A Framework for Developing and Evaluating Data Center Maintenance Programs

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> Executive summary

Inadequate maintenance and risk mitigation processes can quickly undermine a facility's design intent. It is, therefore, crucial to understand how to properly structure and implement an operations and maintenance (O&M) program to achieve the expected level of performance. This paper defines a framework, known as the Tiered Infrastructure Maintenance Standard (TIMS), for aligning an existing or proposed maintenance program with a facility's operational and performance requirements. This framework helps make the program easier to understand, communicate, and implement throughout the organization.

Contents

Click on a section to jump to it

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Introduction

Billions of dollars have been spent building highly redundant data center facilities in order to deliver high availability IT solutions to an increasingly information- reliant world. These large investments have produced a variety of sophisticated facility infrastructure designs that are inherently reliable and progressively more energy efficient. However no facility design, regardless of how well planned and constructed, can withstand the disruption of a poorly designed or implemented Operations and Maintenance (O&M) program. Inadequate maintenance and risk mitigation processes can quickly undermine the facility design intent. It is therefore crucial to understand how to properly structure and implement an O&M program to achieve the level of performance for which the facility has been configured. This paper defines a method for aligning the operational requirements of the business with maintenance program standards that can be easily understood, communicated, and implemented throughout the organization.

Tiered Infrastructure Maintenance Standard (TIMS) for Mission-Critical Environments

While it may be commonly understood that a well-organized O&M program is required to achieve data center performance and efficiency goals, it can be very difficult for those who are not maintenance professionals to understand what such a program looks like. The inherent resiliency of a facility will often mask operational deficiencies that have the potential to negatively impact data center availability, performance, and efficiency.

In response to this need, a simplified framework for classifying operations and maintenance programs for mission critical facilities is presented in this paper. Called the Tiered Infrastructure Maintenance Standard (TIMS), this system provides a straightforward method for evaluating the maturity of an O&M program (existing or proposed), gives an understanding of the associated level of risk, and helps effectively communicate these concepts throughout the organization. An understanding of TIMS facilitates the development of a maintenance strategy that aligns with corporate data center performance goals, in a way that is transparent to everyone involved in the operation, administration, and management of the mission-critical environment.

Describing the framework

The framework is comprised of four maintenance service tiers or levels:

- TIMS-1: Run to Fail
- TIMS-2: Unstructured Maintenance
- TIMS-3: Structured Maintenance
- TIMS-4: Facilitated Maintenance

TIMS-1: Run to Fail

This level of service reflects the old adage, "if it isn't broken, don't fix it." Maintenance at this level is reactive. When an equipment failure occurs, a maintenance technician is summoned to perform the repair. Where system redundancy exists and is functional, there may be little or no impact to the critical load for an isolated failure. However, the lack of a preventive maintenance program will increase the likelihood of multiple concurrent failures, which can take down even redundant systems.

Operating at this level implies that the perceived cost of an outage is low compared to the cost of preventative maintenance. Unfortunately, when budgets are tight, deferring maintenance is often viewed as a way to cut cost. This is a risk calculation similar to forgoing medical insurance because you are feeling healthy, which can have catastrophic results. Statistically speaking, any perceived, short-term savings in maintenance costs will likely be overshadowed by costly outages and expensive repairs over the long run.

In many cases, a lack of system redundancy forms the justification behind a run to fail strategy when the ability to perform maintenance is restricted without removing a portion of the critical load from service. This, for example, could be the result of a single point of failure in a switchboard, or a PDU feeding single-corded servers. Ironically, this approach guarantees that an outage will occur when (not if) a system component fails, possibly for an extended period of time.

TIMS-2: Unstructured Maintenance

TIMS-2 maintenance programs are characterized by the performance of basic preventative maintenance only, with little organizing structure to regulate how the work is conducted, or to evaluate its effectiveness. The fact that it is commonly performed by qualified manufacturer's service representatives or trusted in-house technical staff can create a false sense of security. Even qualified personnel can make mistakes, or focus too intently on individual components without considering the system as a whole. This type of program may deliver adequate results in some environments, but does not meet the stringent requirements of mission-critical data centers. Unfortunately, it is a common practice throughout the industry.

