National Manual of Assets and Facilities Management
Volume 6, Chapter 3

Preventive and Predictive Maintenance Program Procedure

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IMPORTANT NOTICE

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1.0 PURPOSE

This Procedure assists the Entity responsible for asset and facilities management, in preparing a Planned Maintenance Program. The program helps to ensure that the maintenance types selected are high-quality, relevant, mature and remain current, thus ensuring reliable and cost-effective, asset performance.

The purpose of this Procedure is to guide Entity stakeholders responsible for asset management to provide a Planned Maintenance Program that ensures appropriate and mature maintenance types are selected and remain current, thus underpinning reliable, cost effective asset performance.

The document will also assist an Entity and maintenance contractors to identify and differentiate assets, systems and subsystems for a Planned Maintenance (PM) regime that is supported by Preventive and Predictive Maintenance (PdM) types. Adopting this Procedure will assist an Entity and maintenance contractor in assessing the characteristics of their engineered assets, in the context of their estate, and select the most appropriate type of PM.

2.0 SCOPE

The scope of this Procedure is to provide all stakeholders with the framework and methodology to actively evolve towards cost effective intelligence – based Planned Maintenance. This is done by establishing a mature maintenance operation that evolves from a contract inception, to a long-term stakeholder relationship. This high-standard refers to the quality and maturity of the Entity's client, and the maintenance contractor's performance and relationship.

Implementation of this Procedure will help to ensure that the PM regime, is set-up and managed on good technical, and operational fundamentals.

Using this Procedure should complement and respect the associated documents in other Volumes, particularly, the National Manual of Assets and Facilities Management (NMA&FM) Volume 7: Work Control and, the advice given on Operations and Maintenance Management in Volumes 5 and 6.

The Procedure presented here should be considered the minimum standard for 'Best Practice' and may be developed to meet the needs of an Entity, sector, contract, or site.

The guidance provided, applies across several types of contracts and PM operating models, including multi-site contracts, out-sourced delivery models, and specialist environments; it is applicable to all sectors.

3.0 DEFINITIONS

Term	Definition
Asset Management System (AMS)	A dedicated software application system, used to record and track an asset throughout its life cycle, from procurement to disposal
(Asset) Criticality	The relative risk of costs arising due to a less than acceptable level of performance (or failure) of that asset, where two or more assets reside within a given financial control boundary
Asset Register	A list of assets owned by an Entity, and specific and relevant details about each, maintainable asset. The Register may identify the location, description, value, and age of the asset
Condition Assessment	A collection of data about the condition of an asset, which is assessed against a pre-defined standard to identify actions necessary to achieve and maintain a particular standard, over a specified time horizon
Campaign Maintenance	Maintenance of an asset, subsystem or system, that includes all disciplines simultaneously (mechanical, electrical, control, and structural), with the intent of limiting outage duration and/or frequency. May also refer to a particular asset type that is abundant across an estate (such as lifts, pressure relief valves). Campaign

Term	Definition
	Maintenance is often motivated by the availability of a specialist contractor. May also be called Lean Maintenance
Change Management	Process, tools, and techniques to manage the human-resource side of change, and achieve the required business outcome
Continuous Improvement	An ongoing effort to improve products, services, or processes
Corrective Maintenance	Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance
Failure Mode, Effects and Criticality Analysis (FMECA)	A method which involves quantitative failure analysis. FMECA involves creating linkages between potential failures (Failure Modes), the impact on the mission (Effects), and the causes of the failure (Causes and Mechanisms)
Infratech	The deployment or integration of digital technologies with physical infrastructure, to deliver efficient, connected, resilient, and agile assets
Intelligent Maintenance	A Maintenance system that utilizes the assets' historical data, in order to optimize the maintenance operations between planned and unplanned activities (data-driven approach)
Maintenance Strategy	Defines the rules for the selection and sequence of planned maintenance work
Maintenance Type	Refer to NMA&FM, Volume 6 Chapter 3: Types of Maintenance
Maintenance Philosophy	A 'mix of strategies that ensure assets, subsystems and systems operate as expected when needed'
Planned Maintenance	• Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance • Planned Maintenance has two subcategories: Preventive and Predictive
Predictive Maintenance (PdM)	Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance
Preventive Maintenance	Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance
Program	An extensive and comprehensive arrangement or collection of like requirements, measurements or activities, best practices, fundamentals and idealism, combined into a methodology with the intent of outlining a process with a particular long-term goal or vision towards supporting a mission, job or operation
Reliability-Centered Maintenance (RCM)	Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance
Run to Failure (RTF)	Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance
Success Factor	An element that is necessary for an organization or project, to achieve its mission
Total Maintenance Costs	The sum of Unplanned Maintenance Costs and Planned Maintenance Costs, based solely on maintenance costs (not business interruption impact costs)
Unplanned Maintenance	• Refer to NMA&FM Volume 6 Chapter 3: Types of Maintenance • Unplanned Maintenance has two subcategories: Corrective and Emergency
Acronyms	
AMS	Asset Management System
AR	Asset Register
BMS	Building Management System
BSRIA	Building Services Research and Information Association
CA	Condition Assessment
CIBSE	Chartered Institution of Building Services Engineering
CMMS	Computerized Maintenance Management System
FCU	Fan Coil Unit
FMECA	Failure Mode, Effects and Criticality Analysis

