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Roadway Safety Barriers and Signage Maintenance Plan

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1.0 PURPOSE

The purpose of this Roadway Safety Barriers and Signage Maintenance Plan is to provide information and advice needed by the various stakeholders in setting up and executing the maintenance of the different types of assets associated with transportation systems.

This Maintenance Plan provides advice and instruction that is international best practices, and is currently adopted, or could be adopted as part of continuous improvement, in the Kingdom of Saudi Arabia (KSA).

This Maintenance Plan is useful from the pre-bid stage through the operational stage to the contract termination stage.

2.0 SCOPE

This Maintenance Plan is designed to guide all stakeholders tasked with the responsibility of ensuring that maintenance work is carried out to a high standard and in a consistent, contract compliant, and comprehensive manner.

This advice will be applicable across varying types of contracts and operating models, including multi-site contracts, outsourced delivery models, and specialist environments.

The guidance provided here is intended for application within the transportation systems sector but the principles can be applied to the hard services maintenance environment.

The advice presented here resides within the context of several related documents within Volume 6. Reference should be made to sections of Volume 6 titled ‘Conduct of Maintenance’ and ‘Types of Maintenance’. This Maintenance Plan resides within the context of several plans pertaining to roads and structures within Volume 6.

Maintenance Plans are essential to the writing and execution of maintenance procedures. A Maintenance Plan is not always necessary but can help, from a quality assurance and management perspective, to ensure that the business operates in a manner that is in line with good practice.

Maintenance Plans are a key tool in moving a maintenance operation away from a reactive model to a planned model, and to better connect operations and asset management.

This Maintenance Plan presents relevant advice to assist the following stakeholders to carry out their responsibilities:

- Client-side Representative
- Contracts/Bid writer
- Mobilization Manager or Team
- Human Resources (HR) Recruiter
- Stores/Procurement Manager
- Asset Management System (AMS) Programmer (Scheduler)
- Asset Management Team
- Operations Team
- Property Management Team
- Supply Chain Team

This Maintenance Plan refers to the base fixture measures (i.e. foundations) or other attachment arrangements such as buildings, bridges/underpasses, etc. It addresses the structural elements that extend from the fixture point/foundations to the supported asset.

The maintenance strategy of signage and safety barriers, in common with many structural assets, will consist primarily of planned inspections and address corrective maintenance issues as they arise.

This Maintenance Plan is written keeping the Ministry of Transport assets in mind, but it is also applicable to privately owned structures, such as advertising signboards attached to buildings or ground secured advertisement boards.

Parking lot barriers are not referred to in this Maintenance Plan as they are discussed elsewhere within Volume 6 (under Roads Maintenance Plans).

3.0 DEFINITIONS

A Maintenance Plan is a document that addresses the requirements for the delivery of maintenance to an entire system, or group or type of asset, records the decision making or recommendations, and describes the strategy selection and to what standard the asset will be maintained. A Maintenance Plan consists of many aspects, including the use of job plans or task lists as part of work orders to deliver the intended maintenance strategy.

Term	Definition
AASHTO	American Association of State Highway and Transportation Officials
AMS	Asset Management System
Asset Condition Report (ACR)	A report, written by a technically competent and responsible individual, containing information, observations, conclusions and recommendations for other stakeholders to consider and act accordingly
Best Practice	A method or technique that has been generally accepted as superior to any alternatives because it produces results that are superior to those achieved by other means or because it has become a standard way of doing things (e.g., a standard way of complying with legal or ethical requirements)
BOD	Basis of Design
BSRIA	The Building Services Research & Information Association
Chainages	A defined area of ground within which all relevant assets will be maintained under a unique maintenance instruction (work order)
Consumable	Physical part of an engineered system, Personal Protective Equipment (PPE) or a cleaning, treatment or preservative liquid or compound whose consumption or use as part of a maintenance task is necessary and predictable
Corrective Maintenance	Refer to Volume 6, Section 3 for ‘Types of Maintenance’
Criteria	The selection of one or more parameters that defines the technical condition or performance of a system
Criticality	Typically, a 4-5 level ranking system that categorizes the importance of the component, asset, or maintenance task. Refer to Volume 2
Equipment	Plant that is designed to be mobile or requires erecting or putting together in order to be used, such as scaffolding
Frequency	Refers to a cyclic time period
Hot Works	A category of work activity that requires the use of heat and/or flame and is subject to an elevated level of risk assessment and work control
Inclusive Repair Limit (IRL)	A remedial cost threshold figure stated within a contract under which the maintenance contractor is responsible for funding. Costs above this figure are funded by the client and require authorization prior to progressing the work
Inspection/inspect	Activity of non-invasive visual observation of a stationary or operating asset
Job Plan	A list of pre-designed tasks that are recommended to be performed at certain frequencies on plant. Different frequencies will have different ‘job plan’ details, i.e. tasks. See task list

