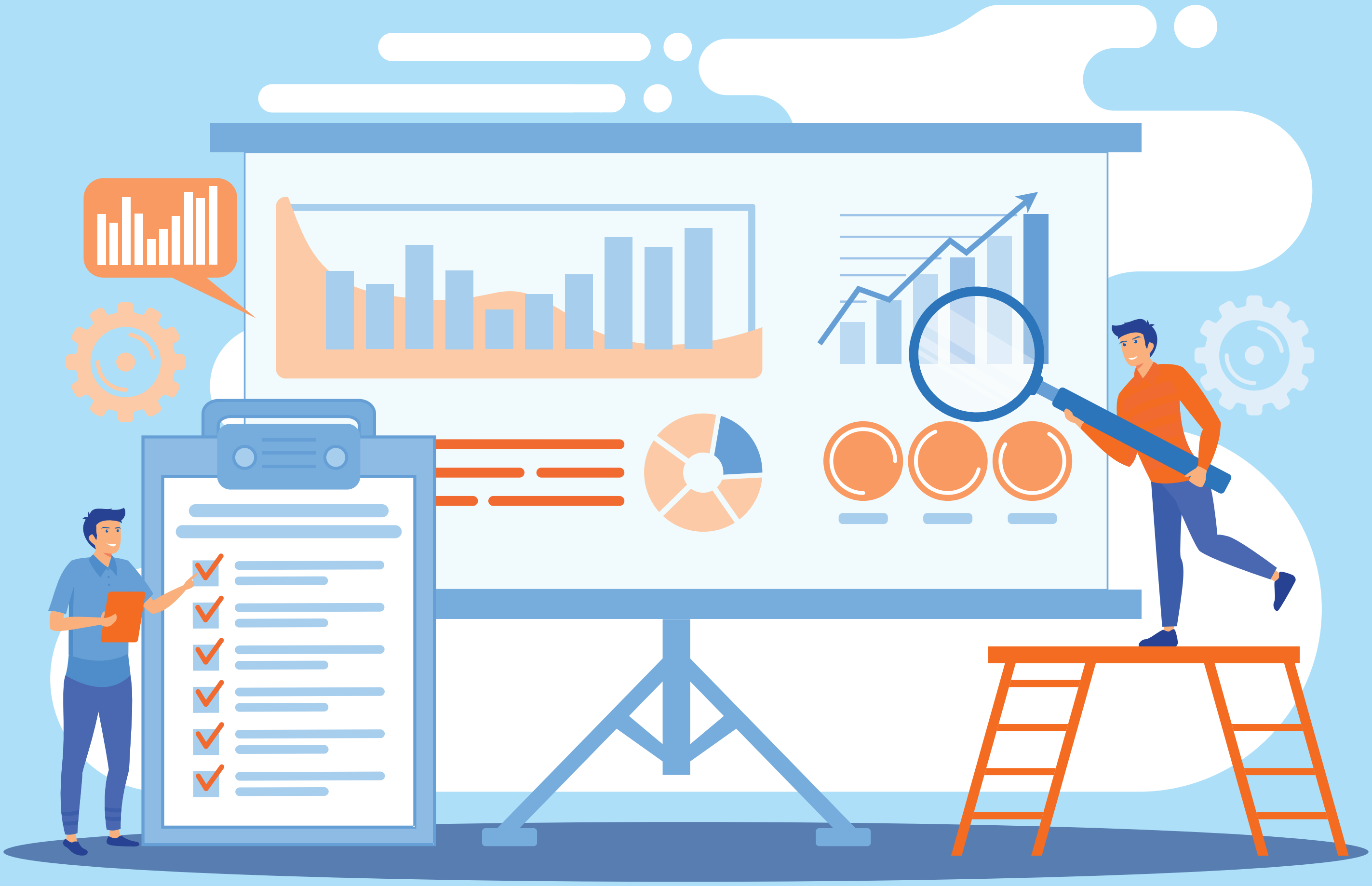
LIFE CYCLE ENGINEERING

RISK-BASED ASSET MANAGEMENT (RBAM®):

Accounting for Risk in Your Asset Management Strategy



Risk-Based Asset Management (RBAM®): Accounting for Risk in Your Asset Management Strategy

A **risk-based asset management (RBAM®) strategy** will optimize your physical assets while preserving their capital value, optimize your maintenance schedule for increased asset uptime, and meet stakeholder requirements. It's also a critical step in building a strong foundation for digital transformation (sometimes referred to as Industry 4.0).

This paper reviews the importance of asset management, presents the asset life cycle stages and cost implications, outlines a risk-based asset management strategy, and explains the five phases of a risk-based asset management implementation model.

Introduction: The Focus on Asset Management

The **ISO 55000 series** establishes a global standard for asset management systems. The series has three parts:

ISO 55000	ISO 55001	ISO 55002
Overview with standard terms and definitions	Requirements and specifications	Implementation guidelines

These standards provide the elements of a holistic asset management program and should be referenced when creating a corporate or site policy and program. LCE's implementation framework (Figure 1) is based on the ISO 55000 standards and establishes the key concepts and flow necessary for many important asset management-related deliverables. The implementation methodology comprises more than 80 key processes and 8 critical knowledge domains associated with each individual life cycle phase. At the heart of the implementation framework is an asset life cycle management system that will drive your ISO 55000 compliance, ISO 31000 risk management, operational and reliability excellence, and digital transformation objectives.

