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Volume 3, Chapter 2

Condition Assessment Planning

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1.0 PURPOSE

The purpose of this document is to set out the requirements to be met for the creation, implementation, and management of a Condition Assessment Plan (CAP). Effective application of the provisions of this document will enable the Entity to develop plans that detail what needs to be done, how, by when, and by whom.

The development and implementation of an effective CAP will provide the Entity with the ability to manage activities associated with understanding the level of safety and performance risk, manifested by the condition of its assets.

It is essential that the Entity can demonstrate the manner in which it intends to obtain data relating to an asset's condition, on a periodic basis, in a reliable and evidence-based way.

2.0 SCOPE

This document does not cover the specific technical aspects of how to conduct a Condition Assessment Survey (CAS). For information on how to conduct a CAS, refer to Volume 3 Chapter 3. The scope of this document extends to the effective planning and management of activities associated with conducting the Condition Assessment itself.

The requirements set out within this document are intended for Asset Managers, Maintenance Managers, Engineers and Technicians.

3.0 DEFINITIONS

Term	Definition
Asset	An asset is an item, thing, or entity that has potential or actual value to an organization. The value will vary between different organizations and their stakeholders, and can be tangible or intangible, financial or non-financial.
Asset Classification	Asset Class is a term used to refer to a group of assets having a similar nature or function and which, for purposes of disclosure, are shown as a single item.
Asset Lifecycle	The phases through which an asset transitions, from planning to disposal.
Asset Management	The coordinated activity of an organization to realize the full potential of any asset.
Asset Management Software (AMS)	A software-based, asset management tool or solution, used to record and track an asset throughout its life cycle, from procurement to disposal.
Asset Management System	Any set of interrelated or interacting elements a Company or Entity employs, to keep track of its equipment and inventory, that is vital to the continued operation of its business.
Asset Register (AR)	A list of all assets, often computerized, that contains pertinent details about each asset to track the value, physical location, operating cost, condition, utilization, and all other details, necessary to better manage the asset.
Condition Assessment (CA)	The process of periodic physical inspections, assessments, measurements, and interpretation of the resultant data to indicate the condition of a specific asset.
Condition Assessment Plan (CAP)	The Condition Assessment Plan. A documented set of time bound activities, setting out the manner in which Condition Assessments shall be conducted and managed.

Term	Definition
Condition Assessment Survey (CAS)	The element of the Condition Assessment that shall include all the factual asset condition findings as stipulated in the Planning instructions.
Forward Maintenance Register	A projection of work/maintenance required, specifically for assets held within the Entity. Also referred to as the Maintenance Plan.
Industry Best Practice	In relation to any undertaking and any circumstances, the exercise of that degree of skill, diligence, prudence and foresight, which would reasonably and ordinarily be expected from a skilled and experienced operator engaged in the same type of undertaking, under the same or similar circumstances.
International Standards Organization (ISO)	The international, standard-setting body composed of representatives from various national standards organizations.
Lifecycle	The cycle of activities that an asset (or facility) goes through, while it remains an identity as a particular asset, i.e. from planning and design, to decommissioning or disposal
Linear Asset	Linear Assets often connect with each other, defined by the length (or area), and are often part of a network, such as rail lines for trains, water pipes for water and roadways for cars
Non-Linear Asset	Non-Linear Assets occupy a specific space and can be tracked by their location (Buildings, Offices, Plant and Equipment).
Operating Context	The environment within which a physical asset or system is expected to operate.
Quality Management	Quality management is the act of overseeing all activities and tasks needed to maintain a desired level of excellence.
Risk Appetite	It is the nature and extent of risks that the Entity is willing to accept, and will impact the asset base and its operating context.
Subject Matter Expert (SME)	An individual who possesses the necessary competence in a subject matter that enables them to offer advice and guidance on all aspects of managing the subject matter in question.
Strategic Plan	A plan containing the long-term goals and strategies of an organization.
Strategic Asset Management Plan (SAMP)	A documented plan that specifies how the organizational objectives are to be converted into Asset Management activities, the approach for developing Asset Management Plans, and the role of the Asset Management System in supporting the achievement of Asset Management Objectives.

Table 1: Terms & Definitions

4.0 REFERENCES

- ISO 55000:2014 2.5.3.7 Performance Evaluation
- National Manual of Assets and Facilities Management (NMA&FM) Volume 2: Asset Management
- NMA&FM Volume 4: Financial Planning
- NMA&FM Volume 10: Health, Safety, Security and Environment
- NMA&FM Volume 12: Risk Management
- NMA&FM Volume 15: Performance Monitoring
- NMA&FM Volume 3 Chapter 3: Condition Assessment Survey
- ISO 13372: 2012 Condition monitoring and diagnostics of machines — Vocabulary
- ISO 13374-1:2003 Condition monitoring and diagnostics of machines — Data processing, communication, and presentation — Part 1: General guidelines
- ISO 13374-4:2015 Condition monitoring and diagnostics of machine systems — Data processing, communication, and presentation — Part 4: Presentation
- ISO 13379-1:2012 Condition monitoring and diagnostics of machines — Data interpretation and diagnostics techniques — Part 1: General guidelines

- BS ISO 13381-1:2015 – TC Tracked Changes. Condition monitoring and diagnostics of machines. Prognostics. General guidelines
- BS ISO 2041:2018 – TC Tracked Changes. Mechanical vibration, shock, and condition monitoring. Vocabulary