Term	Definition
FMP	Facilities Management Professional
IFMA	International Facilities Management Association
ISO	International Standards Organization
KPI	Key Performance Indicator
LEV	Local Exhaust Ventilation
NMA&FM	National Manual of Assets and Facilities Management
OEM	Original Equipment Manufacturer
O&M	Operations and Maintenance
OOH	Out Of Hours
PdM	Predictive Maintenance
RCM	Reliability-Centered Maintenance
RTF	Run to Failure
UPS	Uninterruptible Power Supply
WMC	Work Management Center

Table 1: Definitions

4.0 REFERENCES

- 2015 International Facilities Management Association (IFMA), Facilities Management Professional (FMP), Chapter 3
- Building Services Research and Information Association (BSRIA) Business – Focused Maintenance (BG 53/2016)
- Chartered Institution of Building Services Engineering (CIBSE) Guide M Sections 3.3 Types of Maintenance and 5.1 Maintenance Strategy
- International Standards Organization ISO 41001 Facility Management – Management systems
- International Standards Organization ISO 45001 Occupational Health and Safety
- International Standards Organization ISO 55001 Asset management – Management systems
- National Manual of Assets and Facilities Management – Volume 5: Operations Management and Volume 6: Maintenance Management
- National Manual of Assets and Facilities Management – Volume 7: Work Control
- National Manual of Assets and Facilities Management – Volume 6 Chapter 26: Maintenance History for Guidance
- National Manual of Assets and Facilities Management – Volume 12: Risk Management
- National Manual of Assets and Facilities Management – Volume 6 Chapter 4: Development of Maintenance Plans
- National Manual of Assets and Facilities Management – Volume 6 Chapter 3: Types of Maintenance
- National Manual of Assets and Facilities Management – Volume 12: Risk Management
- National Manual of Assets and Facilities Management – Volume 7 Chapter 2: Developing Maintenance Procedures

5.0 RESPONSIBILITIES

Role	Description
Development Lead	Responsible for analyzing development needs, as well as proposing and implementing the improvement plan
Entity Client	Commonly represented by a senior manager responsible for the client function of cost effective, contract compliant Facilities Management. This person is knowledgeable and competent in the technical and contractual aspects of the maintenance contract and senior enough to provide awareness to the most senior level of management within the client organization
Maintenance Contractor	Commonly represented by a 'Contracts Manager' who may have a key responsibility of presenting the required responses to the Entity/ Client. The Contracts Manager might rely on various technical, commercial, and operational stakeholders to provide evidence to support the relationship with the Client

Table 2: Responsibilities

6.0 PROCESS

6.1 Introduction

A program is defined as a comprehensive arrangement or collection of like requirements, measurements or activities, best practices, fundamentals, and idealism combined into a logical and reasonable methodology with the intent of outlining a process in a coherent and common sense practice with a particular long-term goal or vision in supporting a mission, undertaking, or operation.

Compliance with this Procedure requires the Entity and the maintenance contractor to meet the recommendations stated here, and to apply the 'Types of Maintenance Selection Procedure flowchart' (Refer to Attachment 1), to their particular situation.

The level of success that is achieved by applying this Procedure to the maintenance operation, is measured by a year-on-year progression towards Intelligent Maintenance. This is the balance between Total Maintenance Costs, and Effective Asset Performance (minimized operational downtime).

An identified 'Development Lead,' usually guides the management of continuous improvement. Adopting such an approach is a continual process, and the contract documentation and delivery management needs to enable, and motivate the continuous improvement towards the ideal, Intelligent Maintenance balance.

This management of continuous improvement is normally led by an identified Development Lead. The adoption of such an approach is a continual process and the contract documentation and delivery management needs to facilitate and incentivize continuous improvement towards the optimum applicable Intelligent Maintenance balance.

6.2 Philosophy

'Maintenance Philosophy' can be defined as a 'mix of strategies that ensure assets, subsystems, and systems operate as expected'.