LCE's Asset Management System Framework

Asset Life Cycle Management

The **ISO 55000 Asset Management Standard** clearly establishes the expectation that assets will be managed throughout their life cycle. LCE's asset management system framework integrates the people side – the capabilities, processes, procedures, and knowledge along with the asset management enablers, the technology, and the technology-enabled people – into the asset life cycle stages. RBAM® principles and practices are deeply integrated into the asset life cycle's four stages.

Asset Management System

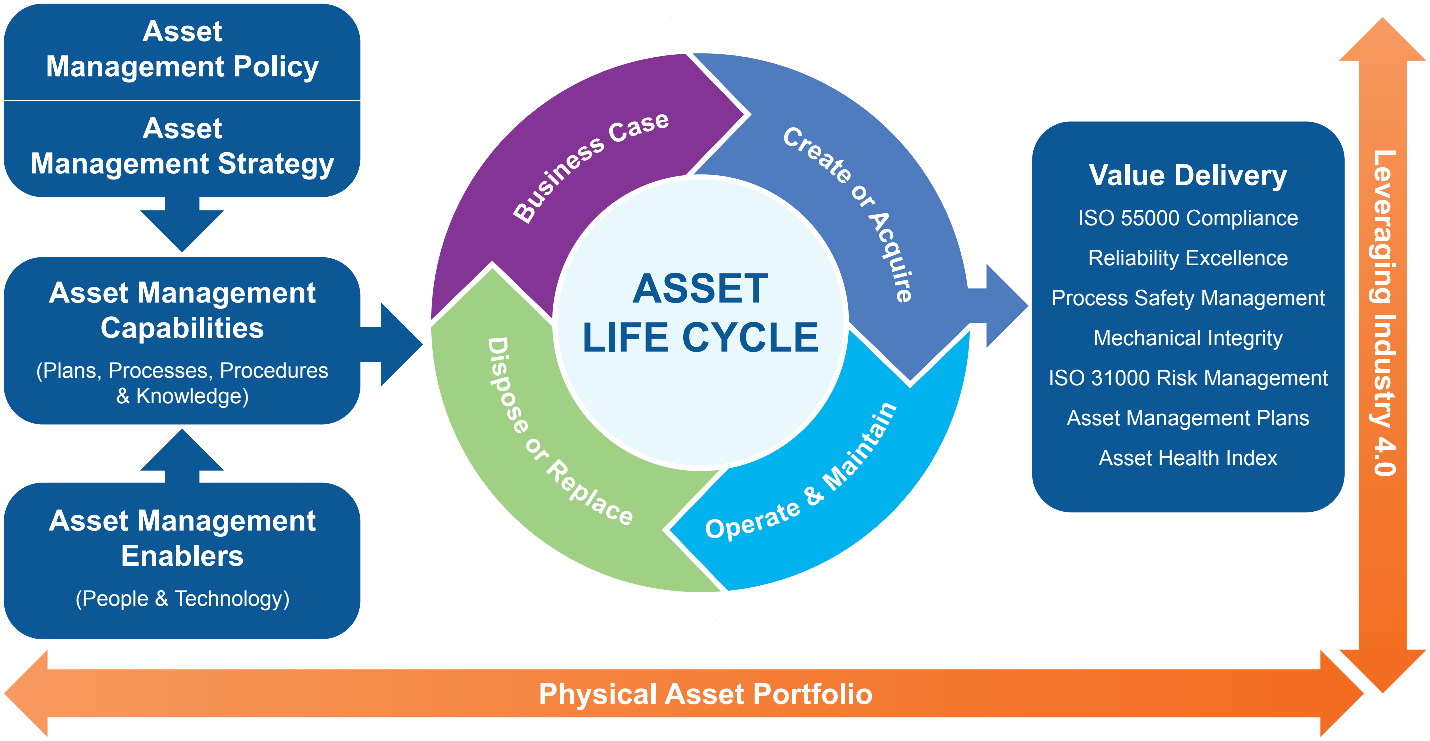


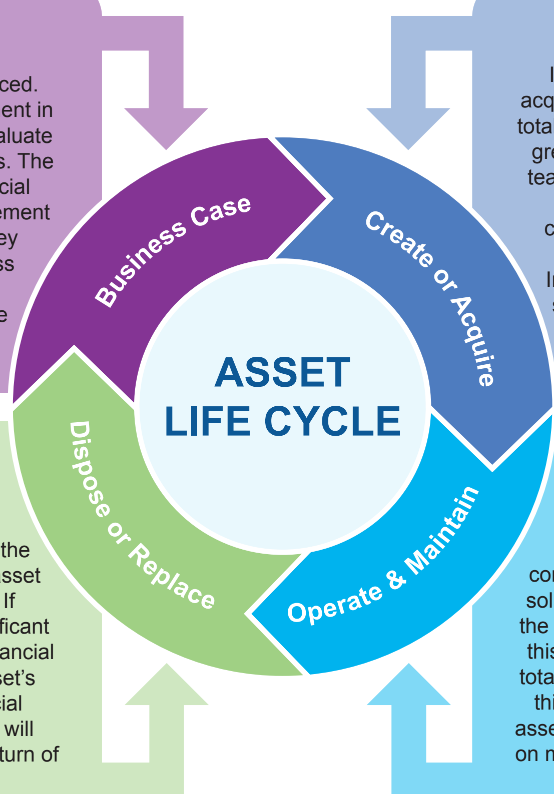
Figure 1 – LCE's Asset Management System Implementation Framework

STAGE 1

In **Stage 1** the business case is produced. This is the single most important document in helping an organization's leadership evaluate the return on physical asset investments. The business case is more than just financial justification; it defines the problem statement and potential business impact. The key processes associated with the business case phase include strategic planning, capital planning and evaluation, life cycle cost analysis, and auditing.