5.0 RESPONSIBILITIES

Role	Description
Entity	Each Entity will have the following responsibilities and be accountable for: • Providing support and advice on development and deployment of the Asset Management System • Responsible for developing the risk management system in compliance with Saudi Law, Industry-specific, and local regulations. • Preparing plans for appropriate Condition Assessment (CA). • Ensuring that Condition Assessments are aligned with Government Regulations and the details laid out in Volume 3 of the NMA&FM. • Identifying or sourcing the appropriate resources to carry out the Asset Management System' tasks. • Training or briefing (whichever is more appropriate depending on resources selected), the selected resources to ensure uniformity across all asset categories, and conformity to the NMA&FM. • Assisting in the compilation of the Condition Assessment Report (CAR), particularly in the prioritization of assets, and possible future requirements for their use. • Planning and implementing recommendations established by the Condition Assessment Report (CAR) • Establishing Entity-specific, Asset Management stewards and Entity champions, to accelerate deployment of Asset Management policy • Establishing Entity-specific asset data management stewards and Entity asset data champions to manage data quality to the highest standards.
Service Delivery Team	• Carries out workplace risk assessments, and supports the development of method statements. Supports risk assessment management across Entities. • Provides detailed reports and advice, based on facts and evidence, in collaboration with the Entity.

Table 2: Responsibilities & Accountabilities

6.0 PROCESS

It is essential that the Entity applies the CA process in its entirety. The steps outlined below are intended to provide a complete and integrated approach to the planning of CAs. Omitting aspects of the outlined planning steps will affect the value and credibility of the plan.

CAs comprise three key phases, each containing key elements to ensure completeness, and quality of the plan ((Refer to Figure 1). For this process, the measure of success is the establishment of factual and current information about an asset's condition, based on objective and testable evidence.

The planning phase of a CA is intended to ensure that all information, personnel, tooling, techniques, and methodologies, are correct and fit for purpose. Discrepancies will lead to inaccuracies in the results, which will directly impact strategic decisions, and therefore the value of the asset to the Entity.

CA is initiated and repeated as a necessity, and the planning phase shall be followed in its entirety, regardless of whether it is applied to develop the initial plan, or to manage an existing plan.

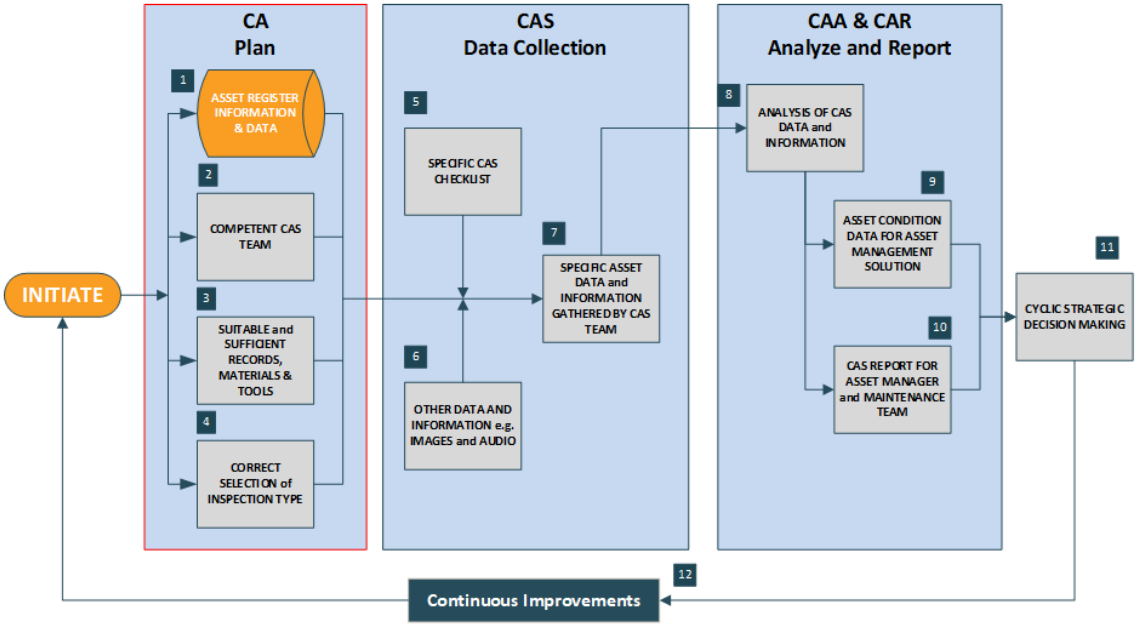

Figure 1: High Level CA Process Flow

6.1 Associated Factors

6.1.1 Measures

For the outcomes to be consistent, the following shall be applicable:

- Industry-standard, units of measurement shall be used throughout the CAP process.
- The specific asset's identification and location quoted in the CAP, is in accordance with NMA&FM AM's hierarchy and formatting.
- Personnel who are employed in the planning and execution of a CAP are competent, and fully familiar with NMA&FM Volume 3.
- A Health and Safety, Risk Assessment (RA) has been carried out, in accordance with Volume 10 of the NMA&FM.
- Irrespective of the type of inspection to be used, the execution of the CAP will not leave a residual risk to the asset, facility, operation, or the public who use it.
- The overall priority for carrying out a CAP is aligned with the Critical Asset list, as formulated by the Asset Managers and key stakeholders associated with that asset, or facility type.