The goal of applying this Procedure is to achieve Intelligent Maintenance. A secondary aim is for the Entity's Client and maintenance contractor to work together to achieve an agreed maintenance philosophy and shared vision, that is sustainable in the long term.

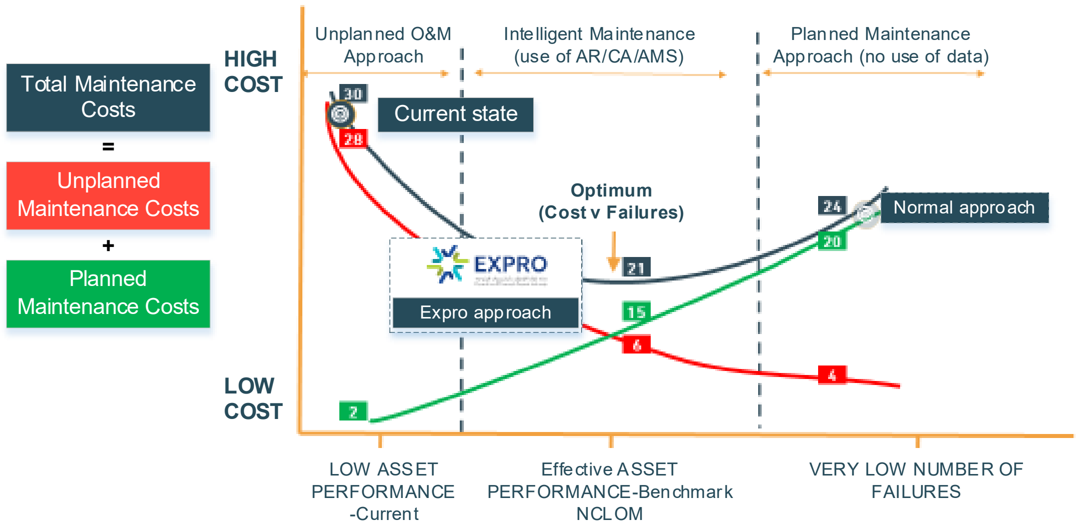

Figure 1: Intelligent Maintenance Philosophy

6.3 Strategy

A maintenance strategy should be in line with entity's main strategy towards defining the rules for the specification, resourcing, selection, and delivery of planned maintenance work.

The successful formation of a maintenance strategy will lead to achieving the goal of selecting the most cost-effective, Intelligent Maintenance solution by means of the Types of Maintenance Selection Procedure flowchart (Refer to Attachment 1).

The basis of the maintenance strategy defined in this document is objective, transparent data, clear communication at all times, and that the use of key-reference documentation is agreed upon by all stakeholders.

The setting of the decision-making rules relating to specification, resourcing, selection, and delivery for each asset, subsystem, or system will result in different solutions in order to achieve Intelligent Maintenance. This difference in ideal solutions refers to both technical merits, and time.

6.4 Implementation

The selection, accuracy, and completeness of information, both past and present, is key to the ability to establish and populate the measurements necessary for each grouping of assets. The foundation of this information will allow for the adoption of, and comparison with, available benchmarks.

Below are the recommended key elements of a successful strategy for the establishment and management of a maintenance contract.

Entity to provide:

- Asset Register
- Business impact advice, including detailed criticality and downtime
- Operational aspects affecting maintenance planning
- Maintenance History
- Service Level Agreement
- Where specifically motivated, solution to requirements
    - Maintenance frequencies (Site Specific Schedule)
    - Maintenance references
    - Planning Aspects supporting statements

Contractor to provide:

- Expert advice on new technologies and their implementation
- Comprehensive requirements response
- Maintenance types Risk Assessments
- Tailored maintenance proposal
- Continuous improvement focus including early client engagement

Tender and contract documentation, as well as on-going stakeholder engagement and communication, shall promote intelligent maintenance and conflict resolution. The success of this methodology will be improved by the proper addressing of the following aspects of the Entity client and maintenance contractor's relationship.

Fundamentals

- Shared ownership of risk
- Change Management procedures are fit for purpose
- Resourcing, motivation, and flexibility to optimize planned maintenance

Idealism

- Benefit over cost
- No-blame culture, partnership promotion

Measurable

- Balanced Scorecard/Key Performance Indicators (KPI) – weighted to promote planned maintenance and attenuate reactive maintenance.
- Audit program, including Formality of Maintenance Performance
- Investment management – assets, resources, and technology

Best Practices

- Continuous Improvement – ease of 'Contract Amendments' including amendments formula
- Asset Management Strategy – clear, adopted, and formalized
- Information transparency

Recommended further reading is provided by the references given in Section 4: References.