STAGE 2

In **Stage 2**, decisions about creating or acquiring assets have the greatest impact on total cost of ownership. This is also where the greatest collaboration of a cross-functional team is needed to ensure intended benefits will be realized. In this phase, asset connectivity requirements should inform engineering through commissioning. Important deliverables pass from stage to stage as the process moves the acquired or created asset from an idea onto the shop floor.



STAGE 4

In **Stage 4**, assets are disposed of, decommissioned, or replaced following the end of their service life or a change in asset requirements due to rationalization. If unplanned, this phase can have a significant negative impact on an organization's financial statement. Prematurely ending an asset's useful life will have a negative financial impact, while extending the useful life will have a positive financial impact in the return of asset value.

STAGE 3

In **Stage 3**, value is created as assets are operated and maintained. Newly commissioned assets function to provide the solution defined in the business case. This is the longest phase of the asset life cycle. Once this phase is reached, only about 15% of the total operational cost can be influenced. Since this phase of the life cycle is focused on an asset's functional performance, the tools focus on monitoring to drive continuous improvement and extend asset useful life.

Risk-based Asset Management Strategy

Whether an organization seeks holistic implementation of an asset management system and ISO 55000 certification, or a more tactical application to achieve performance gains, a risk-based approach delivers the greatest value from assets at the lowest cost.

An effective asset management system provides transparency to risk so that appropriate decisions can be made throughout an asset's life cycle. For guidance on risk management, the ISO 55000 series defers to ISO 31000. Figure 2 illustrates the guidelines and principles for a risk management process in accordance with ISO 31000.

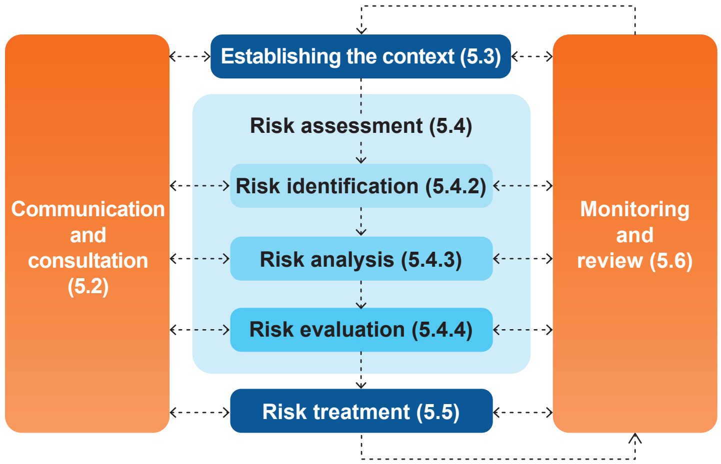
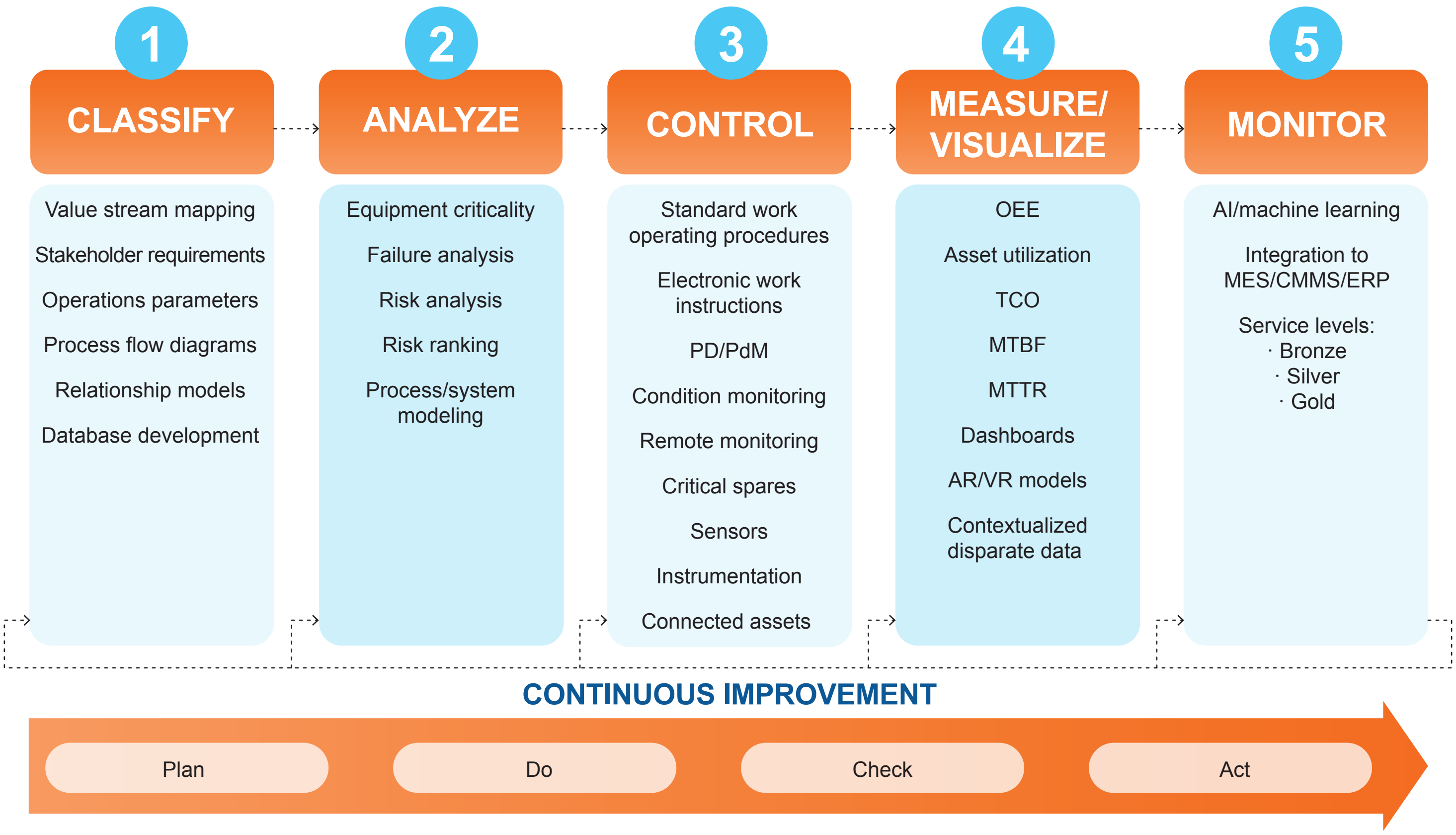


