critical aspects in the repair and rehabilitation of existing steel building structures:

- General provisions for evaluation of existing steel buildings and its repair
- Material properties and tests for evaluation of existing steel buildings and repair
- Evaluation by structural analysis of existing steel buildings
- Evaluation by load testing of existing steel buildings
- Evaluation Report
- Design, implementation, execution, durability and quality assurance requirements for steel repair

13.0 BRIDGE REHABILITATION/STRENGTHENING

- Strengthening and rehabilitation work shall be controlled to ensure assets meet the required parameters.

- Strengthening and rehabilitation work shall be designated a corrective action to address life-expired assets or elements (in accordance with the supplier's program for lifecycle management or a change in use, function, or duty of the asset/element).
- Strengthening and rehabilitation work shall be based on the principles of lifecycle asset management.
- Strengthening and rehabilitation work shall be based on inspection reports (section 11.0), Load Rating/Bridge Assessment (Section 14.0), and Analytical inspection (section 11.6).
- The work carried by the Entity/Contractors for strengthening and rehabilitation to existing bridge assets shall comply with the provisions mentioned in the relevant sections and the AASTHO design and maintenance documents, white book guidelines (Document No. EPM-KES-GL-000001) and any other relevant Entity specific regulations.
- The strengthening and rehabilitation work shall be carried out in the manner that the minimum design loads shall be similar to when the bridge was constructed. If any structural component is exposed during the strengthening/rehabilitation and if the condition assessment of the components establish that these structural elements are unsound or dangerous, then these shall be made to comply with applicable clauses of AASTHO LFRD codes, white book guidelines (Document No. EPM-KES-GL-000001) and any other relevant Entity specific regulations.
- The Contractors shall provide and acquire approval from the Entity for the designated work area and access. The work area shall be clearly highlighted and identified within the construction documents.
- The Entity/Bridge Owner reviews and approves all drawings and specifications related to strengthening and rehabilitation of existing bridge structures and structural systems.

14.0 BRIDGE ASSESSMENT/LOAD RATING

14.1 Purpose:

The Bridge Assessment/Load Rating is performed in the following circumstances:

- The bridge has developed deterioration, and overall strength has diminished.
- Loading standards have changed.

Assessment results should determine the type of maintenance to be performed on bridge assets.

The Entity shall develop a Bridge Assessment/Load-Rating program for the bridge assets to establish the following:

- Load carrying capacity.
- Assure safety where routine inspection/examination results in insufficient information to confirm load-carrying capacity.
- Establish actions, including programs of physical works and/or consultation with customers and stakeholders on asset capability requirements.

14.2 Scope:

- The Bridge Assessment shall include the use of two- and three-dimensional computer grillage or frame analysis (as appropriate for the structural configuration).
- The elements of the structure to be assessed shall include all components where the insufficient load-carrying capacity would pose a risk to people in the vicinity of the structure and the operation of the network.

14.3 Bridge Assessment/Load Rating Activities

The Entity shall undertake and develop the following Bridge Assessment/Load Rating Activities:

- Desktop studies including surveys and record searches
- Reconnaissance
- Planning the inspection for assessment
- Identification and provision of data for the management of hidden parts and susceptible fatigue

- Inspection for assessment (including specifically targeted aspects to address issues identified in earlier routine inspections)
- Determination of load-carrying capacity of the structure
- Assessment report with calculations, photographs, and drawings
- Results and reports added to asset management systems (such as BMS)
- Defect and bridge risk matrix
- Recommendations on future actions following the Bridge Assessment/Load Rating Activities:
    - Bridge strengthening or replacement
    - Impose traffic restrictions for the safe load-carrying capacity of the bridge
    - Bridge monitoring; determination of failure will not be fatal, and signs of failure are readily visible.