Simply following manufacturer's recommendations is no guarantee that all necessary steps are being taken to maximize availability of the critical load. If the maintenance program lacks a detailed scope of work for each piece of equipment that factors in system interdependencies, chances are that important steps are being neglected. If Methods of Procedure (MOPs) are not employed for critical systems, there's an elevated risk of human error occurring during maintenance events, where even experienced technicians can become distracted and operate the wrong valve or switch.

A common characteristic of Unstructured Maintenance is an over-reliance on individual effort. It can be reassuring to rely on a trusted individual who has been providing maintenance services for years. However, it creates a high degree of risk when an organization's facility maintenance knowledge resides inside the head of individual technicians, who are susceptible to making mistakes no matter how experienced, and who may leave at any time and take that critical information with them.

Another indicator of Unstructured Maintenance is a training program that almost exclusively consists of shadowing more experienced workers for a period of time, after which they are allowed to perform a wide variety of work without certification, testing, or formal training. Unstructured, under-documented maintenance programs create an environment in which maintenance can be somewhat haphazard, and the risk of human error is elevated.

TIMS-3: Structured Maintenance

The goal of Structured Maintenance is to maximize uptime by eliminating guesswork and minimizing human error. This requires a degree of discipline and experience to execute properly. Every part of the maintenance process is closely evaluated. Policies are established to exert control over how and which information is gathered, acted upon, and recorded. Programs are created to identify, train, supervise, and evaluate qualified personnel. Procedures are developed to precisely manage how and when work is performed.

Structured Maintenance utilizes best practices from every facet of the O&M environment and integrates them into a program that is more than the sum of its parts. The goal is to systematically eliminate variables that can introduce errors. Maintenance activities at this level are extremely proactive, controlled, and documented.

Characteristics of Structured Maintenance include a formal staff training program, a document library that includes a scope of service and Standard Operating Procedures (SOPs) for all site equipment; a change management program that utilizes detailed Methods of Procedure (MOPs) for all maintenance activities; a robust emergency preparedness and response program; a quality management system; and specialized support systems such as an Electronic Document Management System (EDMS).

Note that it is not necessary to have a facility with a high availability tier rating to be able to enact a Structured Maintenance program. Enacting Structured Maintenance will enhance the performance of any facility design, as long as the program is fully enacted. In situations where concurrent maintenance is not possible controlled shutdowns may be required, but this is vastly preferable to an unplanned, uncontrolled shutdown that is preventable.

TIMS-4: Facilitated Maintenance

Facilitated Maintenance is the highest level of maintenance service. It combines a Structured Maintenance program with a data center design that facilitates concurrent maintenance by providing multiple power and cooling distribution paths with redundant components (i.e. Tier III or above). Such a design allows individual pieces of equipment to be isolated and maintained without a disruption in service. Another important component is a Building Automation System (BAS) and/or Data Center Infrastructure Management (DCIM) system, which continually monitors the critical infrastructure, trends equipment performance, alerts operators when conditions fall outside preset parameters, and allows automated control of equipment sequencing. Finally, the use of a Computerized Maintenance Management System (CMMS) enables the efficient scheduling of maintenance events, as well as the analysis and management of maintenance effectiveness.

When Structured Maintenance is performed in this environment, the highest possible level of reliability is achieved in the following ways:

- The ability to easily isolate redundant system components for comprehensive testing and maintenance greatly increases reliability while minimizing the risk of downtime.
- Automated systems take some of the risk of human error out of the equation, and can respond more quickly and accurately to sudden changes.
- Continuous monitoring of the critical systems and the ability to trend equipment operating parameters facilitates predictive and condition-based maintenance practices.
- Systems for managing asset and maintenance data provide tools for optimizing maintenance planning and reporting key metrics used to track and improve equipment reliability.

Evaluating a maintenance program

Having established the TIMS framework above, let's take a look at how it can be used to quickly and reliably evaluate the level of maintenance for an existing or proposed O&M program. Below are a list of tools and assets to refer to when doing this evaluation:

- Maintenance records
    - Asset database/list
    - Annual maintenance schedule

    - Maintenance records for the previous year
    - Scopes of service (maintenance frequency and work description) for critical equipment
    - Scheduled maintenance service contracts
- Operational procedures
    - Emergency operating procedures (EOP)
    - Standard operating procedures (SOP)
    - Methods of procedure (MOP) also known as maintenance procedures (MP))
- Operational processes
    - Walk-through checklist
    - Shift turnover log
    - Change management process
- Training program
    - Training program description
    - Training materials
    - Personnel training records
- Support systems
    - Building management/automation system (BMS/BAS)
    - Data center infrastructure management (DCIM) system
    - Electrical power monitoring system (EPMS)
    - Computerized maintenance management system (CMMS)

With these items in mind, consider whether these tools and documents exist or not:

- Accurate and comprehensive database or listing of critical assets
- Published annual maintenance schedule covering all assets
- Service records that correspond to each scheduled maintenance for the past year

If they don't exist or it is unknown whether they do or not, then the facility is likely operating or going to be operating in a "run-to-fail" (i.e., TIMS-1) mode.

