Chapter 7: Asset Management for Plant Wellness

Enterprise asset management (EAM) is the system of organization, processes, practices, knowledge, and information management used to optimize the value gained from your physical assets. It is also known as life-cycle asset management, engineering asset management, or physical asset management. Enterprise asset management, initially called *terotechnology*, began in Europe during the 1980s. Terotechnology is defined in British Standard 3811 as "a combination of management, financial, engineering, and other practices applied to physical assets in pursuit of economic life-cycle costs." Today, the word *costs* would be replaced by *profits*. The standard continues, "Its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation, commissioning, maintenance, modification and renewal, and with feedback of information on design, performance and costs." Terotechnology adopted practices based primarily on maximizing the life-cycle profits from all life-cycle functions through equipment failure data collection, failure data analysis, profit optimization, and feedback to original equipment manufacturers to improve machinery designs.

By the 1990s, the global interest in achieving high reliability of operational assets had prompted a change in terminology, from *terotechnology* to the more acceptable term *enterprise asset management*. The clear implication of the term is that the entire company is involved in its achievement. To fulfill an organization's strategic plan, its human assets, knowledge assets, intangible assets, financial assets, and physical assets must be integrated holistically across time. From this realization, important interactions and relationships emerge throughout the asset life cycle that must always be borne in mind. The groups that affect physical asset management success are those that design the asset, make the asset, select the asset, install the asset, operate the asset, and ensure the asset's ongoing availability. Fostering good decision making in each of these groups to optimize the success of the business is what you want to achieve from a life-cycle enterprise asset management system. The combined achievement of world-class plant reliability and optimal operational performance is known as Operational Excellence.

In January 2014, the international physical asset management standard ISO 55001, Asset Management—Management Systems—Requirements, was released. It indicates what an enterprise asset management system ought to contain but not how to deliver outstanding equipment reliability and operational performance. The drive for a universal asset management standard arose because the international quality standard, ISO 9001, Quality Management System—Requirements, did not specifically focus on the performance of physical assets. Standards such as ISO 55001 require setting corporate policies and asset management plans specifying what to do, but they cannot themselves cause asset management, maintenance, and operational excellence. ISO 55001 does have any means to create higher equipment reliability. It is only by making the right reliability choices and using the right reliability practices in all your business processes that you can get lasting operational success. Achieving world-class reliability and maintenance excellence requires failure-free parts, zero breakdowns, least maintenance costs, and utmost operating profit. That needs a life-cycle system for causing reliability; an enterprise asset management system alone will make little difference in the quest for Operational Excellence.

An effective asset management system as part of a life-cycle system-of-reliability will endlessly produce optimal life-cycle profits from your plant and equipment. The main benefits of useful enterprise asset management, in no specific order, include the following:

- Utmost return on investment and profit growth through effective stewardship of assets

- The ability to demonstrate best value for money within a constrained funding regime
- Greater customer satisfaction from improved product and service quality and reliability
- On-time order delivery to the required specification and performance standards
- Evidence demonstrating legal, regulatory, and statutory compliance with controlled and systematic processes
- Improved risk management and corporate governance that provide a clear audit trail for decisions taken and the control of their associated risks
- Enhanced corporate status through superior shareholder value, improved marketability of product or service, greater staff satisfaction, and more efficient and effective procurement from the supply chain
- Proving that you are meeting community obligations, complying with corporate governance requirements, providing workplace health and safety, and achieving environmental sustainability with your physical asset selections and use

No matter what you call it—terotechnology, Operational Excellence, enterprise asset management, or the Plant Wellness Way—it requires a significant change in attitude and thinking at all levels in the organization.[1] It will take the following:

- A change in philosophy from detecting and fixing problems to not letting problems start
- Cooperative teamwork between finance, operations, engineering, and maintenance
- The realization that "good" is not good enough—only excellence is suitable
- Everyone in the organization proactively reduces risks of future failures in what they do
- The whole supply chain delivers a level of quality at which defects are impossible
- All processes in the life cycle eliminate the causes of the causes of component failure

Attaining those goals requires developing and embedding the right design, project management, procurement, operational and maintenance life-cycle strategies and actions into your company, then sustaining them as standard practices that are continually improved and made more efficient.