15.0 ATTACHMENTS

1. Attachment 1 - List and Schedule of Recommended Bridge Planned Maintenance Activities
2. Attachment 2 - EOM-ZM0-TP-000041 – Bridge Inspection Template

Attachment 1 – List and Schedule of Recommended Bridge Planned Maintenance Activities

Task	Frequency	Standard/Regulation
Scheduled Planned Maintenance		
Clean/Sweep Deck	1 Year	• ACI 546R-14: Guide to Concrete Repair • ACI 562-19 Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary • Joint Transportation Research Program: Indiana Department of Transportation (Technical Report FHWA/IN/JTRP-2015/22): Bridge Preservation Treatments and Best Practices (Appendix G) • AASHTO Maintenance Manual for Roadways and Bridges – 2007 (Chapter 3) • Kingdom of Saudi Arabia Ministry of Communications/Transportation (MOT) General Specifications for Road and Bridge Construction (Part 5) • Kingdom of Saudi Arabia Ministry of Municipal and Rural Affairs (MOMRA), General Directorate of Operation and Maintenance (Bridges and Tunnels Maintenance Manual) (Chapter 5) • Maintenance and Repair Techniques Maintenance Supervision of Bridges for the City of Makkah (June 2015) Pennoni International
Seal Deck	5 Years	
Clean Deck Drains/Scuppers	1 Year	
Clean/Flush Expansion Joints	1 Year	
Clean Superstructure	2 Years	
Seal Superstructure Elements	5 Years	
Seal Substructure Elements	5 Years	
Clean/Flush Bearings	1 Year	
Lubricate Bearings	4 Years	
Paint Bearings	10 Years	
Remove, Place New Wearing Surface	12 years	
Seal curb, Sidewalk, Fascia	5 years	
Paint Bridges	12 years	
Fill Cracks & Joints	5 Years	
Deck Partial Patching	5 Years	
Approach Slab Cleaning/Flushing	1 Year	
Approach Slab Drainage Cleaning/Flushing	1 Year	
Spot Painting Steel Elements	10 Years	
Vegetation Control	1 Year	
Remove Debris Substructure	1 Year	
Clean/Flush Connections	2 Years	
Lubricate Connections	4 years	
Spot Paint Connection Members	10 years	
Responsive Maintenance		
Spot Paint Steel Members	As Needed	• ACI 546R-14: Guide to Concrete Repair • ACI 562-19 Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary • Joint Transportation Research Program: Indiana Department of Transportation (Technical Report FHWA/IN/JTRP-2015/22): Bridge Preservation Treatments and Best Practices (Appendix G) • AASHTO Maintenance Manual for Roadways and Bridges – 2007 (Chapter 3) • Kingdom of Saudi Arabia Ministry of Communications/Transportation (MOT) General Specifications for Road and Bridge Construction (Part 5) • Kingdom of Saudi Arabia Ministry of Municipal and Rural Affairs (MOMRA), General Directorate of Operation and Maintenance (Bridges and Tunnels Maintenance Manual) (Chapter 5) • Maintenance and Repair Techniques Maintenance Supervision of Bridges for
Clean Abutments/Caps	As Needed	
Maintain Spillway	As Needed	
Replace/Repair Joints	As Needed	
Remove bush - Spot Locations	As Needed	
Maintain Stream Channels	As Needed	
Maintain Bank Protection & Walls	As Needed	
Repair Bearings	As Needed	
Repair Joints	As Needed	
Spot Painting	As Needed	
Maintain Elec. & Mech. Equip.	As Needed	
Repair Wearing Surface	As Needed	

Task	Frequency	Standard/Regulation
		the City of Makkah (June 2015) Pennoni International

Attachment 2 – EOM-ZM0-TP-000041 – Bridge Inspection Template

Rating Scale: From 1 to 9		Description	PRIORITY		Asset Name	
NEW		New	1	URGENT	Asset Number	
8 to 9	Very Good	Almost new condition. No repairs required in foreseeable future.	2	ESSENTIAL	Location	
6 to 7	Good	Generally good condition. Could be upgraded to new condition with very little effort.	3	DESIRABLE	Inspection Date	
4 to 5	Fair	Acceptable condition and functioning as intended. No repairs necessary at this time.	4	LONG-TERM work outside 5-year planning	Inspector	
2 to 3	Poor	Below minimum acceptable condition. Presence of distress or deterioration. High priority for replacement, repair, an d signing.				
0 to 1	Immediat e Action	Danger of collapse and/or danger to users. Replacement, repair, and signing required as soon as possible.			General Asset Condition	ADEQUATE ☐ SUBSTANDARD ☐ INADEQUATE ☐
N		Elements not sufficiently accessible for an adequate visual inspection				