If those tools exist and are in active use by the organization, then the next set of items should be carefully considered:

- Each equipment type has a documented scope of service that defines the maintenance frequency and details the required work activities
- This information is used to create a detailed method of procedure ("MOP", a.k.a., maintenance procedure) that is used to oversee each maintenance event
- Emergency procedures are developed to script emergency response activities for probable/consequential system failures
- Drills are regularly performed to practice responding to these scenarios
- Documented checklist for facility walkthroughs
- Log used by the engineering staff to communicate across shifts
- Documented change management process that is followed during equipment installation and maintenance
- Documented training program that covers all of the site systems along with written evaluations and annual re-certification processes

If one or more of these items are missing, then the data center may be operating in an unstructured (TIMS-2) environment.

If all of these exist and are actively being used, then the data center is most likely operating with a structured (TIMS-3) maintenance program. Even better, if all of the systems are concurrently maintainable, there is a functioning BAS/DCIM system with an EPMS capability and a CMMS exists to facilitate maintenance; then the facility is operating at the highest (TIMS-4) level from a maintenance and operations standpoint.

Appendix A at the end of this paper contains a more detailed checklist that can be used to identify the elements of a Structured Maintenance program. While not an exhaustive list, you can use this to perform a quick self-assessment to determine if your maintenance program meets the TIMS-3 criteria. Note that each item on the list must be actually observed, not simply reported to be in place. Being "observed" should mean that processes, programs, and procedures are all documented and in active use, and not just reported as "understood" or "occurring".

Interpreting the results

While it isn't possible to provide a scoring system that works for every circumstance, it's safe to say that if you are missing more than one or two elements; your program has not yet met the overall criteria for designation as TIMS-3 Structured Maintenance. In practice, few maintenance programs fall neatly into a single category as described in the preceding sections. More often, there will be elements of two or more maintenance tiers being exhibited. For example, a program might embrace Structured Maintenance on the electrical systems, but exhibit Unstructured Maintenance methods on the HVAC plant by not utilizing MOPs or good change management practices. Another example would be a facility that incorporates Structured Maintenance methods across the board, but has a single switchboard that cannot be maintained without interrupting electrical service, and is operated in "run-to-fail" mode due to the inability to schedule a maintenance window with end-users. In cases such as these, the weakest link principle applies: overall service level is only as high as the lowest level of maintenance being performed in any critical area of the facility.

The evaluation process described above will provide a quick indicator of an O&M program's alignment with industry best practices for mission-critical facilities. Due to the complex nature of these programs, it may be necessary to perform a more thorough analysis to develop a complete understanding of their strengths and weaknesses. Such an audit should be performed by a mission-critical facility specialist, either as a stand-alone service or as part of a comprehensive facility assessment. Independent audits of the O&M program are in themselves a best practice for ensuring program effectiveness and will pay for themselves with increased reliability, uptime, and efficiency.

Optimizing your maintenance program

If you discover as a result of this exercise that your maintenance program is not in alignment with your business objectives, immediate action should be taken. This doesn't mean that every data center needs a TIMS-4 or even a TIMS-3 program. For instance, organizations that deploy multiple Tier II facilities that are designed to maintain operations if one site fails, may not require that level of effort to meet their business objectives. On the other hand, just because you have a Tier II facility doesn't mean that you shouldn't be running a TIMS-3 program. It's all about the criticality of the business your data center supports. As a rule of thumb however, if you have made the investment for a Tier III or Tier IV facility, you should be protecting that investment with a TIMS-3 or better program.

If you are looking to increase the reliability of your facility whatever its Tier rating, applying TIMS-3 principles to an existing infrastructure will minimize risk and maximize your bottom line. It could even be argued that a Tier II facility operating at TIMS-3 can be more reliable in than a Tier III facility operating at TIMS-2, given the likelihood of higher incidences of human error in the later example.