Successful Asset Management by Design

A successful enterprise asset management system will deliver world-class physical asset performance and reliability. It has integrated business processes that maximize lifetime operating profits from your production assets. A truly effective physical asset management system delivers optimal plant operation, ensures failure-free equipment, and maximizes productivity by

- Doing proactive operational risk elimination during project design
- Producing outstanding equipment reliability and zero breakdowns
- Optimizing life-cycle profits and minimizing life-cycle costs
- Using defect elimination throughout the life cycle to make equipment failure-free
- Continually eradicating supply chain, safety, operational and equipment risk
- Applying new, better individual asset and business-wide solutions to lift reliability
- Making it normal for everyone in the operation to deliver best practice performance

The most powerful asset management results are achieved when you have a holistic, life-cycle mind-set. Figure 7.1 indicates the phases in the life of a physical asset. The life cycle extends from the birth of the business concept to the end of the asset's useful life. Because of the time-dependent and interactive nature of the life cycle, everyone in your organization eventually has a part to play in getting the maximum sustainable availability and utilization of your physical assets.

Although human factors such as leadership, motivation, and culture are intangible assets, they are critical to the successful achievement of physical asset management and require due consideration. They influence how an organization treats its staff, employees, contractors, and suppliers during the asset management life-cycle phases. The purposes and duties of the operations, engineering, finance, and maintenance teams must not be taken in isolation. It is essential that the distributed knowledge they have is shared through interaction to find the best ways to get optimal operating performance. This optimization is only realized when operations, engineering, finance, and maintenance work in partnership across the life cycle with a common responsibility to achieve the organization's asset management goals successfully and quickly.