6.1.2 Safety

Entities have a duty of care to safely carry out activities which may present a risk to the wellbeing of those employed. This duty of care extends responsibilities to the employees to also make sure that they, and other people are safe in the workplace, and requires that they cooperate with the employer in this regard.

If you are an employer, you have a responsibility for the health and safety of everyone in your workplace, including visitors. In order to carry out the responsibilities held in this respect, it is essential that the risks associated with such activities, carried out by the Entity, are understood, documented, mitigated and controlled. Examples of such risks, within the context of this document, are where the plan requires lone working of employees, or that employees are required to carry out their duties in confined spaces, or near traffic. A focus and structured approach is necessary to fulfill that duty of care, and where doubt exists, the advice of the Entity's Health & Safety (H&S) department, or the asset's Subject Matter Expert (SME) shall be sought after, for an expert opinion.
The CAP assists the Entity by setting out the nature and number of assessment activities to be carried out, so that measures to safeguard its employees can be set in place in good time.

Guidance on the identification and management of H&S matters can also be found in Volume 10 Health, Safety, and Environment of the NMA&FM, where details about Risk Assessments (RA), Personal Protective Equipment (PPE), and Safety procedures are stipulated.

6.1.3 Evaluate Asset Complexity

Assets can be simple or complex. A simple asset is one that does not contain complicated systems, structures, or materials such as a wall, pavement, or a desk. The level of technical competency required to maintain or repair this type of asset, is relatively low. A complex asset such as a bridge, a hydraulic system, or an X-Ray machine that requires a higher level of competence to maintain or repair.

In understanding the level of complexity involved with assessing the asset in question, suitable provisions can be made within the CAP for the allocation of resources, with the appropriate level of competence.

6.1.4 Access to Documentation, Drawings & Records

Provision and access to information such as asset records, drawings, technical manuals, and data from previous assessments, including new information from handover and commissioning, is essential to the formulation of the plan, as it enables accurate assessment of timescales required for carrying out the actual assessments required.

Obtaining and reviewing such documentation provides the Entity with the opportunity to identify, and potentially correct discrepancies.

6.1.5 Coordination with Asset Owners

Access to specific assets may only be available at certain times of the day, week, month, or year. Examples of these are roads, railways, offices, facilities; in fact, most assets and facilities fall in to these categories. Therefore, early engagement will be required throughout the planning and consultation with asset owners, in order to ensure that timescales allocated for CAS activities are realistic, and take into account any requirements for obtaining permits and permissions to gain access. An example would be the requirement to have security clearance and a security guide, to enable access due to the security levels imposed.

6.1.6 Preparation of Hardware

The preparation shall cover the following points in readiness, and ahead of initiating any inspections:

The most important aspect to completing any task is the people involved. Consideration of Human Factors is key to a successful CAS report; therefore:

- A suitable work routine shall be evaluated i.e. rest breaks must be regular, sufficient refreshments and food should be consumed, and a robust communications system established with all involved, and lone working shall be avoided wherever possible.

In addition to the Human Factor aspects, the following shall also be included in the preparation of hardware:

- Spare power capacity for all software items i.e. batteries and power leads.
- Clothing, including footwear, should be suitable for the terrain, and environmental conditions.
- All the drawings, maps, technical manuals, and instructions required are gathered. It is worth assigning the responsibility of looking after these items to an individual in the team.
- Transportation is available for the whole duration of the CAS and is suitable for the task, there is sufficient fuel, and it has the capacity to carry the team and all associated equipment.
- Electronic-data storage devices have enough storage capacity for all data to be collected. This includes cameras, laptops, and dicta-phones.
- Equipment such as ladders and platforms are fit, and safe for purpose.
- Equipment that is subject to regular calibration checks must be in date for calibration to ensure quality.

Part of any effective CAP will be ensuring that sufficient tools, equipment, and hardware, such as access equipment, are available to the assessor at the time the assessment is planned.

6.1.7 Execution Work Plan

A detailed execution work-plan shall be developed in order to perform each CAS, complying with referenced standards, and in accordance with best practices and Entity guidelines. The execution plan shall be submitted to the manager responsible for the review and approval, prior to commencement of the survey. In addition to standards and requirements, the following points shall be adhered to:

- CAS checklist scope and scoring criteria is relevant to the type of asset to be assessed.
- Where historical data exists, carry out a sense check against it, which may help to clarify results.
- Interview stakeholders who can provide information about the asset or facility.
- Data and information collection methods used, are of appropriate technology and consistent with previous inspections.
- A review of maintenance activities and spares consumption will assist in the correlation of asset history, and information relating to the rate of deterioration.
- Where an asset or Facility's condition is potentially putting safety, reputation or intended function at an unacceptable risk, it shall be brought to the asset owner's attention.
- In the interest of continuous improvement, any specific or generic lessons learned during the CAP creation, should be included in the CAP report. This might include access issues, conflicting interests with end-users or other stakeholders, inaccurate Asset Register (AR) data, and resource issues.

Once all associated CA factors are identified and correlated, it will be possible to move forward with the main part of the Planning Phase.