Considerations

In preparing to undertake the establishment of an effective O&M program as defined by TIMS, the following items must be considered:

1. Scope: What specific actions need to be taken to achieve the desired TIMS tier?
2. Budget: Does your budget allow you to meet your chosen goals?
3. Skills: Do you have the internal skills to manage and perform the activities required?
4. Impact: What is the impact on your business operation to implement the plan, and what are the risks?

Conclusion

An organization's cost of downtime and risk-tolerance level must first be established in order to determine which TIMS level best matches their goals. This knowledge is a prerequisite for the development of a realistic maintenance program. Ultimately, the TIMS level achieved will be determined by resource availability and the commitment of the organization's management team to implement and maintain the program over the long term.

When evaluating the entire scope of the mission-critical enterprise, the effectiveness of the maintenance program is one of the key components that must be factored in to determine the true level of sustained reliability. The tremendous variability in how maintenance is implemented can make it difficult to judge what constitutes the proper level of service in a given situation. Defining maintenance levels and using that to evaluate a given O&M program as described in this paper is a tool to achieving such an understanding.

The Tiered Infrastructure Maintenance Standard offers a systematic approach to matching maintenance activity levels with the level of reliability expected of the facility. Applying these principals to your maintenance program is a crucial step in attaining data center availability and business continuity goals.

About the author

Bob Woolley has been involved in critical facilities management for over 20 years. Bob served as Senior Vice President Critical Environment Services at Lee Technologies and Vice President of Data Center Operations for Navisite, as well as Vice President of Engineering for COLO.COM. He was also a Regional Manager for the Securities Industry Automation Corporation (SIAC) telecommunications division and operated his own critical facilities consulting practice. Mr. Woolley has extensive experience in building technical service programs and developing operations programs for mission critical operations in both the telecommunications and data center environments.

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Appendix A: Structured Maintenance program checklist

CATEGORY	ITEM	OBSERVED	NOT OBSERVED
SAFETY			
	Workplace Safety Program		
	Hazard Analysis performed on all work procedures		
	Lockout/Tagout Program		
	PPE Inventory and Testing Records		
	Hazardous Materials Labeling		
	Hazard Communications Program		
SECURITY			
	Vendor Access Control		
	Key Control Program		
	Vendor Personnel Orientation		
EMERGENCY PREPAREDNESS AND RESPONSE			
	Emergency Operating Procedures		
	Emergency Drills		
	Escalation Procedures		
	Crisis Management Plan		
	Incident Logging and Reporting		
	Failure Analysis Program		
MAINTENANCE PROGRAM			
	Comprehensive Asset Management Database		
	Scopes of Service for Critical Equipment		
	Preventative and Predictive Maintenance Standards		
	Annual Maintenance Schedule		
	Spare Parts Inventory and Management Plan		
	Subcontractor Selection Process		
	Test Equipment Calibration Records		
CHANGE MANAGEMENT			
	Risk Analysis and Communication		
	Change Control Process		
	Notification and Alerting		
	Quality System		
	Methods of Procedure		
	Drawing Update Process		
PERFORMANCE			
	Service Level Agreements		
	Key Performance Metrics		
	Performance Measurement and Reporting Guidelines		

CATEGORY	ITEM	OBSERVED	NOT OBSERVED
EFFICIENCY			
	Performance Benchmarking		
	Airflow Management Procedures		
	Energy Efficiency Measurement and Reporting		
	Systems Optimization Procedures		
	Continuous Improvement Program		
DOCUMENTATION			
	Document Management Program		
	Accurate Drawings		
	Critical Facility Work Rules		
	Facility Walk-Through Checklist		
	Standard Operating Procedures		
	Administrative Procedures		
	Shift Turnover Procedures and Log		
OPERATIONS MANAGEMENT			
	Services Scope Description		
	Staff Roles and Responsibilities		
	Vendor Management Procedures		
	Materials and Tool Inventory		
TRAINING			
	Training Requirements		
	Qualification Standards		
	Certification Program		
	Individual Training Records		
	Lessons Learned/Near-Miss Program		
	Ongoing Education Program		
OPERATIONAL SUPPORT SYSTEMS			
	Work Order Management System		
	Electronic Document Management System		
REPORTING			
	Weekly Report		
	Monthly Report		
	Quarterly Performance Report		
	Project Report Template		