Figure 2 – Process for Assessing and Managing Risk (ISO 31000:2009)

An RBAM® strategy combines risk management, standard work, and condition-based maintenance to properly apply resources based on process criticality. This ensures proper controls are in place, and reliability analysis is used to ensure continuous improvement. An effective RBAM® system includes an enterprise asset management solution that properly catalogs asset attribute data, a functional hierarchy, criticality analysis, risk and failure analysis, control plans, reliability analysis and continuous improvement.

The Five Phases in LCE's RBAM® Implementation Model



1 Phase 1: Classify

Operating Conditions – Value stream maps are developed to identify waste and understand how asset reliability impacts the value stream. Stakeholder analysis clearly defines the operating requirements and parameters. Process flow diagrams and relationship models such as functional block diagrams are used in the classify phase when establishing the functional hierarchy that will be used to develop the CMMS/EAM database.

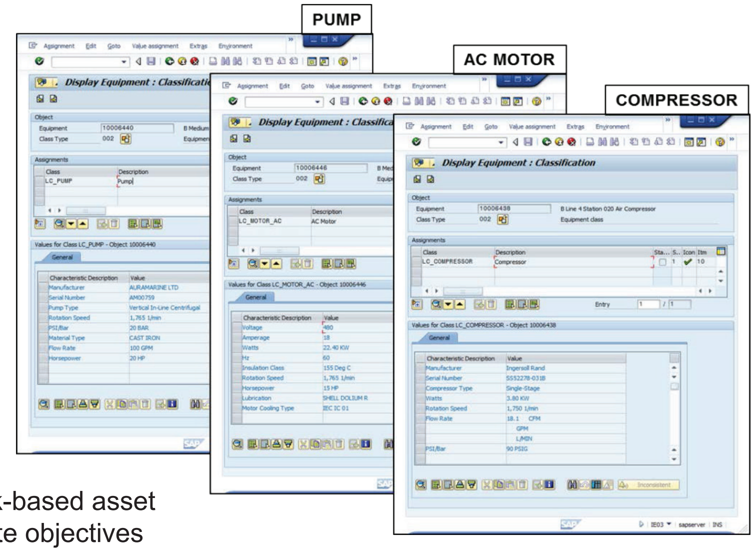


Figure 3 – Classified by Asset Type

Database Development – This is probably one of the most overlooked components of a successful risk-based asset management system. For your system to meet corporate objectives and to enable the optimal use of digital tools, data for each asset must be clearly captured based on its type and required attribute data.

Figure 3 is an example of developing the “asset type attribute” fields.

Collection – Data can be collected manually, with the aid of electronic media or even digital imagery. Figure 4 shows a digital image of an electric motor specification tag.

Figure 4 – Digital Image of Motor Specification Tag

Cataloging – It’s critically important to create a functional hierarchy. The hierarchy will provide the level to which work orders are assigned, bills of material are written, and failure analysis is conducted. It also allows for rollups to cost centers, providing total cost of ownership and budgetary analysis.