6.5 Maintenance Selection Options

The output from the Types of Maintenance Selection Procedure is a recommended maintenance type which is guided by the assessment of several factors:

- Non-technical
- Business Impact
- Planning Aspects
- Infrastructure Technology
- Success Factors
- Maintenance History

The outcome of the assessment against these factors is a recommendation of the most likely appropriate maintenance type for each asset, sub-system, or system.

A summary of the outcomes is given here.

6.5.1 As Required

The types of maintenance selected here are determined by non-technical factors which are prescriptive and therefore, eliminate the selection of other types of maintenance, based on technical or operational merit. This 'As Required' outcome will most likely prescribe a calendar-based, planned Preventive Maintenance type that is designed to keep the system compliant with one or more of the following: statutory legislation, warranty, contract or life safety system Operations and Maintenance (O&M) requirements.

Questioning the progression of the system through the remainder of the flowchart selection is beneficial for identifying any technical needs or advantages in a maintenance-level above that dictated by these non-technical requirements.

6.5.2 24/7 Resident

This outcome is decided by a business impact analysis, concluding that the failure of an engineering asset, subsystem, or system will result in a very high impact on the business operation, or its reputation. It is considered to be successfully managed, only by having technical staff on-site 24/7.

This assessment of high-business impact may be due to the business operating in a high-value sector such as banking, trading, air travel, or a hospital. Many of these businesses will have 24/7 operational hours. The assessment may also be due to the complexity of the engineering system, such as Uninterruptible Power Supply (UPS), though not all UPS systems will be assessed as requiring 24/7 Resident attendance.

The 24/7 attendance may be achieved through a variety of attendance patterns. For example, a mix of senior technical staff during operational hours, and a reduced technical-skills level of attendance during Out Of Hours (OOH) time. Another attendance pattern is 'extended day' (split-shift). These may be supported by the design of an engineering system's ability to respond well to a problem, and OOH 'on-call' attendance by senior or highly-skilled, technical staff.

6.5.3 Planned Maintenance

Planned Maintenance is periodic, pre-planned, and cyclic in nature. The cycle frequency can be (calendar) time-based, 'hours run' based (such as a generator), or on distance travelled such as fleet assets. The frequency can be determined by (technical) Risk Assessment, contractual obligations like 'Good Practice', or statutory/legal requirements.

The Planned Maintenance cycle is typically spread evenly throughout the year. An alternative arrangement is described as Campaign (or Lean) Maintenance, where all maintenance is carried out on an asset or facility simultaneously. For example, in a data center hall, the cooling, electrical final circuits, smoke detection, lighting and public address systems all have their planned and existing unplanned maintenance requirements carried out in a concentrated timespan, such a 4-8 hours. An alternative Campaign

Maintenance is maintenance on a particular type of asset, subsystem or system across an estate that has that particular maintenance task carried out simultaneously, for example, all of the numerous Very Early Smoke Detection System (VESDA) smoke detection systems on site have their periodic maintenance carried out within a concentrated timespan, such as 1-3 days.

The reader should refer to the appropriate NMA&FM chapter on Types of Maintenance in Volume 6, for more information and advice.

6.5.4 Intelligent Maintenance Philosophy

Intelligent Maintenance is defined as a maintenance regime that utilizes the assets' historical collected data to support intelligent decision-making, in the development of Planned Maintenance activities. This may also be described as a data-driven approach to Planned Maintenance. Intelligent Maintenance is therefore a maintenance philosophy. The Intelligent Maintenance Philosophy relationship with Predictive Maintenance is that the Intelligent Maintenance approach accepts reactive, unplanned maintenance as part of the solution. Intelligent Maintenance has the potential to deliver savings greater than that of Predictive Maintenance.

Intelligent Maintenance requires that the review of the most applicable mix of maintenance types is continuously carried out. The selection of assets, subsystems, and systems for this category recognizes that accurate and reliable cost and performance data is available to be plotted against operating uptime.

To achieve an optimal maintenance outcome, Intelligent Maintenance relies on good quality information and decision-making, in a continuous improvement environment. Section 4, 'References', should be consulted, in particular NMA&FM Volume 6 Chapter 4: Development of Maintenance Plans and NMA&FM Volume 7 Chapter 2: Developing Maintenance Procedures, in order to maintain a high-quality, maintenance management operation.

6.5.5 Predictive Maintenance

Predictive Maintenance (PdM) features three separate activities - the recording (on-site and remote) of equipment/system operational condition and separately, the analysis of information that supports the decision of what level of, and when, (invasive) maintenance will be carried out.

The data measuring function has minimal intrusion or disruption to the business operation. The analysis task is an intellectual task usually performed in an office, and can be assisted by computer programs. The analysis and decision-making role requires a good level of knowledge, skills, and understanding of engineering maintenance and mathematics. The analysis is the 'decision-making' step that may recommend postponing the intervention of a maintenance activity, which in turn provides cost-savings and reduced disruption to the business.