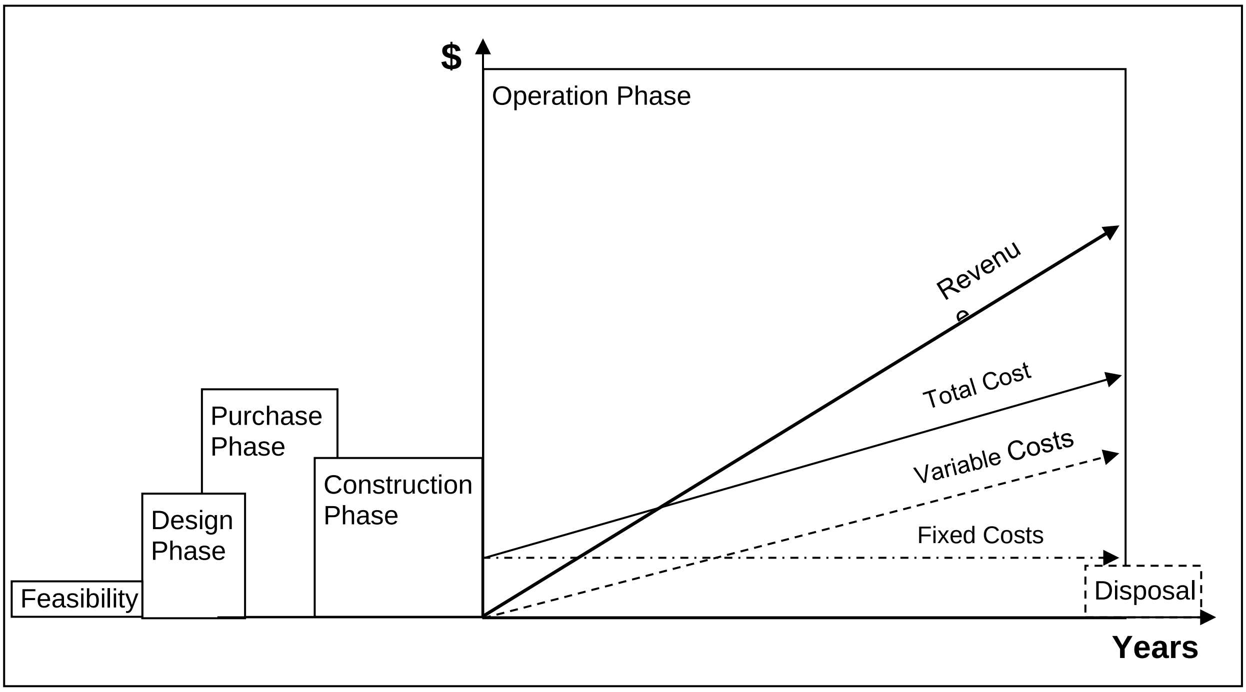

Figure 7.1—Phases of the Asset Life Cycle

The profitability of an operation is determined before a shovel of dirt has been turned. Figure 7.2 shows the typical phases of an industrial operation's lifetime and the points during its life when future operating costs are committed.[2] Some 95% of all operating costs are fixed during the feasibility and capital project phases. The decisions and selections made during the project conception and design phase set the scope and extent of your future operating success. Operational Excellence and return on investment stem from project decisions—the future operating profits come from the process and plant design choices that you make. Poor design choices plague the maintenance, production, safety, and financial success of an operation for all of its life. Low operating costs are a business feasibility and project design engineering outcome, not an operational result. Once you make your financial and engineering choices during the feasibility and detailed design stage, you are stuck with them for the future of the operation. Those first choices are self-fulfilling. If the concept and design are flawed and failure-prone from the start, nothing can fix them when your operation is up and running. Make poor choices early in your operation's life cycle, and you will always have poor operating profits. If you want world-class production success, you have to design it into your business as part of your project financing and engineering choices.

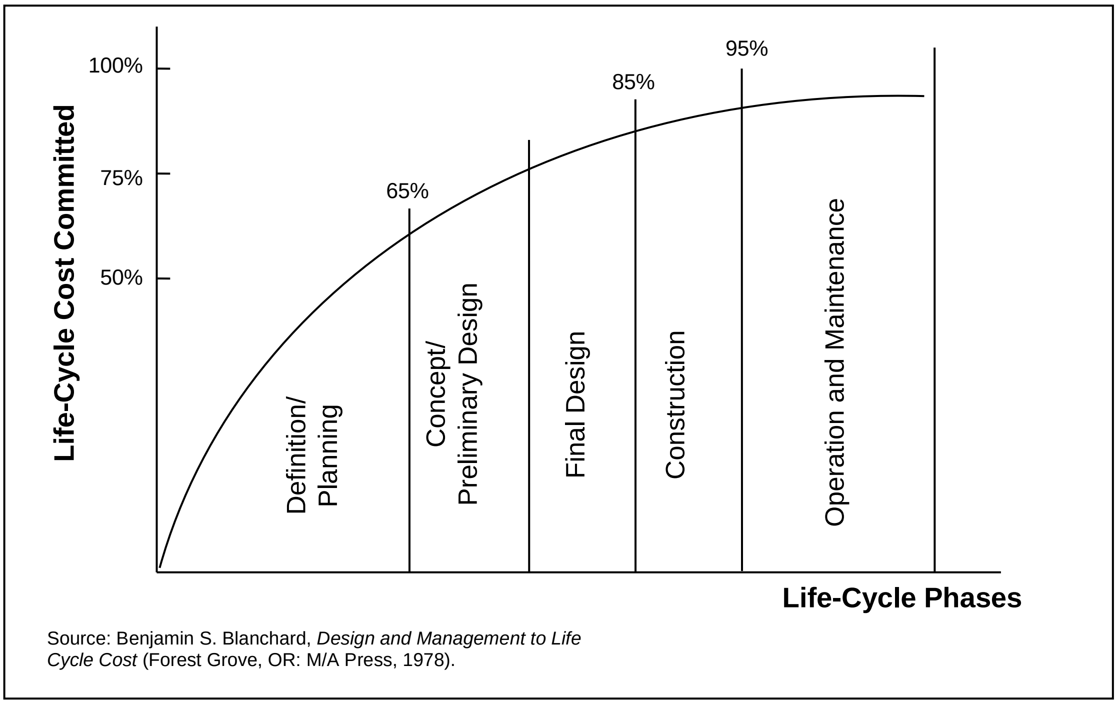

Figure 7.2—Operating Cost Commitments across the Life Cycle

Analyze Operational Consequences during Project Design

The design and selection phase are the most critical period in the long-term success of an industrial business. The choice of technologies, the choice of production processes, the choice of layout, and the choice of equipment to make the product mix all fix the facility's cost structure. This is the period when a facility's future profits and options to adapt to changing market forces are set. When you buy an operating asset, you also get its inherent behaviors, performance, and costs of operation. If the equipment chosen requires major upkeep or cannot sustain quality production for long runs, then you get high-cost product and much waste. Operating profit will always be less because part of the profit margin must pay for the extra upkeep of the facility and equipment. There will be less cash available for business and plant improvements to make products more competitively. In time, the products will become uncompetitive and will be replaced as your rivals deliver cheaper, better-quality choices to the market.