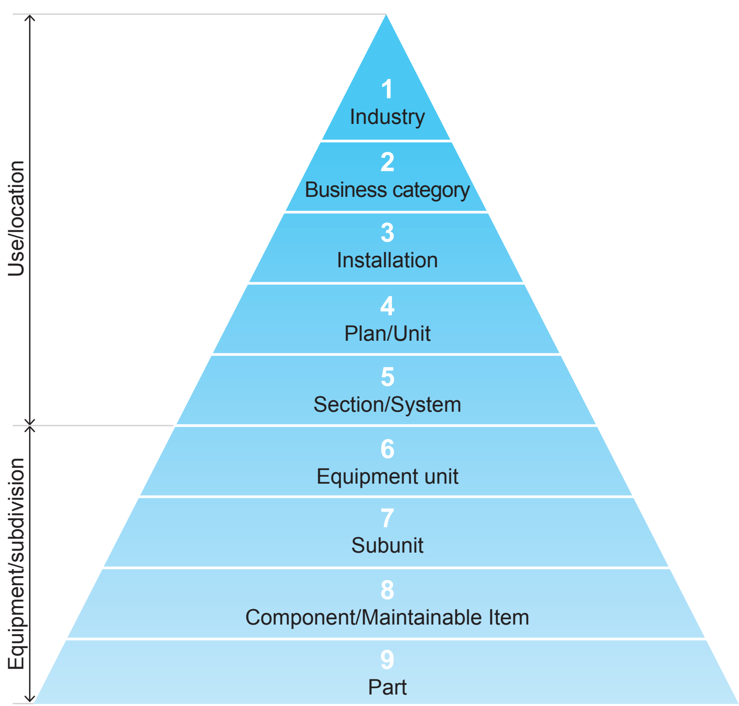


Figure 5 – Functional Hierarchy Example – ISO 14224

Main category	Taxonomic level	Taxonomic hierarchy	Definition	Examples
Use/location data	1	Industry	Type of main industry	Petroleum, natural gas, petrochemical
	2	Business category	Type of business or processing stream	Upstream (E and P), midstream, downstream (refining) petrochemical
	3	Installation category	Type of facility	Oil/gas production, transportation, drilling, LNG, refinery, petrochemical, (see Table A1)
	4	Plant/Unit category	Type of plant/unit	Platform, semi-submersible, hydrocracker ethylene cracker, polyethylene, acidic acid plant, methanol plant (see table A2)
	5	Section/ System	Main section/system of the plant	Compression, natural gas, liquefaction, vacuum gas oil, methanol regeneration, condition section, reaction system, distillation section, tanker loading system (see Table A3)
Equipment subdivision	6	Equipment class/unit	Class of similar equipment units. Each equipment class contains comparable equipment units (e.g., compression)	Heat exchanger, compressor, piping, pump, boiler, gas turbine extruder, agitator, furnace, Xmas tree, blow-out preventer (see Table A4)
	7	Subunit	A subunit necessary for the equipment unit to function	Lubrication subunit, cooling subunit, control and monitoring, heating subunit, pelletizing subunit, quenching subunit, refrigeration subunit, reflux subunit, distributed control subunit
	8	Component/ Maintainable item (MI)[a]	The group of parts of the equipment unit that are commonly maintained (repaired/restored) as a whole	Cooler, coupling, gearbox, lubrication oil pump, instrument loop, motor, valve, filter, pressure sensor, temperature sensor, electric circuit
	9	Part[b]	A single piece of equipment	Seal, tube, shell, impeller, gasket, filter plate, bolt, nut, etc.

2 Phase 2: Analyze

Criticality Analysis – Next, conduct an analysis of your equipment and the significance of failure to work flows, business processes, value stream, etc. As the example in Figure 6 illustrates, this analysis includes such considerations as environmental impact, safety, production, quality, or reputation issues associated with the organization.

SYSTEM/ASSET	Business Impact	Profit Plan Impact	Customer Impact	Strategic Plan Impact	HSE Impact	On-site Impact	Community Impact	Environmental Impact	Reliability Value	Failure Rate	Replacement Cost	Maintainability	MTTR/Spares Availability	Utilization	Quality Impact	Critically Ranking
RA REACTOR	8	10	10	5	14	10	7	10	6	2	10	10	10	10	2	80
RL REACTOR	8	10	10	5	14	10	7	10	6	2	10	10	10	10	2	80
CHILLER	5	6	4	5	12	10	7	7	9	10	8	8	6	10	4	76
H2 FURNACE	8	10	10	5	7	7	1	5	8	6	10	10	10	10	4	74
RB FURNACE	7	10	5	5	14	10	7	10	7	3	10	7	10	4	3	73
RC FURNACE	7	10	5	5	14	10	7	10	7	3	10	7	10	4	3	73
H3 FURNACE	8	8	10	5	7	7	1	5	8	6	10	10	10	10	4	72

Figure 6 – Criticality Analysis Example

Risk Analysis – Identifying risk is the first step in risk management. Your analysis needs to include potential sources of risk, the severity if uncontrolled, and the likelihood of occurrence. Risk can also include the risk that is not mitigated if you choose to do nothing. An example of a simple risk table is presented in Figure 7. Items in the "A" category have the greatest risk and would therefore receive the most attention.

		SEVERITY			
		low	medium	high	EXTREME
OCCURRENCE	low	E	D	C	A
	medium	E	C	B	A
	high	C	B	A	A

Figure 7 – Risk Analysis Table

Failure Analysis – The next step is conducting formal failure analysis to determine the predominant failure modes that will be addressed based on risk ranking. Complexity will depend on the criticality analysis. For example, you may take a reliability centered maintenance (RCM) approach to the most critical assets. This method usually requires assembling a cross-functional team and can be time consuming.

Failure Mode and Effects Analysis (FMEA) is performed on the most critical assets. "Failure modes" means the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual. "Effects analysis" refers to studying the consequences of those failures.