PdM may be applied to systems that may typically be expensive to maintain. Failing despite current planned maintenance regime, or disruptive to needlessly take offline for maintenance; expensive to replace if Run to Failure (RTF); failure could lead to high consequential costs or unacceptable situations; failure would be critical for the overall building operation.

Within the Asset and Facilities Management field, the wealth of knowledge (benchmarks) available is still limited, and hence the risk of asset and contract failure needs to be carefully assessed.

Success of this maintenance type relies heavily on the availability of good quality Maintenance History, as well as competent analysis that confirms that technical risks are manageable.

The reader should refer to the appropriate chapter on Types of Maintenance in NMA&FM Volume 6, for more information and advice.

6.5.6 Unplanned Maintenance

Unplanned reactive maintenance has three subcategories:

- Corrective
- RTF
- Emergency

Very few assets, subsystems, or systems should be maintained under this type of maintenance. Whenever possible, unplanned maintenance should be avoided as a maintenance type.

Whenever an asset, subsystem or system has only unplanned maintenance applied, these should be highlighted to the Client, and the maintenance type recorded on the Asset Register section of the Computerized Maintenance Management System (CMMS).

6.6 Procedure Narrative

This Preventive and Predictive Maintenance Program Procedure is used to assign the most suitable maintenance type to assets, sub-systems, or systems.

The Procedure flowchart attached to this document should be applied to each asset, sub-system, and/or system on a periodic basis, and at each event or change that impacts the earlier maintenance type decision. As a guide, this periodic review of decisions may range from 6-monthly, to 2-yearly cycle.

This Procedure and the attached flowchart represents a step-by-step sequence that requests or prompts decision-making and information gathering/confirmation, in a logical order. It uses a scoring system that is mainly based on descriptive ratings, for example ‘low’, ‘medium’, ‘high’ or similarly ‘poor’, ‘fair’, ‘good’.

It must be remembered that the importance of an asset, subsystem or system, depends on the facility or building it is located in, and especially the business function that it serves. An air extraction system, such as a system in an office building that serves the restrooms, may have a different level of asset criticality to the same type and size of system serving a gym, swimming pool, food production and manufacturing facility, or clinical environment. For this reason, one factor in assigning asset criticality is location. For further advice on asset criticality refer to NMA&FM Volume 12: Risk Management.

Some systems justify the need to be split into subsystems because different parts merit a different maintenance type. For example, a Fan Coil Unit (FCU) cooling system serving an office building could be considered to be split in to three subsystems: the chillers; the pumping and distribution network; and thirdly the FCUs throughout the building.

The criticality of the chiller or chillers is likely to be considered the highest because their failure, either one of several or the single available chiller, will have a wide-ranging impact on the function of the system. The urgency to reinstate the heat rejection function of the chillers is tempered by the mass of chilled water residing in the distribution system. Similarly, the failure of the pumps conveying the cooling fluid to the chiller or FCUs will have a wide-ranging impact. Though the pumping technology is less complex than that of the chillers, the criticality of the pumps may be considered similar. At the low end of the impact, are the FCUs. If a single FCU fails, it will impact a very limited area, though this could be critical if it is the only FCU in a particular area.

6.6.1 Non-Technical

There will be non-technical requirements that dictate the maintenance type. For example, specified Fire Alarm maintenance may be required by Health and Safety legislation, and deviating from this may not be statutory compliant.

Legislation beyond Life Safety systems may also set the maintenance requirement. For example, water quality management, or electrical installation testing, may have a legally specified maintenance requirement that is applicable to the systems and environment of the building being considered. Sector-specific requirements may also dictate the maintenance type, though this is normally restricted to specialist systems.

Similarly there are other non-technical factors that directly influence the choice of maintenance type. For example, insurance requirements applicable to pressurized systems may require specific maintenance tasks and frequencies of Pressure Relief Valves or Local Exhaust Ventilation (LEV) systems.

6.6.2 Business Impact

The criticality of systems, besides technical concerns such as electrical power back-up, can impact the business. Failure of FCUs in a hotel has a potentially higher reputational risk to the business than an FCU serving a medical surgeon's consultation room.

Failure Mode, Effects and Criticality Analysis (FMECA), involves understanding how something can fail. The result of doing so, allows each mode to be ranked by priority. It may apply to the business and its dependence on engineering systems, maintained under the maintenance contract. The systems are typically building service systems, but many Facilities Management contracts include the maintenance of business operation-specific, engineering systems. Some examples include baggage handling, goods conveyor systems, medical gases, catering equipment, projector equipment. When assigning a Maintenance Type to these systems, the frequency of failure along with the level of urgency to reinstate their services, should be considered.