KSA	Kingdom of Saudi Arabia
LED	Light Emitting Diode
LOLER	Lifting Operations and Lifting Equipment Regulations
Maintenance Levels	The complexity of maintenance activity (e.g., Level 1:Rreset, Level 2: Planned Maintenance (PM), Level 3: Monthly) related to the skillset/competence level and experience of the Operative; sometimes referred to as 'task level'
Maintenance procedure	Maintenance procedures outline the activities associated with the execution of maintenance work, from pre-start to completion, with activities at both the maintenance contractor's management office and 'on site', involving technical, and non-technical people
Monitor	See 'facility surveillances'
MEWP	Mobile Elevated Work Platform
MUTCD	Manual on Uniform Traffic Control Devices
NCLOM	National Committee for Legislation for Standardization of Operation and Maintenance.
Non-Destructive Testing (NDT)	Such as ultrasonic thickness testing on metal structural elements
Parameter	The name of a unit or metric, (e.g., 'pressure', 'velocity', 'temperature')
Plan	Compilation of activities, procedures, resources and schedule etc. to achieve an outcome
Personal Digital Assistant (PDA)	An electronic tablet type device that provides instruction to the user and allows them to record and confirm and update status
Planned Maintenance (PM)	Refer to Volume 6, Chapter 3 for 'Types of Maintenance'
POWRA/JHA	Point of Work Risk Assessment/Job Hazard Analysis: A short checklist that Operatives refer to at the location of and immediately before carrying out a task
PPE	Personal Protective Equipment
Predictive Maintenance	Refer to Volume 6, Chapter 3 for 'Types of Maintenance'
Procedure (maintenance)	Refer to 7.2.5.4
Program	Same as schedule. Refers to the time basis of the delivery activity
Permit-to-Work (PTW)	A safety management documented system adopted by most organizations for management of high-risk work activities
Risk Assessments and Method Statements (RAMS)	Risk Assessments and Method Statements
Reactive Maintenance	Refer to Volume 6, Chapter 3 for Types of Maintenance
Remedial	Refer to Volume 6, Chapter 3 for 'Types of Maintenance'
Repair	The physical activity of carrying out a remedial work order
Run to Failure (RTF)	A maintenance strategy where the asset is deliberately not maintained but allowed to run until it fails
Safety Person	Person responsible for monitoring surrounding dynamic risks presented by traffic or pedestrian movements in order to warn Inspectors or others working
Satisfactory	Fulfilling the requirements, needs or expectations
Schedule	Same as program. Refers to the time basis of the delivery activity
Skillset	Refers to one or more work related skills of a person. Sometimes referred to as 'craft code'
SLA/KPI	Service Level Agreement/Key Performance Indicator
SME	Subject Matter Expert
System	An arrangement of components and parts that, when combined, perform a desired function
Task list	A list of tasks that, when combined in various combinations, can constitute a 'job plan'. See job plan
Test	Verifying by means of observation or measurement that the system meets the expected and/or acceptable requirements

Threshold	Numerical value of a parameter at which a decision is made
Unplanned Maintenance	Refer to volume 6
Unsatisfactory	Failing to fulfil the requirements, needs or expectations
Work Management Center	Team or office responsible for the management of planning and execution of resources to meet the needs of planned and unplanned contractual and customer requirements. Refer to Volume 7 'Work Control'
Working at Height (WAH)	A work location category designated for safety management reasons so that additional measures can be applied to ensure safe working
PMT	Post Maintenance Testing
NCLOM	National Committee for Legislation and Standardization of Operation and Maintenance

4.0 REFERENCES

- American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide
- Inspection of Highway Structures: Inspection and Maintenance, Section 3, BD63/17
- KSA Ministry of Transportation Guide November 1998
- Lifting Operations and Lifting Equipment Regulations (LOLER) Regulations
- Maintenance of signs and sign support, Federal Highway Administration 2010
- Manual on Uniform Traffic Control Devices (MUTCD)
- National Committee for Legislation and Standardization of Operation and Maintenance (NCLOM)
- National Manual for Assets & Facilities Management – Volume 2: Asset Management
- National Manual for Assets & Facilities Management – Volume 3: Condition Assessment
- National Manual for Assets & Facilities Management – Volume 6, Chapter 2: Conduct of Maintenance
- National Manual for Assets & Facilities Management – Volume 6, Chapter 27: Post Maintenance Testing (PMT)
- National Manual for Assets & Facilities Management – Volume 7: Work Control, Maintenance Procedure Writers Guide
- National Manual for Assets & Facilities Management – Volume 8, Chapter 11 Equipment and Tool Control
- National Manual for Assets & Facilities Management – Volume 9 Contracts Management
- National Manual for Assets & Facilities Management –Volume 6, Chapter 3: Types of Maintenance
- The Building Services Research & Information Association (BSRIA) Computer-based Operating and Maintenance Manuals – Options and Procurement Guide
- Traffic Performance Improvement Guide for Streets and Roads, Ministry of Municipal and Rural Affairs (MOMRA) A 2005
- Traffic regulation, Ministry of Interior, General Traffic Department 2010