SUBSYSTEM FUNCTION	FUNCTIONAL FAILURE	COMPONENT	POTENTIAL FAILURE MODE(S)	POTENTIAL EFFECT(S) OF FAILURE	POTENTIAL CAUSE(S) OF FAILURE	CURRENT CONTROLS	CURRENT PROCESS KNOWN FREQUENCY	RISK ASSESSMENT (AS IS)				RECOMMENDED IMPROVEMENTS/ ACTIONS
								SEV	OCC	DET	RPN	
Provide 1000 gpm of additive to process	No flow	Motor	No rotation/ torque	Shuts down process	Bearing seizure due to lubrication issues	Lube motor bearings	Y2	10	7	3	210	Include on vibration and IR route

Figure 8 – FMEA Example – Ref. IEC 60812

Risk Ranking – Risk ranking is a product of the outputs from the failure analysis and the criticality analysis. This ranking enables you to deploy resources to the assets and predominant failure modes that have the greatest risk of impacting corporate objectives (stakeholder requirements) and the process value stream.

Process/System Modeling – Computer simulations (digital twins) can be created for the most critical systems using known failure rate data. This will enable you to run multiple simulations to predict failure rates and make adjustments to the assets and maintenance intervals until you are satisfied with the level of reliability.

Phase 3: Control

Control plans consist of tasks that will be accomplished to mitigate or eliminate the risk of failure by targeting how equipment is monitored, maintained and operated. Standard work must be established to minimize variations in execution. Each FMEA can produce the following control strategies:

Control Strategy	Examples
Digitalization activities leverage emerging technologies to collect data, connect disparate data sources, and analyze data to identify early patterns of failure that can drive to a possible action or non-action.	• Installation of wired and/or wireless sensors • Development of asset process models • Connection of historical and real-time data to artificial intelligence (AI) software • Deployment of machine to machine (M2M) learning • The creation of electronic work instructions
Predictive maintenance (PdM) activities are based on a specific operating condition of an asset to detect the onset of a failure prior to a functional failure. This uses algorithms to determine time duration to failure.	• Thickness testing to monitor pressure vessel corrosion • Infrared thermography to detect an abnormally hot fan drive pulley due to drive belt misalignment • Vibration analysis to monitor the condition of a critical centrifuge bearing
Preventive maintenance (PM) activities are scheduled to be completed based on a specific timeline or cycle regardless of the asset condition.	• Changing HVAC air handler drive belts every year, regardless of wear • Changing oil in a gearbox every 6 months, regardless of oil condition • Injecting 2 ounces of a specific grease into a conveyor bearing
Operator care (OC) tasks are executed by operators during normal production.	• Operator daily inspection of oil level in a critical compressor • Operator weekly cleaning of inlet screens to cooling tower pumps • Operator quarterly test of tank high level alarm
Design modification or reliability upgrade projects intended to minimize unacceptable risks.	• Installing a sealless pump to reduce risk of a shaft seal leak • Installing redundant equipment to reduce risk to the value stream • Upgrading blower impeller material from ductile iron to stainless steel to reduce the risk of corrosion-related failure

Another control strategy – stocking critical spares – is intended to lower the risk to the value stream in the event of an equipment failure that requires a spare. It is imperative to keep critical spares in stock or readily available at all times. While the intent is not to use the spare on a regular basis (if at all), the negative consequences of not having one when needed far outweighs the purchase and inventory costs associated with maintaining it in the storeroom or close at hand. Critical spares are often expensive and may be one-of-a kind items, with anticipated low usage and frequently long lead times. However, if a high-risk failure mode lacks a mitigating action, stocking a critical spare may be the default strategy.

4 Phase 4: Measure

Measures must be established that define the key performance indicators supporting the value stream and corporate objectives.

Overall equipment effectiveness (OEE) is a good high-level metric that will point your investigation to the areas of opportunity. OEE is based on "controllable" performance within a plant or production area. OEE is a ratio of actual/scheduled performance for availability, performance, and quality as illustrated in Figure 9.