Design and Operations Cost Totally Optimized Risk (DOCTOR)

Project groups have the power to build great businesses or just "also-ran" businesses. When project teams design a plant, select its equipment, and build and install it, they are creating the future of a business. You have one chance to get it right—after that, you must live with what you are given. Project groups need a financial tool to visualize the impact of their decisions on the future success of the business they are creating. In the Plant Wellness Way, the tool that is used to successfully improve operating profits by design is called DOCTOR—an acronym for Design and Operations Cost Totally Optimized Risk. Figure 7.3 represents the life-cycle perspective of DOCTOR. It uses

TDAF costing to optimize the plant design and selection of equipment based on eliminating future operating costs and failures so that you maximize operating profits as a project design outcome.

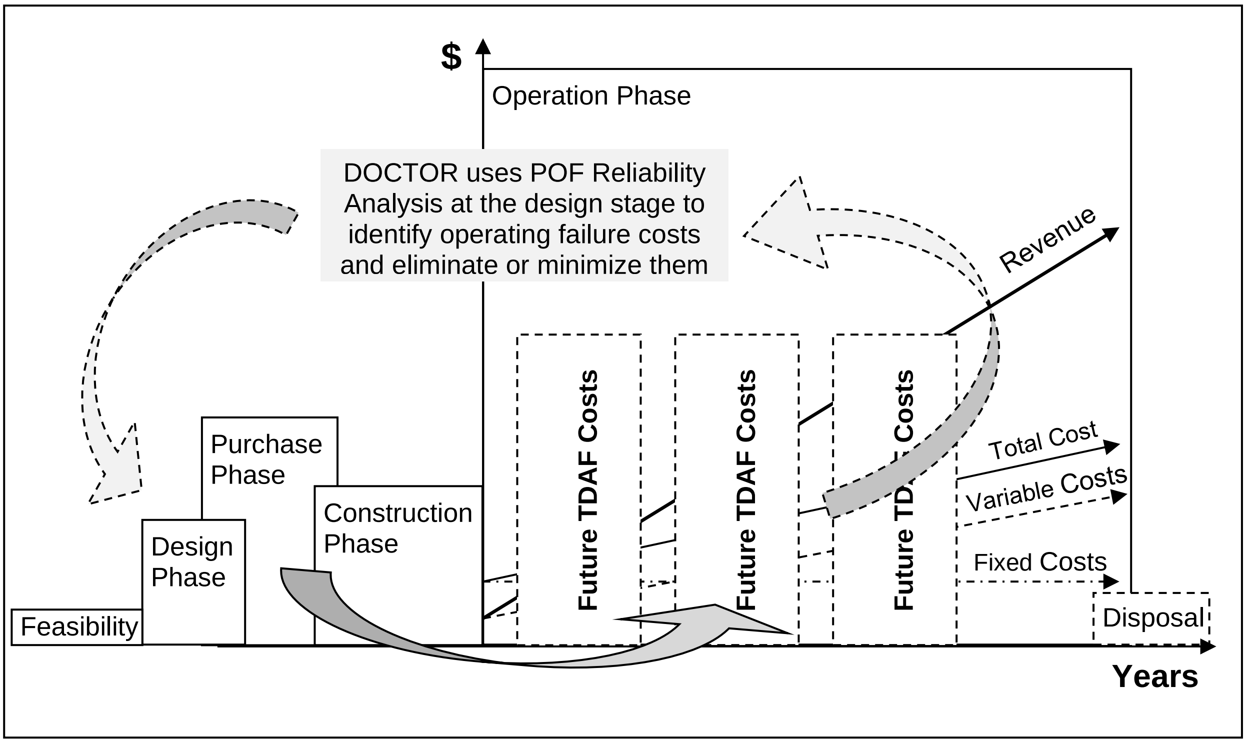

Figure 7.3—DOCTOR Uses Future Operating Costs to Prevent Operating Risks at Design

DOCTOR applies Physics of Failure Reliability Strategy Analysis of an operating asset's design to determine the cost and likelihood of a failure incident during operation. It takes the TDAF costs incurred from future failures and brings them into the design and equipment selection phase so that a designer can make the most profitable business decisions and build them into the operation's future success. Figure 7.4 shows how to use DOCTOR during the project feasibility and detailed design phases.