5.0 RESPONSIBILITIES

Responsible	Description
Maintenance Plan Writer	Technically competent person responsible for writing the Maintenance Plan
Operative	An unskilled or semi-skilled person with enough knowledge and experience in transportation systems would be able to carry out the tasks assigned to them. This general term covers a range of trade skills such as painter, welder, concrete worker, scaffold erector, etc. applicable to transportation system maintenance. Generally, has a supervisor as a line manager
Inspector	A semi-skilled or skilled person with enough qualifications, knowledge, and experience of transportation systems in order to carry out the tasks they are responsible for to a satisfactory standard. Generally, the line manager for the Operatives/Supervisor

Responsible	Description
Subject Matter Expert (SME)	A person considered very knowledgeable in their subject(s) of expertise and are providing advice to the Maintenance Plan Writer and others as appropriate. SMEs would be more qualified, knowledgeable, and experienced than required by the Inspector

6.0 PROCESS

A Maintenance Plan is a key document to any maintenance organization. Although it caters to many stakeholders, it must remain concise and focused.

The aim of this Maintenance Plan is to provide all the information needed by the various stakeholders who tender, recruit, engage, resource, plan and schedule maintenance activities, as well as advice on, the opportunities for continuous improvement and potential risks. Therefore, this Maintenance Plan will consider the connections and dependencies of asset management, operations management, financial and performance management, supply chain management (inventory), business reputation, and health and safety.

Maintenance Plans are dynamic documents, generally embedded in the AMS, and should be continuously and periodically reviewed as part of a continuous improvement activity. It is recommended that this periodic review be carried out at a frequency of two years as a minimum unless the client or contractor organization have specific requirements for documents of this type. This periodic review is not to exclude adoption of improvements arising from continuous improvement opportunities. This Maintenance Plan has been written with reference to the various documents listed in the References section.

Transportation assets are mostly static and have no moving parts. Movement often indicates the potential of a fault materializing. As a result, the monitoring and measurement of movement is a key opportunity in transportation systems maintenance plans, as this activity can improve predictive repair.

Planned inspection of structures follows a condition monitoring and predictive maintenance approach, where the intention is to identify and rectify any defect before it has an impact on the facility or infrastructure that it serves. Repair is dependent on available resources, access to the asset, available spares and funding.

6.1 Traffic Sign Types

The General Traffic Department in the Ministry of Interior specifies three classes of signs defined by their function.

6.1.1 Regulatory Signs

Regulatory signs are used to communicate the rules and regulations of the road. It is very important to maintain this type of sign because their absence or damage may contribute to the frequency of road traffic accidents. Work Orders for damaged or missing regulatory sign shall be assigned a high priority and should be repaired or replaced within hours of notification. Regulatory signs are usually a combination of black, white and red colors as shown in the figure below.

Figure 1: Examples of Regualtory signs

6.1.2 Guide Signs

Guide sign are usually used to help drivers to navigate and get to a particular destination. Road users could miss their destination due to the absence of or damage to this type of sign which could lead to erratic driver maneuvers, slowing or stopping, and making abrupt turns. The repair or replacement of these signs depends on how critical the sign is. The shapes and colors used in this type of sign vary upon the intended message to be conveyed.

Figure 2: Examples of Guide signs

6.1.3 Warning Signs

Warning signs provide drivers notices of potential hazardous situation or conditions. Work Order for the repair and replacement of this type of signs shall be assigned a suitable priority.

Figure 3: Examples of Warning signs

6.2 Maintenance Plan

6.2.1 Maintenance Strategy

Strategy Options and Recommendations

- The recommended strategy for maintenance of transportation systems is planned maintenance.
- This planned maintenance will take the form of periodic inspections leading to follow-on activities which may include additional/specific monitoring (facility surveillance), corrective maintenance or major repair and rehabilitation.
- This planned maintenance strategy is commonly adopted internationally and is considered the most applicable and effective strategy for transportation systems assets.
- The risk of impact to traffic, reputation, contract penalties, etc. arising from the catastrophic failure of a road sign (e.g., motivates the importance of good quality and timely inspections) should be assessed.
- Planned periodic inspection maintenance for structural assets commonly occurs under two frequencies. These typically take place every two years (often referred to as 'Preliminary Assessments') and every five years (often referred to as 'Detailed Assessments'). Refer to 'Inspection of Highway Structures: Inspection and Maintenance', Section 3, BD63/17. However, manufacturer and maintenance contracts with specific recommendations or requirements may dictate other frequencies.
- In the absence of specific documents requiring different frequencies, the biannual and five-yearly frequencies are recommended for transportation systems in KSA.
- Asset management advice recommends that planned maintenance work orders are assigned to a chainage 'asset area'. A 'chainage' is for example, 250 sq.m in towns and cities, or 1 kilometre of 'main road'. The size of this chainage will be influenced by natural boundaries such as major junctions, but also the density of sub-assets. Similarly, a main road may have few distinct sub-assets and hence the chainage may be 25 km. However, the principle of including all sub-assets within the area, regardless of type, remains valid.
- Reactive maintenance will always be a feature of the maintenance of transportation systems assets because of the risk of damage to the assets by vehicles. Reactive maintenance differs from corrective maintenance, as corrective maintenance is raised by the Inspector carrying out the planned maintenance, while reactive maintenance is raised by anyone who reports a fault and may follow a traffic accident or other damaging incident.
- Depending on the maintenance contract details, in particular the threshold value of the inclusive repair limit, it is possible that the contractor may not be responsible for funding the repair work but it is their name that is easily associated with the lack of progress on repairs.
- Spare parts for transportation systems should be readily available as there is limited variation in asset designs affecting selection of replacements. Also, repairs can often be carried out on the asset rather than the need to source a replacement. These repairs are often simple in terms of technology, with metal fabrication being a common solution.
- Predictive maintenance is not recommended as the maintenance strategy for transportation systems inspections. However, the inclusion of facility surveillance can supplement planned maintenance inspections where there is a concern that requires more frequent inspection than the default or contracted frequencies. Facility surveillances could incorporate the continual 'predictive' maintenance philosophy.