6.2 Asset Register - Establishing Assets to be included in the CA

The emphasis of CA shall focus on the nature of an asset's function i.e. those assets whose performance is important to the function of the Entity's overall operation, safety of personnel, and the public. Consultation with Subject Matter Experts (SMEs), Original Equipment Manufacturers (OEMs), Operational Staff and end-users, will assist in understanding the asset priorities held within each location. Some examples of higher priority assets are listed below:

- Medical Equipment and Facilities

- Safety Equipment
- Vehicles
- Bridges, Dams and Tunnels
- Elevators, Escalators and Travellators
- Roads, Pathways and Signage

The object of CA is to establish the current condition of priority assets, and to monitor this over time to establish degradation trends, which may create a risk to performance. Therefore, the identification of assets subject to CAS, is essential to the Entity and the overall management of assets.

The Asset Register (AR) shall provide an empirical list of all maintainable assets held for any given Entity, and will include per asset, their current condition rating. An AR and CAP for carrying out CA, shall be developed and maintained by the relevant Entity.

Due to the volume and potentially, wide dispersal of assets geographically across the various Entities, the ability to CA all assets, may present particular challenges. In these circumstances it may be acceptable to select a representative sample of assets from the AR, to be subjected to CA. The scope of the sample shall provide a suitable selection of assets to represent the asset group. However, it is essential that, if conducting a CAS on a reduced sample of assets, the number selected is statistically relevant, and the scores of the reduced population are extrapolated across the total population. The higher the percentage of the total population assessed, the higher the likelihood of the sample group findings being representative.

Consideration must be given to the options available to optimize the data gathering productivity. An example might be the use of high-speed cameras mounted on vehicles or the use of drones, which can dramatically increase data capture rates; however, this approach shall be managed responsibly due to the safety implications, and the method of recording the data shall be well prescribed by the Entity.

6.3 Competencies

Personnel involved in the overall CA process shall be evaluated to demonstrate competence, and ensure quality. There are differing requirements for demonstrating competency, depending on the role of the individual, complexity of the asset, CAS technique to be used, and the environment that the asset resides in.

This section sets out the requirements and attributes that CA personnel must possess, in order to be assessed and deemed competent.

6.3.1 Competence of Components

While there is a very broad range of processes, tools and technologies that will enable or assist the team in performing CA, fundamentally it is the competence and capacity of the team members conducting the inspections, that is critical to producing meaningful and valuable information for the Asset Managers.

Competence, by definition, is the ability to do something successfully or efficiently.

6.3.2 Knowledge & Training

The people performing CA and the Asset Assessment Inspector should have the appropriate academic qualifications in an engineering discipline relevant to the asset being assessed. For example, Building Services Engineering qualifications such as electrical or mechanical, or civil engineering are essential for doing an assessment or inspection on built assets like schools, hospitals, and offices.

Up to date and relevant training, ensures that the knowledge and skill levels remain consistent, in terms of the actual requirements to be undertaken, and the output required. For instance, Priority Rating frameworks may differ from when a CAS was last carried out by a specific CAS procedure.

There are also continuous advances and changes in the knowledge of technical disciplines, such as engineering; Therefore, personnel performing CAS must keep up to date with current advances in technology, as well as changes in their field of expertise. Furthermore, an inspector must show evidence that they are continually developing their skills and education through attending courses, seminars, industry conference, and so forth. This aspect is the responsibility of the relevant Asset Managers, and the line management structure.

The ability to read architectural and engineering drawings is a necessity. All personnel must be kept informed and trained as necessary, in the standard formats used per Entity and asset, or the system type being assessed.

Familiarity with relevant building codes, geographical layouts, and other forms of asset displacements, must also be understood.

6.3.3 Skill

Skills gained from experience and field work, is an essential attribute for demonstrating competence in understanding how to practically apply academic knowledge, for the development and implementation of the CAP.

Good examples of essential CA skills are the ability to review and understand technical documents, and being able to discuss and support findings when questioned during, or after a CA procedure.

6.3.4 Strength & Resilience

In many cases, inspections can be both physically and mentally tiring. Inspectors must be able to perform their duties effectively in offices, buildings and also in the field, in potentially very arduous conditions.

Members of the CA team must also possess a very high degree of honesty, integrity and reliability, without which the results of a CA will not be consistent and therefore, misleading to the Asset Managers towards shaping a strategy for the future.

6.3.5 Language

The inspector should also have an excellent command of the relevant language, in this case English. This is especially required when writing and reporting on the findings of the inspection. The reports must always be presented in a clear, concise, and unambiguous writing format, that can be understood by the concerned people in the Entity.

6.3.6 Soft Skills

As with all aspects of Business, reliable and effective communication is key to the successful execution of objectives. This is especially true of CA. Before setting out a new or even an existing CA task, it is always advantageous to have dialogue between the relevant managers and the CA team, to ensure the objectives have been made clear, and that everyone understands their part in completing the task efficiently, and completely. CA is about the acquisition of fact, and not opinion.

Asset Management must possess a level of ability in relation to Human Factors associated with each CA task. Therefore, empathy is also an essential soft skill for management, when delegating CA tasks, and to avoid needless harm.