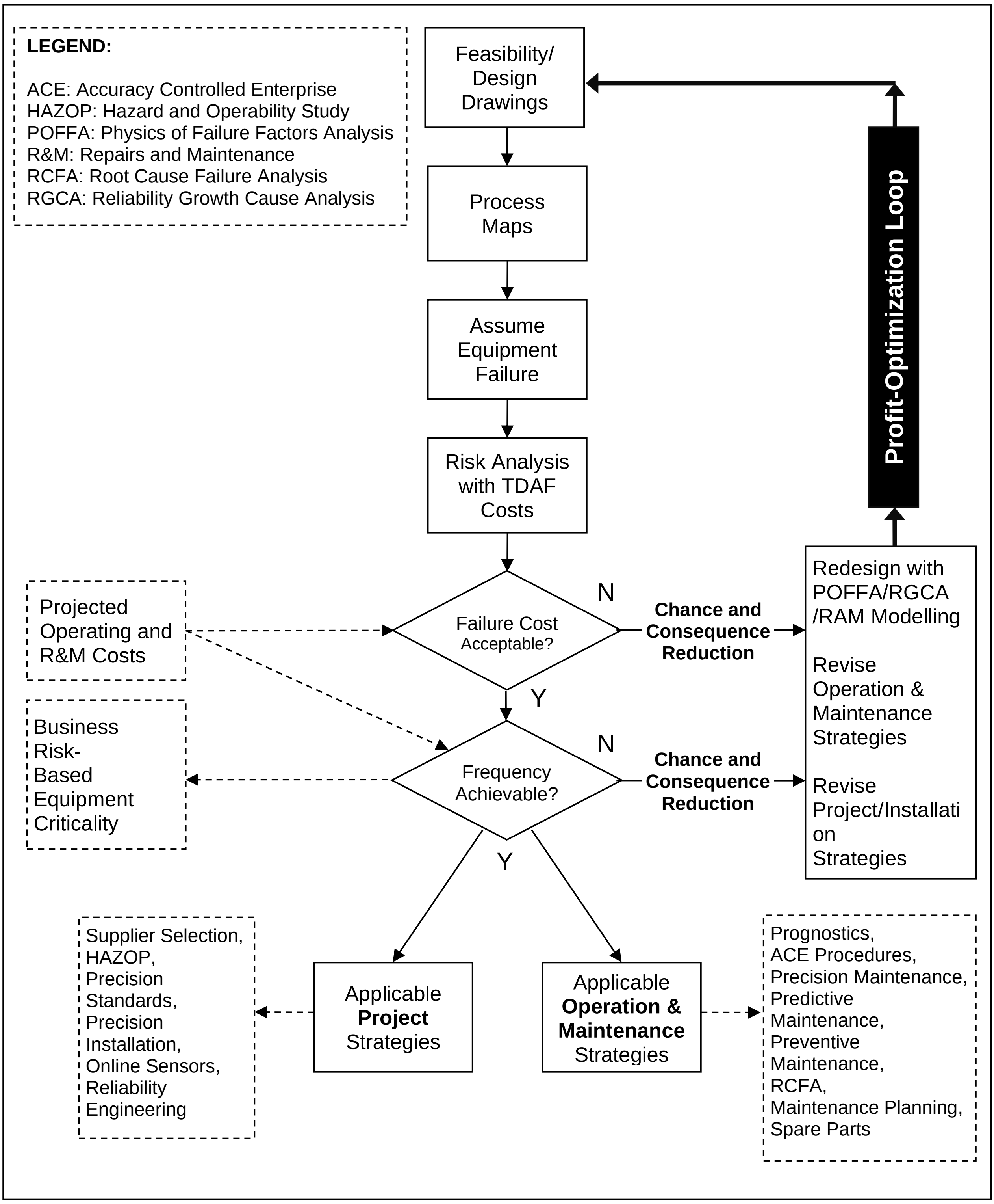

Figure 7.4—Optimized-Profit Operating Risk Management Design Methodology

DOCTOR rates and eliminates operating risk while projects are still on the drawing board. If failures during operation have severe consequences, the possible causes are investigated and removed. When problems cannot be eliminated, effective operating and maintenance strategies are chosen to reduce the likelihood of their occurrence and limit their consequences. Pricing is done using TDAF costing, and the life cycle is modeled with net present value (NPV) methods by the project group. By assuming a failure and building a TDAF cost model, those designs and equipment selections with high failure costs are identified. Investigating the cost of an "imagined" equipment failure lets the project designer see whether decisions will harm the business or make it more profitable. The design and equipment choice are then revised to deliver lower operating risk and costs. By modeling the operating and maintenance consequences of capital equipment selection during the project phase, the plant engineering, operations, and maintenance strategies that produce the optimal life-cycle operating profit are part of the business from the start.