- Facility surveillance of high-level assets could be achieved with the use of binoculars or mobile (vehicle based) elevating platform, removing the need for fixed, erected high-level access equipment. The long-term presence of high-level access to equipment is likely to be prohibitively expensive.

- Unplanned, 'run to failure' maintenance strategy is not recommended for transportation systems maintenance. The catastrophic failure of a transportation system asset is likely to have a significant impact on the transportation infrastructure and public safety. Therefore, unplanned maintenance is not recommended for transportation systems. Overall, maintenance of transportation systems needs to address the findings applicable to these type of systems and assets as reported by National Committee for Legislation for Standardization of Operation and Maintenance (NCLOM).

6.2.2 Maintenance Requirements

6.2.2.1 Maintenance and Competency Requirements

- Maintenance level refers to the complexity of the maintenance task, and therefore drives the skillset level of the maintenance Operative. The maintenance levels associated with transportation systems are described as:

    - Basic: Tasks that an unskilled Operative could be given (e.g. training or instruction), but the Operative is not competent enough to understand the consequences of what they are reporting or to make technically and contractually correct decisions.
    - Semi-complex: Tasks that require an elevated level of attention to detail or qualified technical skill such as welding; a competence to know when to investigate further or question an instruction, and an ability to objectively and comprehensively describe what work has been carried out or needs to be carried out
    - Complex: Tasks that require a high level of understanding of civil and structural engineering, including identifying causes of defects such as corrosion, fracture, etc.

- Competency requirements or 'skillset' refers to the required experience and knowledge of the maintenance Operative, Inspector, Engineer, etc. Skillset levels associated with transportation systems are described as:

    - Unskilled: Operatives that have been trained 'on the job', have no formal qualifications and have limited ability in understanding, analyzing and reporting
    - Semi-skilled: Operatives that have up to five years of good quality work experience, specifically in transportation systems inspection, maintenance and repair and have been given increasing level of responsibility
    - Skilled: Operatives such as degree qualified engineers with several years of relevant experience who can demonstrate continual progression in breadth and depth of knowledge and competence through increased responsibilities

- The maintenance level for planned maintenance inspections and remedial repairs of transportation systems is semi-complex. As maintenance is mostly non-invasive inspections, it is natural that this maintenance be carried out by a suitably knowledgeable, semi-skilled, or skilled engineer. Planned maintenance of transportation systems is not suitable for unskilled workers.

6.2.2.2 Planned Maintenance Requirements

- Planned Maintenance (PM) is the recommended strategy for all transportation system assets when considering access to carry out the inspections, and any remedial work arising from the inspections. Scheduling access, including closing sections of roads, for these types of assets is best suited for planned maintenance.

- Because transportation systems maintenance follows the well-established practice of time-based planned maintenance there are no unusual Service Level Agreement/Key Performance Indicator (SLA/KPI) aspects other than those applied to other assets maintained under a planned maintenance strategy.

- Access to carry out the inspection of some assets relies heavily on being able to manage the traffic for safety reasons (e.g., road or lane closure). This is likely to be dependent on permissions from a government or other authority outside the control of the maintenance contractor. Therefore, any failure to complete the inspection and/or repair within a specific timeframe (e.g., due to inclement weather) may not be the maintenance contractor's fault and they should not be penalized if they have made reasonable attempts at gaining permissions etc. This also applies to weather.

Unplanned Maintenance Requirements

- Unplanned, corrective maintenance on these types of assets is dependent on the extent of the damage and the criticality of the asset. For example, similar damage to a Regulatory sign located in a main road will require a higher priority Work Order than a Warning sign in a residential street. For this reason, each asset or group or type should have a criticality score that advises the default priority for corrective and reactive work.