6.3.7 Competence of the CA Analyst

The competence of an individual or group of SMEs assigned to analyze CAS data and information, is broad in scope. Analysis of CAS data/information into factors of adjustment to existing lifecycle plans, requires competence in the following areas:

- An understanding of the CAP and CAS processes, and the data/information presented to them.
- Engineering acumen, and competency in the classification of assets being surveyed.
- Awareness of present and future operational strategies, and the relationship with other operational strategies outside of their remit.
- Financially astute to understand the implications of changes made to lifecycle plans.
- An understanding of System Engineering, in relation to configuration management.
- Knowledge of local resource management, and the restraints confined within existing competencies, numbers, and limitations of other factors such as obsolescence.
- Ability to convert the CAS data and information into a meaningful report for asset managers and associated stakeholders.
- An understanding of potential solutions, and the likely scope and timescale to implement.
- Understands the context, prioritization, and criticalities of the incumbent asset base.
- Ability to evaluate the rate of changes to an asset's condition, and what those influences might be other than fair wear and tear i.e. misuse, load balancing issues, and design limits.
- Ability to listen to technical personnel on matters pertaining to experience of operating and/or maintaining certain classifications of assets.
- Understanding the implications of changes to power distribution.

6.4 Resource Management

Regardless of who is selected to carry out any particular CA, it is imperative to verify their level of competence against the asset type CAP to ensure safety, standards of work, and quality of reports.

6.4.1 In-House O&M

It is likely that the local O&M Team will possess the necessary competencies to undertake a great deal of CAP, and can potentially provide best value. Their competences should be well documented and proven, their training records kept up to date, and in a safe place. Where evidence is not available via the training records repository, and the individual does not have their original certificates, it will be necessary to seek assistance from a competent Contractor.

6.4.2 Contractors

The engagement and hiring of Contractors to carry out any CA in line with the plan, shall be carried out in a similar manner to that by in-house personnel, although particular attention must be given to ensuring that the selected contractor can demonstrate the competence of its workforce, and its capability to comply with requirements set by the Entity.

The references contained in Chapter 4 of this document, provide guidance on this topic. When consulting with a Contractor or OEM, it is recommended that their level of competence is verified early in any negotiations, to negate possible impact on time or safety.

6.5 Records, Materials & Tools

The purpose of this element of the CAP process is to set out the likely range of practical records, materials, and non-specialist tools, that will be required to support the execution of CASs within the respective Entities. It will also assist with the selection of the most appropriate practical methodology to ensure an acceptable level of accuracy is achievable, during the analysis of data and information captured.

The provision of suitable equipment to carry out CAS, enables the designated team to carry out their duties more effectively, and thus improves the production of accurate information and data.

Senior Asset Managers shall comply with the correct processes involved, to ensure quality of the CAS reports and data gathered.

6.5.1 Records

The term “records” relates to the data or information captured. In practice records can range from handwritten notes, to fully autonomous systems that record and send data automatically to the Asset Management database. CA mostly rely on data and information captured about an asset’s condition being recorded by human intervention i.e. initially recorded onto spreadsheets and or checklists by handwritten notes, and then transferred onto electronic devices.