Optimizing Project and Operating Costs

Applying DOCTOR allows recognition of the operating cost impact of project choices and the risk they cause to a project's return on investment. The costs of future operating failures are used to rate the robustness of the design decisions. Basing capital expenditure justification on actual operating scenarios makes the estimate of future operating and maintenance costs from project decisions realistic. By getting the project group to look at the impacts of their choices on future operating profit during the capital design and equipment selection phase, future profitability can be optimized. Using TDAF costing in design decisions simulates the financial and operational consequences of equipment use so that plant design, operation, and maintenance can be fine-tuned with choices that get the best plant reliability and operating profit results.

A DOCTOR analysis starts by taking each item of equipment in a project and assuming it will fail; this makes the business-wide impacts of a failure clear. TDAF costing of a failure incident is done by the project group. The expenditure and operating assumptions for modeling are those costs and practices used to run the plant and equipment. It is likely that operating costs are available from the plant owner's financial and maintenance groups. The NPV financial models are developed with the help of the plant owner's operations group to reflect the company's management culture. The designed-in operating costs modeled are put through review and compared against other choices. Consideration of parts stock holding is also developed, and plant maintainability is improved to allow fast maintenance response for low cost. This optimization process is reiterated until future operating costs are minimized.

The DOCTOR process can be applied to every item of plant and equipment, even down to component parts. If the failure costs are unacceptable, then one of three things must happen:

- A design change is made to eliminate or reduce the chance of failure
- Risk reduction requirements to reduce opportunity to fail are included in the design
- Supply chain, engineering, operating, and maintenance practices are changed to control operating risk and cost consequences

Each new decision regarding a design or operating practice is run through the DOCTOR process to compare operating costs with previous results. If a new choice reduces risk, the expectation is that it will lower the operating cost. This iterative process is used to achieve a balance between the lowest life-cycle operating cost and the expense of initial capital cost. Once the operating TDAF costs for equipment are known, a risk analysis can be conducted using a table like Table 7.1 to identify strategies that produce the least operating risks. Use of alternative table layouts for more detailed event risk analysis and costing are at your discretion. An example of a more detailed risk analysis is available in the “Operating Criticality” worksheet in the spreadsheet accompanying this book.

Equipment ID No.	Equipment Description	Assembly	Subassembly	Parts	Possible Causes of Failure	TDAF Costs of Failure	Risk-Control Plans	Actions to Be Taken	Proof That Actions Have Been Completed

Table 7.1—Risks Identification and Control Table for a DOCTOR Analysis

If least capital expenditure is important (as opposed to least operating cost), TDAF cost modeling can optimize for lowest operating costs using least capital expenditure. Alternatively, if some other parameter is important—for example, least environmental costs or least maintenance costs—the TDAF cost model lets you optimize for the least capital cost. TDAF costing combined with DOCTOR is a powerful way to make good business investment decisions. It lets you foresee future operating scenarios during design. It allows the project group to make sound, practical choices using optimal long-term financial judgments about capital equipment selection, plant design, and operations and maintenance practices. DOCTOR reduces the chance of poor capital equipment acquisition and destructive long-term financial decisions from not knowing their operating consequences.

Enterprise Asset Management the Plant Wellness Way

Enterprise asset management is defined as the “coordinated activity of an organization to realize value from assets.”[3] It is a corporate-wide solution used to attain the physical asset performance needed to meet business aims. Figure 7.5 is a simplified overview of an enterprise asset management process to deliver an organization’s objectives.