The maintenance contract may emphasize the importance of specific assets in certain locations through tougher KPI rules, applied to types or locations of assets.

Operational resilience of the design or installation, is also an aspect that should be considered when assigning a maintenance type.

6.6.3 Planning Aspects

If assets, subsystems, and systems are critical to organizational operations, it is sometimes difficult for the maintenance contractor to gain permission to isolate the equipment, or gain access to an area to allow maintenance to be carried out. Electrical systems are the most likely to be affected by this as all building services such as lighting, elevators, water services and air conditioning rely on this energy. It is also difficult to organize a maintenance outage for organization-specific equipment, such as medical devices, banking computing systems and catering equipment.

Calendar-based, planned maintenance allows the maintenance contractor and the Entity client to know, with a high-degree of certainty with adequate forewarning when the outage is scheduled. The Entity client can then make arrangements on how to continue their business function, during the planned outage. For this reason, calendar-based, Planned Maintenance is often the most suitable maintenance type.

An asset that requires maintenance input from external specialists will benefit from certainty of timing. If the schedule changes, there specialist may not be available for the revised timing. For this reason, calendar-based, Preventive Maintenance is possibly the most suitable maintenance type. Similarly, if the acceptable outage period is short, the maintenance contractor may want to increase the certainty of meeting the deadline by having enough resources scheduled, and hence the calendar-based Planned Preventive Maintenance may be selected as the most suitable type of maintenance.

Certainty of timing is available from Predictive Maintenance, so long as the selection of data and its analysis is timely, correct, and effective. Notification to a stakeholder regarding a required outage depends on several factors including the criticality of the system, and duration of the requested outage. This notification period can range from several days up to three months typically, as the majority of Facilities Management maintenance tasks require an outage that will impact a client's business operation.

Certainty of 'Return to Service' may be a vital factor in an organization, though the over-use of this requirement makes maintenance unnecessarily expensive. For example, the 'Return to Service' of the most heavily used escalators in a shopping mall by the morning of the first day of a national holiday is a genuine situation where any delay beyond the agreed date and time, would have a disproportionate impact on the clients' business.

Campaign (or Lean) Maintenance is most suited to calendar-based Planned Preventive Maintenance because of the high certainty and lower complexity in planning and scheduling the various resources required.

The most expensive single asset serving a building is likely to be an electrical generator, chiller, or sub-station. Depending on the size of the building relative to the expensive assets, and assuming that the maintenance budget is proportional to the building size and complexity, the financial impact of replacing key assets becomes relatively large. If an organization is financially constrained, they should be made aware that calendar-based Preventive Maintenance can be more expensive than Predictive Maintenance, if the frequency of the Preventive is less than the Preventive. A comparison of the two types of maintenance applied to each situation is recommended, before deciding which is most appropriate. Major maintenance on these high-value assets is usually proportionally expensive; for example the hiring of electrical load banks, and hence the potential opportunity proved by Predictive should be considered.

6.6.4 Infratech

Infratech is the term used to describe infrastructure and technology, their respective functions, and their relationship. The cost of providing the missing links in Infratech and skills need not be great. For example, the adoption of wireless communications can provide the function of communications at cheaper rates than hardwired installations.

Predictive Maintenance will likely require investment in material and human resources. If this investment is available, the potential savings from PdM with sustained operational uptime can be realized.

6.6.5 Success Factors

Predictive Maintenance in Facilities Management is a growing technology and science, and hence the advice available is still growing in strength. Many Facilities Management organizations and contractors have reported on their experiences with PdM. These reports should be referred to wholly, or in part, to identify predictors that are the best indicators of the need for maintenance.

Assessing the applicability of these predictors to the assets, subsystems, and systems installed, is a key factor in the likely success of adopting PdM.

The ease of monitoring will depend partly on the reporting network and hardware that is already installed. A Building Management System (BMS) that is either attached, to or is close to the asset, is capable has capacity to accept additional information, is a factor. The ease of installing wireless technology can also be considered as this is a commonly adopted approach to sending the recorded condition data to a central recording system.

PdM relies on measured operating condition data of assets, subsystems, and systems. This measurement is usually achieved by sensors attached to key parts of the asset, or by periodic readings taken by Technicians. The data is then relayed to a BMS (or similar computerized user front-end), where the data is analyzed by a suitably-competent person. This analysis may be assisted by threshold alarms and graphical representation by the reporting system, and will determine when to schedule intervention maintenance.