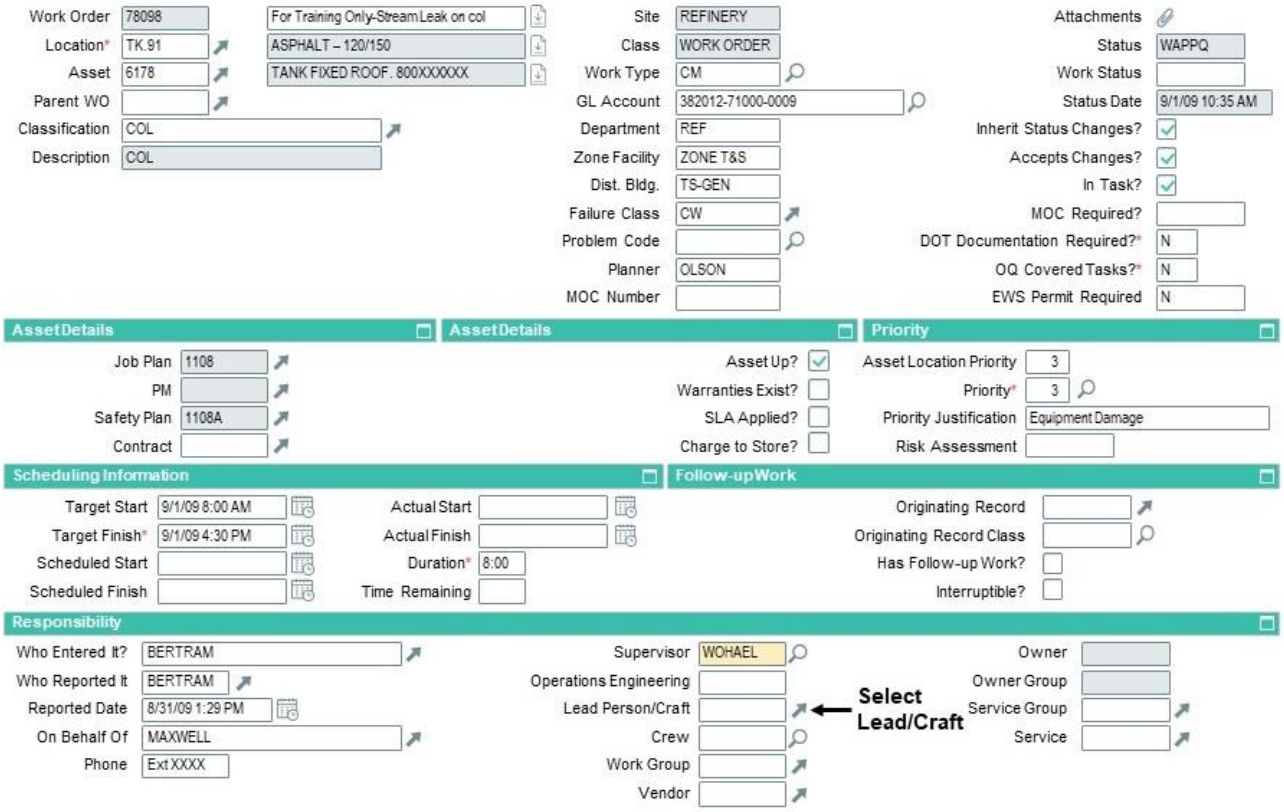

Figure 2: AMS – Asset Record (Example)

Figure 2 is intended to be an illustrative example of a typical asset record, within an AMS. These records support the CA with details about an asset’s history, including details of previous CAS, and the last known Asset Condition rating.

With the advent of small and resilient image capturing devices, it is possible to acquire good quality pictures/images and transfer them, either directly or indirectly to computer databases. In these circumstances the identity of specific assets should be clearly noted on each image or recording, and filed for ease of searching at a later date. Where specific asset identity is not available, it is best practice to utilize its location or an adjacent identifiable asset, as a means locating the asset for future reference.

The preferred methodology for all KSA Entities is capturing asset condition, by use of an electronic device. This approach reduces the opportunities for error in the transfer of information into the AMS.

It is essential that whichever method of capturing and recording asset data is selected, the results must be compatible and transferable, with the criteria stipulated in the chosen Asset Management Solution.

6.5.2 Selection Method for Capturing & Recording Asset Condition

When selecting the most suitable method for capturing and recording Asset Condition, the following points should be considered and included within the CAP:

- How many assets are to be surveyed?
- What resources are available?
- How complex is the survey?
- Does the survey require specialist assistance?
- When were these specific assets last surveyed and where is that report?
- How difficult is it to gain access to the asset(s) to enable effective information and data gathering?

When the above points are taken into consideration, it will assist in establishing the scope and scale of the specific CAP to be undertaken, and hence the method for capturing and recording Asset Condition Data.

6.5.3 Scope & Scale

The scope and scale of the CAP will vary, thus influencing the way CAS data is captured and recorded. The following guidelines can approximately determine these scopes and scales:

- Small/Simple: If the number of assets to be surveyed is low (25 or less), they are all easy to gain access to and are not overly complex in nature, then the method of recording Asset Condition can be very simple. A hard copy data sheet, which is populated by the CAS team as they progress through the task will be sufficient. An example of a CAS checklist is contained in Chapter 3 of this volume. Notwithstanding this point, it is always best practice to utilize an electronic information, and data-gathering methodology.

- Large/Complex: If the number of assets is large (25 to 250), difficult to gain access to, and/or complex in nature, a very different method will be required. In these instances, it will be necessary to utilize a method that can reliably record a very large amount of data. These could include electronic devices such as laptop computers, and/or handheld Mobile Maintenance Systems (MMS), that feed the data directly into the AMS.

- Extreme: Some applications in the acquisition of asset condition can be extremely large (250+). An example of this is Road and Pavement Condition Surveys. In these circumstances it is best practice to adopt automated systems such as High-Speed Cameras and Three-Way Laser Sensors, that have an autonomous method of rating the Asset Condition against benchmark measures. Failing this, a very large measure of resources will be required, unless the Asset Management team are confident that minimizing the scope of the CAS will still reflect the condition of the asset group as a whole.

6.5.4 Historical CA Records

The historical records of previous CAs are an extremely important part of evaluating Asset condition in the medium, to longer term. Asset condition trending profiles are compiled using information and data from maintenance and condition history.

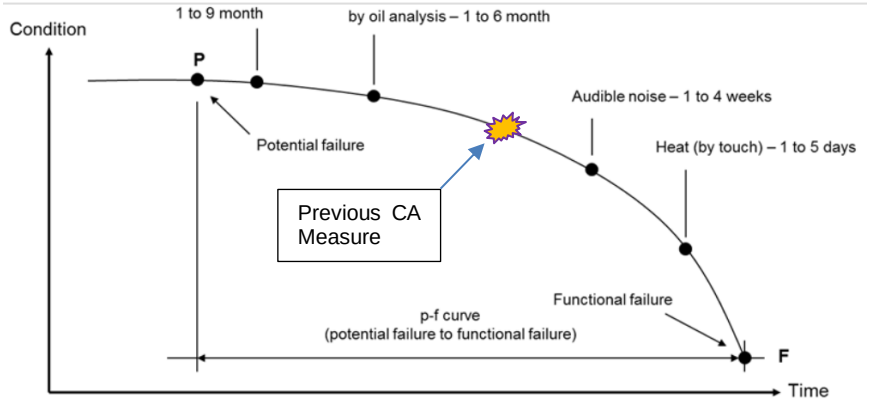

Figure 3: Historical Asset CA Record (Typical Probability of Failure [P-F] Curve)

As part of the planning phase, consultation with asset maintenance and condition history will aid the whole preparation which enforces the importance of reliably storing CAS Records, for future reference. Figure 3 (above) is an example of an Asset CA, record where the Asset was showing signs of advanced wear characteristics.