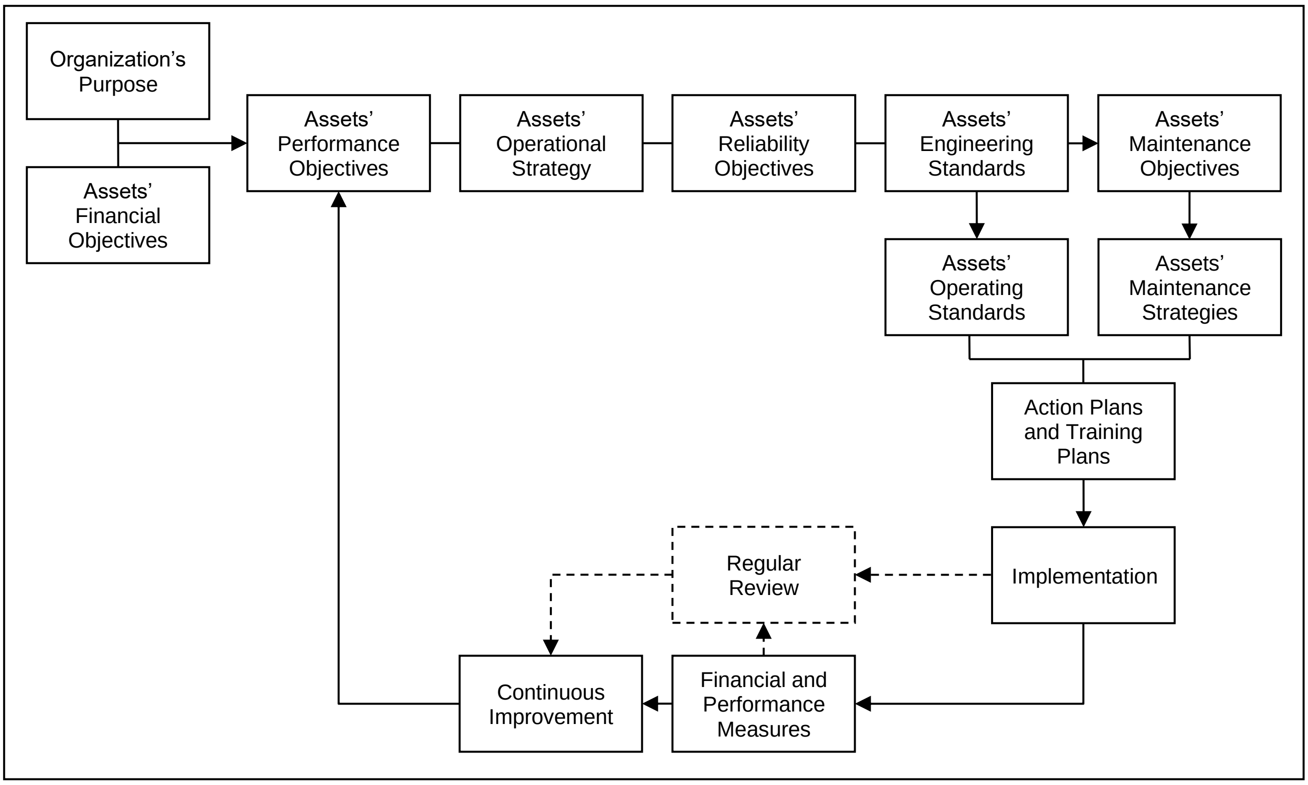

Figure 7.5—Simplified Enterprise Asset Management Model

The appeal of enterprise asset management is its "promise" of maximum life-cycle profit, along with its converse, minimum life cycle cost. To achieve that promise, it is necessary to institute the required practices and systems of physical asset management stewardship throughout the organization and across its lifetime. This is no easy matter in most organizations, especially those that are reactive and those that have failed to stay modern. Enterprise asset management proposes that businesses follow a path to desired equipment performance by using the foundation elements of systems engineering, reliability engineering, maintenance management, operational management, risk management, and industrial engineering, guided by sound financial management. Numerous internationally recognized industrial and military standards form the documented database of the practices applied by organizations seeking to be world-class engineering asset managers. Practically, the intentions of physical asset management have proven very difficult to attain. The evidence shows that extremely few industrial businesses around the world reach the world-class performance level that enterprise asset management is meant to deliver. There are important factors not yet recognized by current asset management models and methods that every business needs to deal with. This book addresses the “missing links” needed for sure enterprise asset management success by providing the Plant Wellness Way methodology to build a business-wide system of reliability.