6.2.3 Technical Standards

The following documents should be referred to and applied when writing a Maintenance Plan for specific transportation systems assets. These documents also provide advice on the standard of repairs:

- Basis of Design (BOD) is a key criterion when specifying the threshold for remedial actions
- Refer to section 6.4.14 and 6.4.15 for general structure Maintenance Plans guidance
- KSA Ministry of Transportation Guide November 1998
- AASHTO Roadside Design Guide – replacements must be compliant
- KSA Road Safety Manual – to maintain these to original condition
- Manual on Uniform Traffic Control Devices (MUTCD)

It is recommended that objective technical standards are provided by a SME to the Maintenance Plan Writer. It is important to have as much of an objective criteria as possible to remove the overuse of subjective descriptors such as 'poor', 'serviceable', etc. which do not ensure consistent feedback and instructions to the work management center.

A sample of objective technical requirements that are recommended for decision making in raising remedial or follow-on work is given here. This type of information will appear in the job plan/task list so that the corrective maintenance arising from inspections are raised consistently:

- Traffic signposts of a height of 2.5 m or less should be less than 10 degrees from the vertical before a remedial action be recommended.
- Roadside linear barriers (e.g., Varioguard), for both median and boundary locations, should be less than 10 degrees from their intended inclination.
- Posts supporting signs at a height greater than 2.5 m should be less than 5 degrees from the vertical before remedial action be recommended.
- Technical standards criteria for deviation of inclination are applicable in the absence of other faults such as corrosion or disturbed ground conditions.
- Where corrosion and/or other damage is also present, acceptable deviation from inclination should be minimal
- Where movement of a bolted joint is observed, and that movement has reached the maximum deflection of the 'tolerance slot', remedial work should be recommended
- Where disturbance of paint at bolted and welded joints of a metal structure is estimated to exceed 10% of the number of joints, attaching 'calibrated/incremental movement trackers' to the key location(s) of cause or concern should be recommended as a minimum. More urgent and invasive repair may be necessary
- Where movement of above ground concrete bases, supporting posts, or any height of more than five degrees from the horizontal is observed, remedial work should be recommended

6.2.4 Engineering Delivery

The following sub-systems and minor assets should be inspected and subject to individual repair.

6.2.4.1 Engineering Requirements

- Safety barriers (roadways) permanent traffic control (e.g. guard rails, linear 'Varioguard' barriers, median and boundary)
  - Ground foundation
  - Other ground fixing devices
  - Post (s)
  - Post/barrier fixing
  - Barrier/barrier fixing
  - Interlocking (concrete)
  - Reflective markers
  - Other markings
  - Attached signs and lights
  - Surface coating

- Safety barriers (Roadways) temporary traffic control (e.g. jersey barriers, concrete, metal, and plastic designs)
  - Structural integrity
  - Lifting hooks
  - Reflective markings
  - Other markings
  - Attached signs and lights

- Signage – roadside (trunk, residential, etc.)
  - Ground foundations
  - Other ground fixing devices
  - Posts
  - Post/sign fixings
  - Fixing to concrete structures (buildings, walls, etc.)
  - Sign integrity
  - Sign markings
  - Surface coating

- Signage – overhead (major roads)
  - Ground foundations
  - Other ground fixing devices
  - Posts (single, lattice, etc. design)
  - Post to horizontal fixing
  - Fixing to concrete structures (bridges, etc.)
  - Horizontal sections
  - Sign integrity
  - Sign markings
  - Surface coating
  - Integral lighting

- Warranties on newly installed assets are mostly limited to the quality of the workmanship and materials, specifically ground foundations and fixing methods installed according to construction requirements, and surface coatings and signage colors that have passed quality assurance checks as materially acceptable and installed according to instruction.

- As there are typically no active maintenance activities (e.g., washing), it is unlikely that lack of maintenance could be a factor in failure of the asset during the warranty period.

- For recently constructed or erected assets, the manufacturer may require access to revisit the installation after an initial period to inspect the tightness of fixings and other items that may have a

settling in period. The maintenance contractor is recommended to ensure that such visits are accommodated in order to not only to prevent voiding any construction warranty, but also to receive identification and feedback on possible issues than may be present outside of the warranty period.

- There are no reasons to recommend whether maintenance is carried out in-house, outsourced or a combination of these two. As is common with many maintenance operations, there is merit in retaining technical staff so that the same staff can benefit from familiarity with the assets over a period of several maintenance visits.

- It is highly recommended that defects on all assets are recorded and not considered 'acceptable' and therefore not requiring formal recording. There can be a tendency for Operatives to decide that 'there is no point' in recording a defect that existed previously and clearly has not been repaired

6.2.4.2 Job Plan/Task List Requirements

- Delivery of this Maintenance Plan will adopt the Expro maintenance (job) plan/task list template.

- The output from a transportation systems planned maintenance work order is an asset condition report, which will generate recommendations for further actions or work.

- Planned maintenance inspection of transportation systems is mostly non-invasive, namely visual or by means of non-intrusive technologies such as acoustic penetration assessment.