The ability of the maintenance contractor to respond to an approaching need to carry out maintenance, will partly depend on the availability of the resources required. For example, a UPS system requiring the changing of batteries will need a reasonably long lead-time, if the batteries and skilled labor are to be sourced from, or installed by, the Original Equipment Manufacturer (OEM).

The availability of spare parts is a factor to be considered. For example, if an estate has developed over time to be served by various manufacturers of equipment, the availability of spare parts may vary. This variation may also affect the performance of the technical team, whether in-house, resident, outsourced or non-attendance, because the Technician with the experience of a particular manufacturer's equipment may not be available.

A safe decision from this stage of the maintenance type selection, is to initially assign calendar-based periodic Planned Maintenance, with the intention of strengthening the case for PdM. This strengthening may be done by gathering more of the right type of data, by installing the required infrastructure and technology, or gathering the data manually through the Planned Maintenance, or Facility Surveillance tasks.

Once a suitable mass of data has been collected at the frequency prescribed by the OEM, the maintenance contractor can experiment with relaxing the intervals between maintenance, and closely monitoring the impact on the condition of the asset and the measured values. The relationship between the condition and the measured values is a key input in the decision-making for PdM.

6.6.6 Age

The relationship between age and failure-rate, is often described by the 'bathtub' curve, with 'age' as the horizontal axis. (Refer to Figure 2 below). The age of an asset is divided in to three phases as follows:
First Phase – is when the asset is new, and considered to initially have high reliability, decreasing to a period where the failure-rate is considered constant.
Second Phase – is the relatively constant reliability phase, and extends for much of the asset's useful life.
Third Phase – is when the failure-rate starts to increase.

The beginning of the third phase of its reliability level depends on the complexity of the asset, as well as the effectiveness of the maintenance that was performed during its lifetime. Maintenance costs, including the human resource requirements, are more predictable during the second phase and hence, PdM has the highest certainty of returning cost savings with high operational uptime.

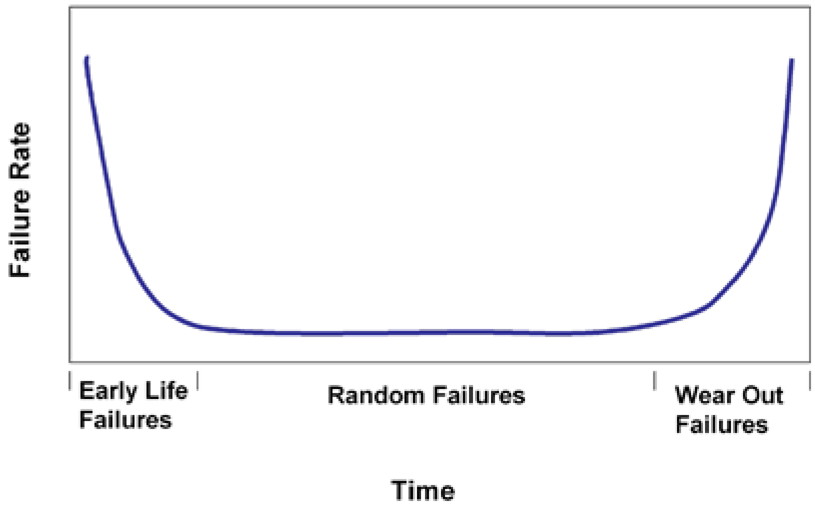

Figure 2: Bathtub Curve of Failure/Reliability against Time/Age

As an asset approaches 85% of its expected Design Life, reliability is likely to have reduced from its highest. The third phase of reliability level may have started before the 85% time. If the asset has received significant investment leading up to this stage of its life, it may be more reliable than its nominal age would suggest. For this reason, Maintenance History is a valuable source of information. At this 85% of Design Life stage, it is recommended that the maintenance type be reviewed. It may be that the maintenance type remains calendar-based or Predictive, or even changes.

6.6.7 Maintenance History

This stage of the Procedure is when Intelligent Maintenance potentially becomes a viable maintenance outcome. Key factors in achieving Intelligent Maintenance is the information provided by Maintenance History.

The success of Intelligent Maintenance starts with good quality Maintenance History. (Refer to NMA&FM Volume 6, Chapter 26: Maintenance History for Guidance).

It may be that the history is complete, but concludes that the asset, subsystem or system is in poor condition with a high frequency of repairs in its past. It may be that the history has a lot of 'blank' entries due to the required information not being recorded in the past. In this situation, the adoption of Planned Maintenance will reduce the cost of unplanned maintenance.

A guide timescale for good quality, appropriate maintenance history is 3 unbroken years' worth of data. As this mass of data is compiled, depending on the stability and content of the reported values, the maintenance contractor may be able to make an early decision to adopt PdM.