$$OEE = \frac{B}{A} \times \frac{D}{C} \times \frac{F}{E}$$

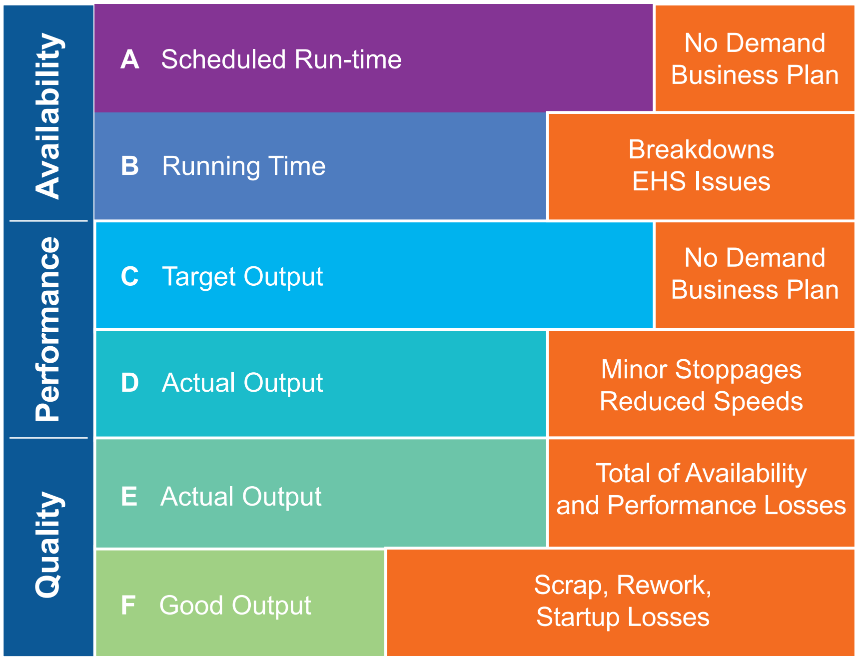


Figure 9 – Calculating OEE Points to Areas of Opportunity for Improvement

Once the control plans are defined, planned, scheduled, resourced, and executed, historical data can be coupled with work order history, failure codes, material usage, etc., for probability modeling, such as Weibull distribution, to understand where the limiting factors reside. Dashboards can be created and automated, leveraging the information provided by digital technology. Augmented reality (AR) and virtual reality (VR) can be leveraged to connected workers, providing the information needed to perform the work correctly. The models developed during the analyze phase can be improved by pulling in actual results.

Figure 10 – Sample Customizable Reliability and Maintenance Metrics – Dynamic Dashboard Using CMMS Data