- While transportation systems assets do not normally have measuring points, it is recommended that components that are repeatedly assessed for condition are clearly identified so that subsequent maintenance visits refer to the same component. For example, if a selection of bolts on several km of barrier is inspected for signs of movement or corrosion, it is recommended that this selection is identified so that the components are inspected repeatedly. Paint or fixed 'tab' with a unique identification is used for condition monitoring purposes. This principle can also be applied to lattice metalwork structures that support signs.

- Proper and complete reinstatement of access panels and other altered or disturbed items should be a step in the maintenance (job) plan/task list instructions for the Inspectors and repair Operatives.

6.2.5 Work Control Center

6.2.5.1 AMS Requirements

- Advice from the asset management team on appropriate chainage areas should be sought. It is likely that part of the recording of the chainage areas are graphical as this is an effective way to record the asset areas with minimum risk of error or misunderstanding.

- Criticality of assets is an important factor in setting the chainage area size. Criticality is applied in the configuration of maintenance operations in two ways: setting of the frequency of the planned inspection and setting the 'size' of the chainage that the work order is applied to. Therefore, a road junction, with the localized area density of high criticality sub-assets such as traffic lights, curbs, signage, etc. is likely a separate chainage 'asset area' to the adjacent sections of main roads that the junction serves.

- Chainage size may also be influenced by the breadth of skills that the contractor is able to deploy. For example, the contractor may not have structural engineers suitably competent for the inspection of steel structures. Hence, carrying out all required inspections in an area may require engaging Inspectors from two different companies.

- The recommended frequencies for the planned maintenance inspections is biannually and five times a year.

- Bi-annual inspections should be carried out by a semi-skilled Operative and involve non-invasive inspections including those requiring high level access such as via Mobile Elevated Work Platform (MEWP).

- For biannual inspections, the Inspector should be able to get to within 300 mm of all parts of the asset but should not require the removal of inspection hatches (overhead road signage systems) or cutting back of shrubbery around concrete bases of structure. The biannual inspection should record any disturbance to the ground around foundations as the method of assessing condition and any need for further inspection or repair. This inspection should include checking for evidence of movement of welded or bolted section of metalwork, commonly identified by cracking of paintwork or surface coating. Fractures to concrete and staining from reinforcement within concrete should also be checked, recorded, and evaluated for any decision for follow-on work.

- The five-yearly inspection should include inspections requiring the removal of inspection hatches and cutting back of shrubbery and removal of limited soil to allow close but partial inspection of subterranean assets. The five-yearly inspection should also require measurement of critical dimensions that have been identified as indicators of compliance with design tolerances. Paint and surface coating thickness and adhesion should also be assessed using the 'peel test' method, and ultrasonic techniques, if recommended by the manufacturer or maintenance specialist.

- Transportation systems are almost always exposed to weather considerations. Annual cyclic, 'extreme' and local geographical factors will also affect the intensity of the weather conditions that the assets are exposed to. These conditions include heat, cold, wind, abrasion (by sand), rain, and to a limited extent infrequent instances of earthquakes. Wind can be influenced by location including such factors as whether or not the asset is located in a side street of a town and protected from exposure to the sun but perhaps subject to specific wind directions. Other factors such as whether or not the asset is located on a major road may impact its exposure to abrasive elements. Scheduling, KPI impacts, and deferred maintenance aspects should be taken into account when considering the potential damage to assets caused by exposure.

- Planned maintenance inspections may need to be deferred beyond the contracted KPI timeframe. Indeed, remedies may need to be deferred. The most likely reason for deferral is not being able to close a section of road or junction to allow the work to be carried out in accordance with the Risk Assessments and Method Statements (RAMS). Closure of sections of roads and junctions may require permissions for a local government authority and hence reside outside of the control of the maintenance contractor. Refer to Volume 3 for more advice on deferred maintenance.

- Depending on the condition of the assets, and the availability of funding, the adoption of a 'facility surveillance' approach to supplement planned inspections is worth considering if the condition of an asset is at risk of worsening or presenting a high risk of failure.

- The recording of data, such as metal thickness or post inclination, needs to be considered. As the frequency of the inspection is quite long, typically biannually, it will take several years before a useful graph of changes in condition will be available.

- Storage of asset/material measurements data needs to be considered, and it is recommended that the inspection reports and objective measured data are stored centrally for business efficiency and continuity reasons.

- Asset/material measurement data should also be shared with the asset management team and others so that the longer planning, and securing of funding for improvement projects, have all the information available for their purposes.

- General advice on AMS is recommended from the 'BSRIA Computer-based Operating and Maintenance Manuals – options and procurement guide'.

6.2.5.2 Planning Requirements

- Planned maintenance inspection activities related to transportation systems should be carried out by semi-skilled Operatives as described above.

- Transportation systems repair work, typically to metal or electrical assets, should also be carried out by semi-skilled Operatives as a minimum.

- Accessibility, weather conditions and sourcing of access and test equipment are key aspects of planning that may require attention.