6.6 Materials

The quality and relevance of materials used during the CAS is important, from a quality control and safety perspective. There are certain CAS techniques that require a very strict selection of materials, such as dye-penetrant techniques, for detecting cracks in stressed structures. The selection of the correct CAS materials shall occur during the planning phase, due to the potential for time constraints in organizing their usage and disposal. There may be substantial 'lead in' times associated with specialist materials, and these must be incorporated within the CAP. If in doubt, consult the Original Equipment Manufacturer (OEM) for confirmation of material specifications, and delivery times relating to the CAS method selected.

Asset Managers are accountable for CA techniques that potentially involve hazards, or hazardous substances. Senior Asset Managers shall refer to Control of Substances Hazardous to Health (COSHH), and were deemed necessary, other regulations such as the Control of Major Accident Hazards Regulations (COMAH) 2015.

The simplest form of CAS is the visual inspection and is the most likely and widespread method to be used across KSA Entities, especially for those areas where CAS maturity is low. This technique can be carried out by asset competent personnel and requires little or no materials to facilitate its execution. However, there could be isolated occasions where assets have to be cleaned, to ensure that an accurate assessment can be made of the asset's condition.

6.7 Tools

The range of CAS Tools held at Entity level, will depend on the range, type and criticality of assets held within that Entity's AR. Local knowledge and use of these tools and equipment, will depend on the maturity and competence of that Entity.

Tool	CAS Application
Camera (digital)	Most CAS methodologies
Dictaphone	Small to medium sample surveys to enable the recording of audio messages whilst walking the CAS
Laptop	Most CAS methodologies – Access to CAS information and Check sheets
Laptop Range Finder	For checking of levels and distances
Light source	For illuminating Assets and Safety of personnel
PPE	Suitable and enough PPE for all the CAS Team

Radio	For communicating over long distances
Stationery	Suitable pens, markers, and paper for making notes
Tape Measure	For checking of displacements
Thermal Camera	Thermal Profile e.g. Electrical Distribution Boards
Thermal Gun	Thermal spot checks of heat e.g. Motor and Gear Boxes
Vehicles	For transportation of personnel and equipment
Video Camera	Most CAS methodologies

Table 3: List of CA Applicable Tools & Equipment

The tools and equipment in Table 3, are the minimum required to be able to carry out non-specialist CA i.e. visual inspections. These are items that could justifiably be held by the Entity's Asset Managers, in support of visual inspection type CA, without having to seek certifications for specialist tooling.

There are different approaches to CA, and the following section explains their breakdown.

6.8 Approaches to CA Inspection

The approach to carrying out a CA, is defined by how intrusive the inspection needs to be, so as to gain access to the critical aspect of the asset. Some assets can be safely assessed without disturbing or having to remove any obstacles in the way. Others require the removal of obstructions, in order to satisfactorily carry out the CA, i.e. to gain access to its primary structure. When developing the CAP, the type of inspection required, must be considered.

The Entity shall consult with the OEM for specific advice, where local knowledge, and guidance of which type of CA to be used, is required.

6.8.1 Basic Approaches to CA

CA inspections fall into one of two types:

- Non-intrusive (including visual Inspections)
- Intrusive

6.8.1.1 Non-Intrusive

As the name implies, this approach is carried out without disturbing the asset, facility, or system; they are observed in their natural form. These are normally the first choice for most applications of CA. Most non-intrusive inspections can be carried out whilst the asset is still in service. Depending on the methodology adopted, in some instances for large assets, there will be a requirement to use specialist teams and equipment, to gain access.

Note: Drone technology is also available to assist in carrying out non-intrusive inspections, such as:

- Video surveys of buildings to assess the condition of façades, fixings, or expansion joints.
- Thermographic building survey to assess insulation properties, and window sealing efficiency.
- Thermographic inspection of High Voltage transmission lines.
- Health and Safety inspections of assets, with minimal disruption to operational capability.

The inspection can be reviewed in real time, and the recorded data used in accurate pricing of repairs or remedial works. Before adopting this methodology, all considerations must be made, with regard to safety and legislation; for example, near airports and power lines.

6.8.1.2 Visual Inspections (VINS)

Where the maturity of Asset Management profiles is still young, it is standard practice to initiate a phased approach to CA schedules, and carry out VINS for at least the first phase. To proceed from an immature CA program to a fully autonomous methodology can take years to accomplish, and requires credible and factual evidence to justify changes to existing methodologies.

VINS are the simplest methodology as they are unlikely to need many tools or specialist equipment to aid the process. Notwithstanding, even the simplest inspections may require specialist equipment to facilitate access to perform the inspection and therefore, safety is of paramount importance.

Advantages of VINS:

- Convenient and relatively easy to deploy
- Asset competent personnel can be utilized to carry out VINS
- Flexibility of use
- Turnaround times can be faster

Disadvantages of VINS:

- Time consuming when having to travel distances and assess many assets
- Open to subjective measuring if scoring parameters are not appropriate or clear
- Reliant on competencies of individuals involved
- Human Factors for each deployment, and variability in results between inspectors, must be considered

If in doubt as to the safety implications of any approach to CA, always consult with the relevant specialist.