Appendix B: Glossary

- **Asset Database**: a comprehensive list of the facility systems and equipment, including make, model, serial number, capacity, location, system ID, and warranty information. This is often part of a CMMS (see below).
- **Building Management System (BMS):** a system designed and implemented to control and monitor the functions of a building and its associated plant.
- **Scopes of Service:** a detailed listing of all the maintenance activities required for a specific piece of equipment and the frequency of each activity. This list usually includes the manufacturer's suggested maintenance, but may also take into account the equipment history, experience of the service personnel and special application requirements.
- **CMMS:** computerized maintenance management systems (CMMS) are software applications that schedule, track, and monitor maintenance activities and provide cost, personnel, and other reporting data and history.
- **DCIM:** data center infrastructure management are systems the collect and manage data about a data center's assets, resource use, and operational status throughout the data center lifecycle. This information is then distributed, integrated, analyzed and applied in ways that help managers meet business and service-oriented goals and optimize the data center's performance
- **EDMS:** electronic document management systems (DMS) are software applications that scan, store, and retrieve documents that are used by an organization. In the facilities environment, these documents are typically facility drawings, Operations and Maintenance manuals, maintenance contracts, MOP's, SOP's, service reports, etc.
- **EOP:** an emergency operating procedures is a detailed procedure for an emergency event that is either high in probability, consequence, or both. It is prepared in advance in order to limit the severity and duration of the event. Such procedures are often rehearsed in drills that combine one or more EOPs, mimicking the behavior of actual emergency scenarios where multiple failures may occur.
- **Manufacturer's Recommended Service:** preventative maintenance activities for specific pieces of equipment as set forth in the manufacturer's Operations & Maintenance instructions.
- **MOP:** A method of procedure (MOP) is a detailed work document that is utilized to perform maintenance on critical systems. The MOP specifies what equipment is being worked on, who will be performing the procedure, what tools and safety procedures are necessary, describes the risk, lists the step-by-step procedure, identifies backout procedures and escalation protocols, contains authorization signatures, and records maintenance data.
- **Onsite Facilities Staff:** dedicated on-site facilities staff that focuses on the site critical systems. This group performs daily walkthroughs, manages vendors, and performs some level of self-performed service. The facilities staff is responsible for creating and maintaining all of the site documentation, including MOP's, SOP's, and emergency procedures. This staff may or may not be providing 24x7 coverage, depending on the level of service required.
- **New Component Testing:** pre-testing of components prior to installation in critical systems. This testing can be performed on-site when possible, but may need to be done at the factory with appropriate documentation provided.
- **PPE:** personal protective equipment
- **Predictive Maintenance:** maintenance activity that's designed to identify precursor indications to equipment wear or failure. Early warning provided by predictive maintenance can be used to budget and plan maintenance activities in advance of the need to actually perform the service. This increases efficiency and reduces the risk of unplanned outages.
- **Quality System:** an organization's arrangements and resources for meeting quality objectives. It is used to ensure the expected outcome of a particular service activity

and to reduce the risk of service related failures. This includes utilizing a MOP review process, pre-testing components prior to installation, quality checking the finished work, and performing periodic program audits.

- **Record Drawings:** up to date architectural, electrical, mechanical, and equipment layout drawings that accurately reflect the facility as it was actually built, plus any adds, moves, or changes that have occurred up to the present day.
- **SOP:** a standard operating procedure (SOP) is a document that is used to describe specific steps to be taken to implement a well understood and defined process. An example would be putting a UPS into bypass or putting a fire system in test mode.
- **Tier Rating System:** a rating system developed by the Uptime Institute to classify facility infrastructure reliability in four levels or tiers, from lowest (Tier I) to highest (Tier IV).
- **Training Program:** a formal and comprehensive staff training program that defines various levels of qualification along with a rigorous testing and certification process. This is used in conjunction with a matrix that identifies specific maintenance tasks and what the qualification levels are for performing them.
- **Vendor Management Program:** a systematic program of vendor identification, selection, management, and evaluation. The purpose is to find competent vendors, document their qualifications, clearly specify the scope of their activities, obtain competitive pricing, monitor their performance, and provide feedback.
- **Walk-through Check List:** a detailed list of critical systems and facility infrastructure equipment, containing fields for inputting data (such as voltage, temperature, and pressure) or status checks. This list is used to perform periodic walk-throughs of the facility to monitor status and create a written record of critical system settings and values.