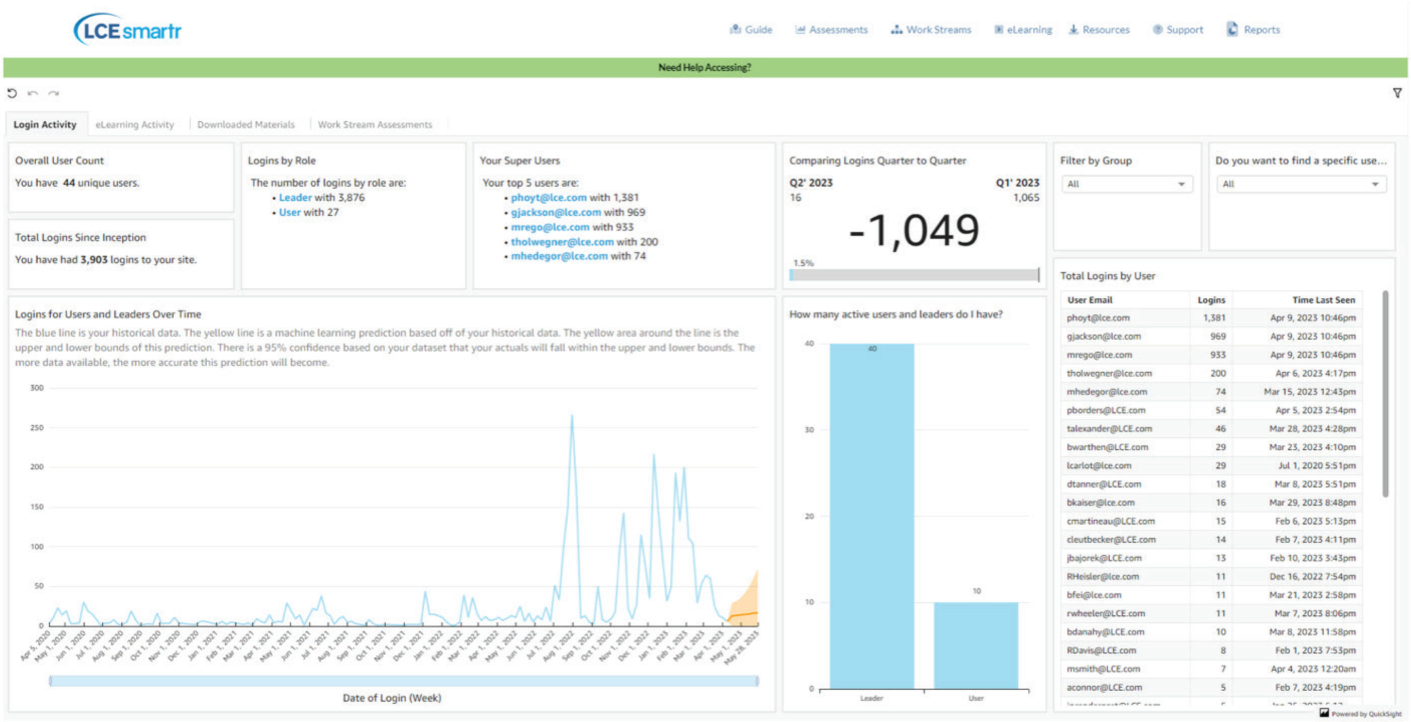


Figure 11 – System Usage Reports: Login Data Showing Engagement and Super Users

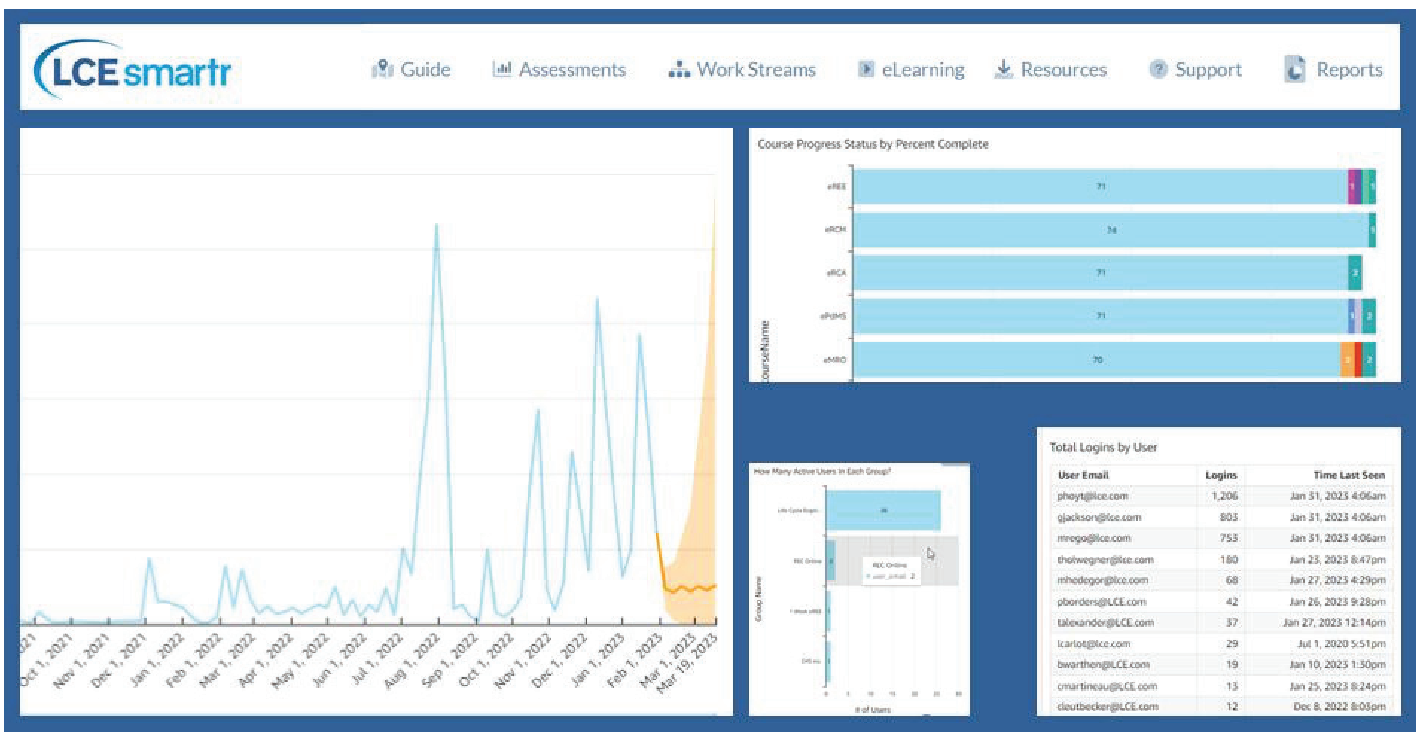


Figure 12 – LCEsmartr Dashboard Examples

The measures and results point to continuous improvement opportunities, supported by strategies that include:

- **Audits/reviews**
- **FMEA reviews**
- **Loss elimination**
- **Root cause analysis**
- **Regulatory reviews**
- **Preventive maintenance optimization**

5 Phase 5: Monitor

In this phase, the next level of digital transformation is deployed. This is where information from the asset performance management (APM) systems are integrated into other site business systems such as the MES and ERP systems. This integration provides a complete end-to-end view of operations and sets the organization up for further improvement and optimization of the entire value stream. The connection between these systems is critical for seamless operational decisions that utilize asset health information.

LCE offers a wide range of service models to help our clients deploy these systems and monitor the information they generate. The service models are:

	BRONZE	SILVER	GOLD
	Phone an Expert	**Contract RE Support**	**RE Program Management**
LCE Support Hours	Up to 16 hours per month of remote support and monitoring.	Up to 32 hours per month of support and monitoring.	Support hours based on actual scope of work.
Service	Provide coaching of your staff on asset management best practices, work with internal resource to develop first eWI using AR. Self-monitoring and high-level review of asset health.	Provide coaching of your staff plus active RE work, provide remote support and monitoring of assets with predictive analysis. Provide monthly reports.	Design, implementation, and execution of RE program, provide remote support or onsite support if deemed necessary, and monitoring of assets with predictive analytics. Provide monthly reports.
IP Provided	Use of LCE RE best practice tools and templates.	Use of LCE RE best practice processes, tools, and templates. Customer access to trends and reports.	LCEsmartr Playbook, including eLearning. Cusomer access to trends and reports.

Implementing a Risk-based Asset Management Approach

Developing and implementing an RBAM® process will ensure the assets the organization needs to meet stakeholder requirements are designed, installed, operated, and maintained in the optimal manner to fulfill stakeholder expectations at the best total cost of ownership across asset life cycles.

Implementation of an RBAM® process begins with documenting stakeholder requirements. From this information we can establish the organization's risk tolerance. That information is then used to analyze the respective assets and develop the appropriate operating, maintenance, and capital plans. Of course the best plans in the world are worthless if the organization lacks the time, resources (people and money), or organizational discipline to effectively and efficiently implement them. Therefore, the required asset management capabilities will also need to be deployed as part of a smart culture that connects and coordinates people with technology, processes, and best practices. And finally, key performance indicators need to be in place along with associated processes for collecting, analyzing, and responding to them, to verify plans are producing the required performance.

For more information about how LCE has helped organizations apply these principles and deliver the most value from their assets at the lowest cost, please contact us at info@LCE.com or visit www.LCE.com.