6.8.1.3 Intrusive

This approach involves disturbance to the asset, facility, or system, usually by the removal of panels, screens and/or facades, to gain further access to such areas as structure, sub-assemblies, or systems. Sometimes, depending on the type of asset or system, these inspections are carried out by a qualified Engineer or Technician, and will require the work to be recorded on a Work Order due to the invasive nature of the task.

The decision to make the CA an intrusive or non-Intrusive task, relies upon the following factors:

- Priority of Asset
- Complexity of Asset, Facility or System
- Structural Design and Nature of Asset
- Risk Profile and Appetite at Senior Management Level within the Entity
- Recommendation of the OEM, Supplier, SME, or Contractor

6.9 Type of Test to Assess Asset Condition

Once the decision has been made on whether the CA should be intrusive or non-intrusive, it will be necessary to conclude which type of inspection is most suited to provide the necessary information or data, pertaining to an asset's current and true condition. Accommodation must be made within the CAP for obtaining the necessary permissions, permits and authorization; this could be where isolations are required in intrusive surveys that require the asset to be taken out of service for a period of time.

There are two categories of test that can be conducted within this context:

- Destructive
- Non-Destructive

6.9.1 Destructive Testing

The testing of assets to destruction is very rarely carried out in the Operational and Maintenance phase of an asset lifecycle, and is normally utilized during the design phase of an asset, or as part of a test if there has been failure of an asset in operation, so as to ascertain the reason behind that failure. The nature of the test can be either to specific standards, or tailored to reproduce set service conditions, and is intended to test the system or component to failure.

Methodology	Application
Aggressive Environment Testing	Physical fracture and fatigue testing at a range of temperatures and pressures in sour (H2S), sweet (CO2) corrosive environments. These tests assess the impact of these conditions, on materials and performance.
Corrosion Testing	Non-toxic, small-scale, aqueous corrosion testing, in a variety of environments i.e. fresh and sea water.
Fracture and Mechanical Testing	Material tension tests, bend tests, impact tests, drop weight testing, peel tests, crush testing, pressure, and fracture testing. Fracture and mechanical tests can be carried out on differing materials, i.e. welded polymers, and ceramics.
Fatigue Testing	Used to test parent materials and endurance of welded joints under constant or variable amplitude loading. Can also be used for fatigue crack growth testing of welds, base metals, and heat affected zones.
Hydrogen Testing	Covers materials that have a risk of corrosion, due to exposure from hydrogen. Can also be carried out at different temperatures, and rates of strain.
Residual Stress Measurement	Stresses that remain in a solid material, after the original cause(s) of any stresses have been removed. This can be intentional, or unintentional, which could lead to premature structural failure. Measurement of residual stresses allows designers and engineers to determine factors such as, near-surface and through-thickness residual stress distribution. These can be utilized in Engineering critical assessments.

Table 4: Types of Destructive Testing

6.9.2 Non-Destructive Testing (NDT)

NDT is non-invasive in nature, and is normally used to assess the integrity of an asset or part of that asset, by using a methodology that does not affect the integrity of the asset's materials or structure. In most cases, NDT can be performed with the equipment or asset still in service.

Methodology	Application
Acoustic Logging	Concrete bond integrity, bore holes, detecting fractures in bore holes.
BMS	Behaviors and output surveys.
Dye Penetrant	Surface crack detection in most non-absorbing solids, metals, ceramics.
Energy consumption	Friction, load balancing, settings, parameters.
Gas analysis	Refrigerants, electrical switch gear.

Laser	Alignment, displacement, distances.
Magnetic particle	Surface crack detection in austenitic metals.
Observations	Gauges, flows, hours run, relative displacements.
Oil analysis	Gearboxes, engines, motors, hydraulic systems.
Pavement roughness	Roads and pavement surface condition.
Remote Cameras	Integrity of pipelines, structures, infrastructure.
Smoke testing	Fire safety systems.
Stress wave NDT	Friction, shock, and dynamic load transfer between rotating parts
Ultrasonic	Subcutaneous fault and finding in metals and selective solids.
Vibrant Analysis	Machinery health, structural integrity, cavitation, resonance.
Visual Inspections	Surface condition, operating characteristics, system integrity, thermal imaging, fluid levels and leaks, excessive heat

Table 5: Types of Non-Destructive Testing

The list in Table 5 (above), identifies examples of NDT that can be carried out on linear and non-linear assets.

6.10 Summary

In all cases of choosing the best CA methodology, it is usually best practice to consult with the Original Equipment Manufacturer (OEM) for advice. When this is not feasible, consultation with Subject Matter Experts (SMEs), such as Service Technicians and other such competent and interested parties, is considered acceptable practice.

In order to assist with the type of CA adopted, the following criteria must be considered:

- The results attained from the methodology, irrespective of scope or scale of the sampling, must be meaningful and factual, to enable credible decision-making with respect to scheduling future inspections and remedial activities.
- The choice of any CA survey must not leave behind or generate residual risks to the functionality of the asset, or danger to people.
- Any form of non-automated form of CA such as VINS, shall be supported by a very strict process and criteria to minimize the variables that it relies upon.

It is essential that the factors described above are taken into consideration and accommodated within the CAP, to support its credibility. The plan must articulate the activities to be carried out and match the capacity of the Entity's resources to carry them out.