A maintenance contractor considering PdM is advised to carry out their own condition assessment to confirm the Maintenance History evidence. The maintenance contractor needs to then decide if the condition of the asset, subsystem, or system is as expected for its age, operating environment and previous investment. Assets that have responded well to maintenance and operating demands, are likely respond well to Intelligent Maintenance.

6.6.8 Resources Available

At this stage of the Procedure the asset, subsystem, or system is a good candidate for Intelligent Maintenance. Resource availability refers to the capital expenditure and skillset required, to achieve the potential costs savings.

7.0 ATTACHMENTS

1. Attachment 1 : Types of Maintenance Selection Procedure

Attachment 1: Types of Maintenance Selection Procedure

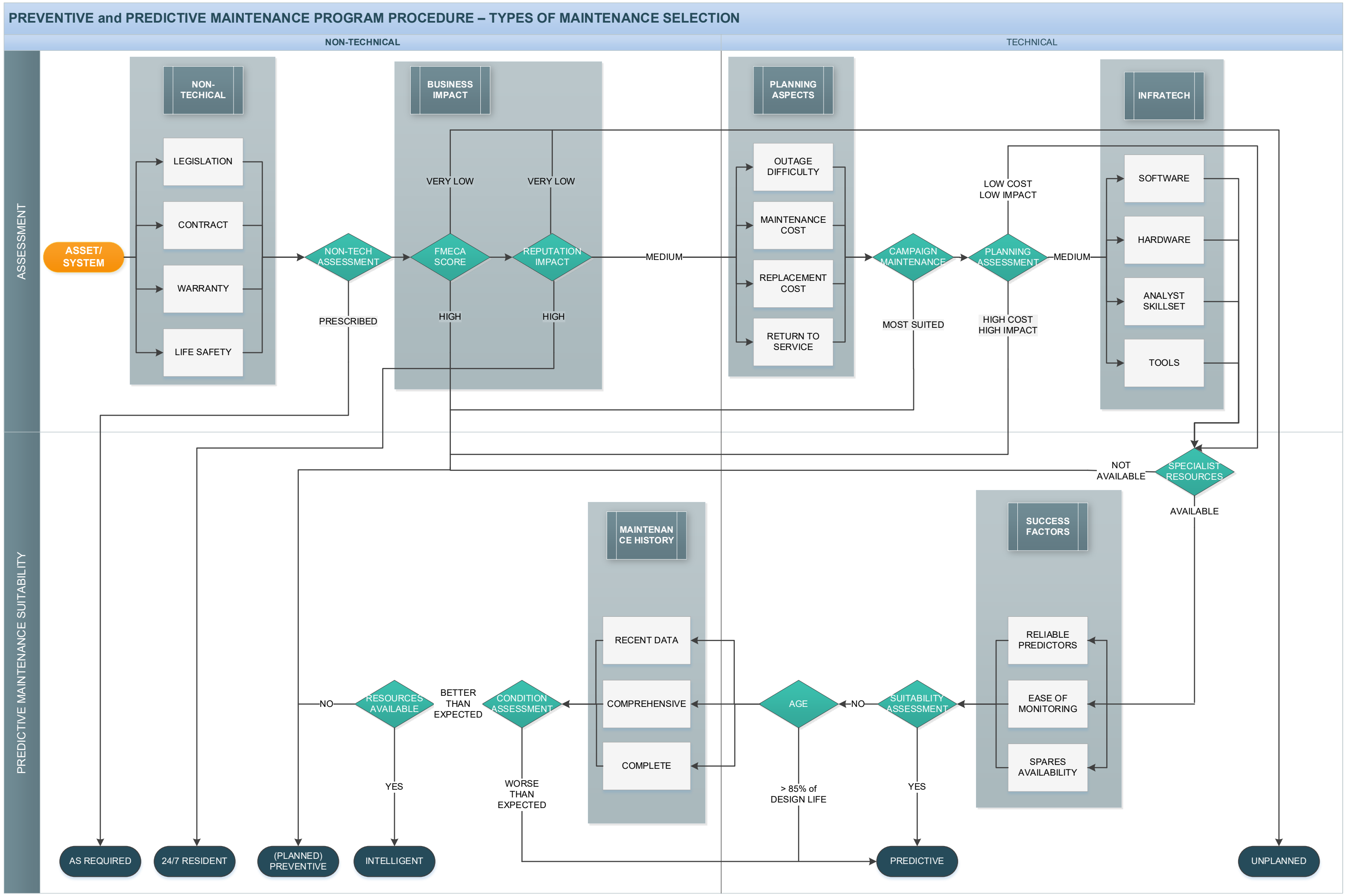

Figure 3: Preventive and Predictive Maintenance (PdM) Program Procedure Flowchart