	Inspection Activity	CONDITION						Identified Defects / Recommended Action	Recommended Priority			
		NEW	8 to 9	6 to 7	4 to 5	2 to 3	0 to 1		1	2	3	4
1.0	National Bridge Elements											
	Decks and Slabs											
	Deck											
	Deck - Top Flange											

	Inspection Activity	CONDITION						Identified Defects / Recommended Action	Recommended Priority			
		NEW	8 to 9	6 to 7	4 to 5	2 to 3	0 to 1		1	2	3	4
	Deck - Open Grid											
	Deck - Concrete Filled Grid											
	Deck - Corrugated / Orthotropic											
	Slab											
	Bridge Railing											
	Bridge Railing											
	Superstructure											
	Girder/Beam											
	Closed Web/Box Girder											
	Stringer											
	Truss											
	Arch											
	Floor Beam											
	Cable - Primary											
	Cable - Secondary											
	Gusset Plate											
	Pin, Pin and Hanger Assembly, or both											
	Bearings											
	Elastomeric Bearing											

	Inspection Activity	CONDITION						Identified Defects / Recommended Action	Recommended Priority			
		NEW	8 to 9	6 to 7	4 to 5	2 to 3	0 to 1		1	2	3	4
	Moveable (roller, sliding) Bearing											
	Enclosed/Concealed Bearing											
	Fixed Bearing											
	Pot Bearing											
	Disk Bearing											
	Other Bearing											
	Substructure											
	Columns											
	Column Tower (Trestle)											
	Pier Wall											
	Abutment											
	Pile											
	Pier Cap											
	Pile Cap/Footing											
	Culverts											
	Culvert											
2.0	**Bridge Management Elements**											
	Joints											
	Strip Seal Expansion Joint											
	Pourable Joint Seal											
	Compression Joint Seal											

	Inspection Activity	CONDITION						Identified Defects / Recommended Action	Recommended Priority			
		NEW	8 to 9	6 to 7	4 to 5	2 to 3	0 to 1		1	2	3	4
	Assembly Joint/Seal (Modular)											
	Open Expansion Joint											
	Assembly Joint without Seal											
	Other Joint											
	Approach Slabs											
	Pre-stressed Concrete Approach Slab											
	Reinforced Concrete Approach Slab											
	Wearing Surfaces, Protective Coatings, and Concrete Reinforcing Steel Protective Systems											
	Wearing Surfaces											
	Steel Protective Coating											
	Concrete Reinforcing Steel Protective System											
	Concrete Protective Coating											
3.0	**Agency Defined Elements**											
	Decks and Slabs											
	Curbs/Sidewalks											
	Sound barrier wall on/attached to the structure											
	Superstructure											
	Seismic Retrofit Components											
	Bridge Mounted Sign Structures											
	Bearings											
	Isolation Bearing											
	Sliding Plate Bearing - Expansion/ Movable											

	Inspection Activity	CONDITION						Identified Defects / Recommended Action	Recommended Priority			
		NEW	8 to 9	6 to 7	4 to 5	2 to 3	0 to 1		1	2	3	4
	Spherical Bearing											
	Bond Breaker Bearing - Expansion/ Movable											
	Substructure											
	Slope Protection											
	Wingwalls											
	Headwalls											
	Fender System											
	Bulkhead											
	Joints											
	Elastomeric Flex-Type Joint											
	Asphaltic Plug Expansion Joint											
	Other											
	Concrete Encasement											
	Bridge Drainage											
	Temporary Support Structures											