- Transportation system planned maintenance inspections can be considered quite dangerous because of the risk of injury from nearby traffic or working at height. For this reason, it is recommended that Point of Work Risk Assessment/Job Hazard Analysis (POWRA/JHA) is performed by the Operatives.

- Advanced inspection tasks that involve Non-Destructive Testing (NDT), such as the use of acoustic penetration assessment, should be supported by RAMS. This will help ensure safe operation of the equipment in a location that may not be easy to access with sensitive and potentially large test equipment. Analysis of the recorded information is an office-based activity.

- Depending on the safety requirements for working on certain types of roads, there may be a requirement to comply with a safe working management system such as Permit-to-Work (PTW). This is most likely in high risk location such as main roads and high-level signage assets.

- Barrier inspections will require a minimum of two Operatives, with one acting as a safety person observing traffic behavior and able to warn the Inspector(s). One safety person is adequate for up to three Inspectors but needs to be risk assessed to confirm.

- Time taken to inspect high-level assets will be dependent on placing and elevating the access equipment and moving them frequently. Depending on the complexity of the high-level asset, the inspection time could equal the placement, erection/elevation and dismantle/lowering time. Regarding linear road barriers, an inspection pace is approximately 1 km per hour and depends on the complexity of the arrangement and whether curbs are being surveyed at the same time. If curbs are being surveyed at the same time the pace will be lower. This time will allow the Inspector to record the condition and detail the remedies as the inspection progress

- Tools required by Inspectors are likely limited to flashlights, camera, clipboard or Personal Digital Assistant (PDA). Tools for repair will depend on the repair being carried out but may include welding, which may be subject to hot works control measures.

6.2.5.3 Materials Resources Requirements

- High-level access equipment will be essential for inspecting and repairing high-level assets such as overhead road signs. MEWPs may be hired or owned, and both approaches causes risk to the maintenance activity. Ownership brings responsibility for repair, logistics of delivery, training of competent persons to operate the equipment and insurance and other maintenance requirements. Hiring of high-level access equipment causes the risk of availability and reliability of the supplying contractor and potential difficulties if changes to schedule become necessary. Maintaining MEWPs to a recognized international standard, such as LOLER, will help ensure this type of equipment is safe to use and, depending on specific agreements, that insurances are not invalidated.

- NDT may be recommended by the Inspector depending on the outcome of the non-invasive inspections. This type of equipment will likely have a periodic calibration requirement. However, if this test equipment is hired, the calibration maintenance responsibility will likely remain with the supplying company. Familiarity and competent use of this type of test equipment is a factor that needs assessing and resourcing, such as training.

- The requirement and responsibility for carrying out testing of the electrical installation associated with integrated lighting will need to be determined. If this work is to be carried out by a separate company to the structural and civil assets, then coordination with the electrical contractor is recommended in order to gain efficiencies with the high level equipment and reduce the impact from any traffic management measures that are required.

- An opportunity for service level improvement is presented when cleaning of high-level signs is carried out while the high-level access equipment is in place.
- Except for lamps, poles and sections of barrier, most parts are unique to each installation and hence any need to store commonly required parts is limited.
- Consumables related to transportation system will depend on the specific installation but is likely limited to lamps for the integrated lighting systems.
- High cost materials are uncommon in transportation systems as the common materials are metal support systems, barriers and signage, concrete foundations and bases, and limited electrical lighting. The main cost of maintenance of transportation systems relates to access equipment, NDT equipment and traffic management.
- A maintenance cost that could potentially be expensive relates to the repair or upgrade of foundation that have been damaged or found to be inadequate. Securing funding for this type of repair will be more successful if the criteria that defines failure is clear, such as inclination angle.
- Obsolescence is not a significant feature due to the relative simplicity of the technologies.
- Where large road signs have a damaged section that needs replacing, care needs to be taken that the replacement part is matched to the existing in terms of font, color and material. Refer to Figure 4 for advice on examples of common faults and repairs of signs.
- Where a large sign is illuminated by several integrated lights, it is best that the replacement lights match the existing one from a color perspective. If the opportunity to improve longevity and energy reduction is to be taken by installing Light Emitting Diode (LED) lighting on signs that are currently illuminated by discharge lamps, it may become necessary to replace all lights serving individual signs even though some/many are working satisfactorily.
- Metal signs are recyclable and hence should be considered for recycling.
- Discharge lamps contain chemical elements that are detrimental to the environment and can usually have these contents removed and recycled in an approved way.

Defect	Repair options	Example photograph
Sign bend	- Try to straighten the sign by bending the sign back in place on the sign post with hand pressure - If the sign cannot be straightened with hand pressure, remove the sign from the support, place it in a flat surface and pound flat with a rubber mallet. - If the sign no longer serviceable, replace it.	
Scrapes and holes	- The sign should be straightened first, then all holes should be pounded flat with a rubber mallet - Clean the areas to be patched with a proper material - Make sure the retroreflective material used for patching is the same as the material used on the face of the sign. If it is not available or there is a doubt, replace the sign. - Use die cut, pressure sensitive, pre-spaced letters, borders and symbols to replace the damaged legend. - Apply aluminum foil tape to seal the hole on the back of the sign in order to stop moisture from reaching the adhesive on the sign sheeting patch.	
Overpaint	- Clean the sign using materials that will not damage the sign face material. - Make sure that paint removal does not affect the sign`s retroreflective properties. - Paint should not be removed with abrasive compounds that will leave scratches on the sign face.	

Figure 4: Examples of common sign faults and repairs

6.2.5.4 Operational Requirements

- Coordinating the attendance of different trades when high level access equipment can be utilized is recommended to reduce costs and disruption to traffic and pedestrians. Likely trades are electrical teams responsible for maintaining integrated lights.

- ‘Client side’ stakeholders are likely to be the Ministry of Transport and/or other authority responsible for the operation and access to transportation systems assets. These stakeholders will be central to providing the permissions to access the assets, the high-level assets and assets adjacent to main roads.

- Repairs to assets may be directed by the client-side stakeholders to be carried out 'out of hours' to reduce the impact on traffic. Working in low lighting conditions may require supplemental lighting, possibly provided by mobile generator.

- The client-side stakeholders may decide to defer repairs until another known project at the same location commences to reduce the impact to traffic. In such situations, the maintenance contractor should formally update their advice on any negative impact of the deferred maintenance.

  Note that overhead signage may be attached to a non-dedicated asset, such as a road bridge. In the railway sector, overhead signage is usually only attached to dedicated structures, not to the overhead power cable support gantries

6.2.6 Risk Management

Supporting/Mitigation Requirements

- Catastrophic failure can potentially arise from weather conditions (force majeure), accidental impact (e.g. vehicular), etc., as well as unexpected acceleration of a known/monitored situation. This can create a situation where a very urgent/emergency inspection or escalation, including engagement of traffic management may be required. An Escalation Plan is recommended for the management of assets.

Mobilization Requirements

- As with all mobilization of maintenance contracts; it is important to have a comprehensive understanding of the asset management, condition and risks presented by each asset. Most contracts have a defined mobilization period, a window of time at the beginning of the contract when the maintenance contractor can bring variations/clarifications to the client's attention for adjustment to the contract as necessary. This mobilization activity reduces the risk of exposure to contractual non-compliance by the contractor or exposure to funding commitments that were perhaps not budgeted for.

- If a mobilization phase activity to inspect each transportation systems asset is carried out, early understanding of the resources needed to carry out inspection will become known. As mentioned elsewhere, access to high-level assets adjacent to main roads is likely the most demanding access challenge, requiring permissions and coordination. This experience will be fed into the work management center, the scheduler and planner.

- During the mobilization stage, the Asset Manager, work management center, and other stakeholders will be able to assess the professionalism and competence of the Operatives and Inspectors in their ability to capture the condition and associated risks of the contract, as well as perform the expected maintenance tasks. Shortcomings observed at this early stage will act as a warning that staff training may be necessary.

6.2.7 Health and Safety

Health and Safety Requirements

- Depending on company policy, contract requirements, and risk mitigation identified in the RAMS, it may be necessary for staff working at height, in certain circumstances, to wear fall arrest equipment.
- Where an Operative is required to crawl within a lattice structure, consideration for 'incapacitated recovery' needs to be given.
- RAMS will recommend the required Personal Protective Equipment (PPE) and other mitigations. These requirements should feature in the maintenance instructions created within the AMS.
- Awareness training of Operatives of the consequences of failure of these transportation systems assets is recommended. Some of these assets are large, exposed to adverse weather conditions and the impact on traffic is likely to be significant, causing actual harm as well as reputational damage.
- Maintenance cannot be carried out in wind conditions in excess of 10 km per hour for structures in excess of 10 m of height. Structures lower than 10 metres may be inspected in wind conditions up to 20 km per hour. Repair work limitations will depend on the activity and require risk assessing.
- Risk Assessment of carrying out inspection and repair work on these types of assets will clearly highlight the risk from traffic and hence carrying out this work during peak traffic times and/or without a safety person or traffic management is not recommended.
- The use of ladders to access high-level assets is likely to be limited as most signs are above 2 m above ground level. The maximum acceptable working height for ladders will vary depending on company policy but it is unlikely that high level signage assets will be within the height restriction
- Also related to high level assets, the use of flashlights and cameras needs to be risk assessed as both are operated by hand and therefore reducing the ability of the Inspector to use both hands to assist in their safety while working at height.
- Competence confirmation of all staff should be set and checked. Erectors of scaffolding and operators of MEWPs will likely need to have completed certified training and this should be checked when engaging a contractor or assigning an Operative.

6.3 Relationship with Maintenance Procedures

This Maintenance Plan should be engaged within the maintenance contract and organization in accordance with procedures, standards, templates, and plans as appropriate. This will help ensure good practice and contract compliance.