The right life-cycle asset management mix requires time for organizations to introduce them in a staged fashion. In large organizations that have successfully introduced asset management, it has taken up to six years to build the necessary culture and skills.[4, 5] For smaller operations, the time is less. In all cases, committed, stable leadership and cultural change management are required to maximize the rate at which enterprise asset management benefits accrue to an organization. The changes necessitated by enterprise asset management usually require developing new knowledge and skills in the people of the executive, finance, engineering, operations, and maintenance groups. A representation of the organizational practices and business processes used in organizations changing from enterprise asset management to the Plant Wellness Way is shown in Figures 7.6 and 7.7. The Plant Wellness Way methodology is designed to more than halve the time it takes organizations to reach world class operating performance.

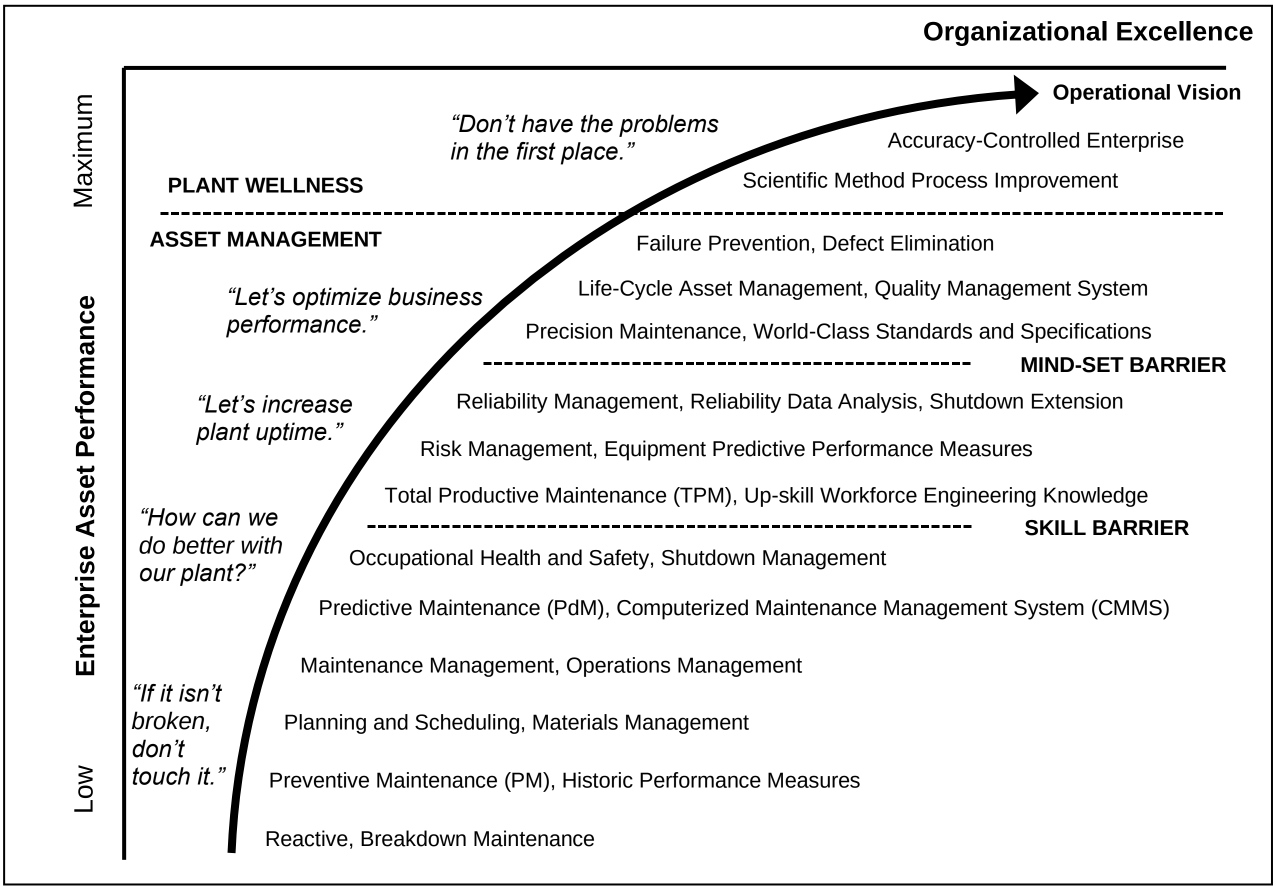

Figure 7.6—Enterprise Asset Management with the Plant Wellness Way

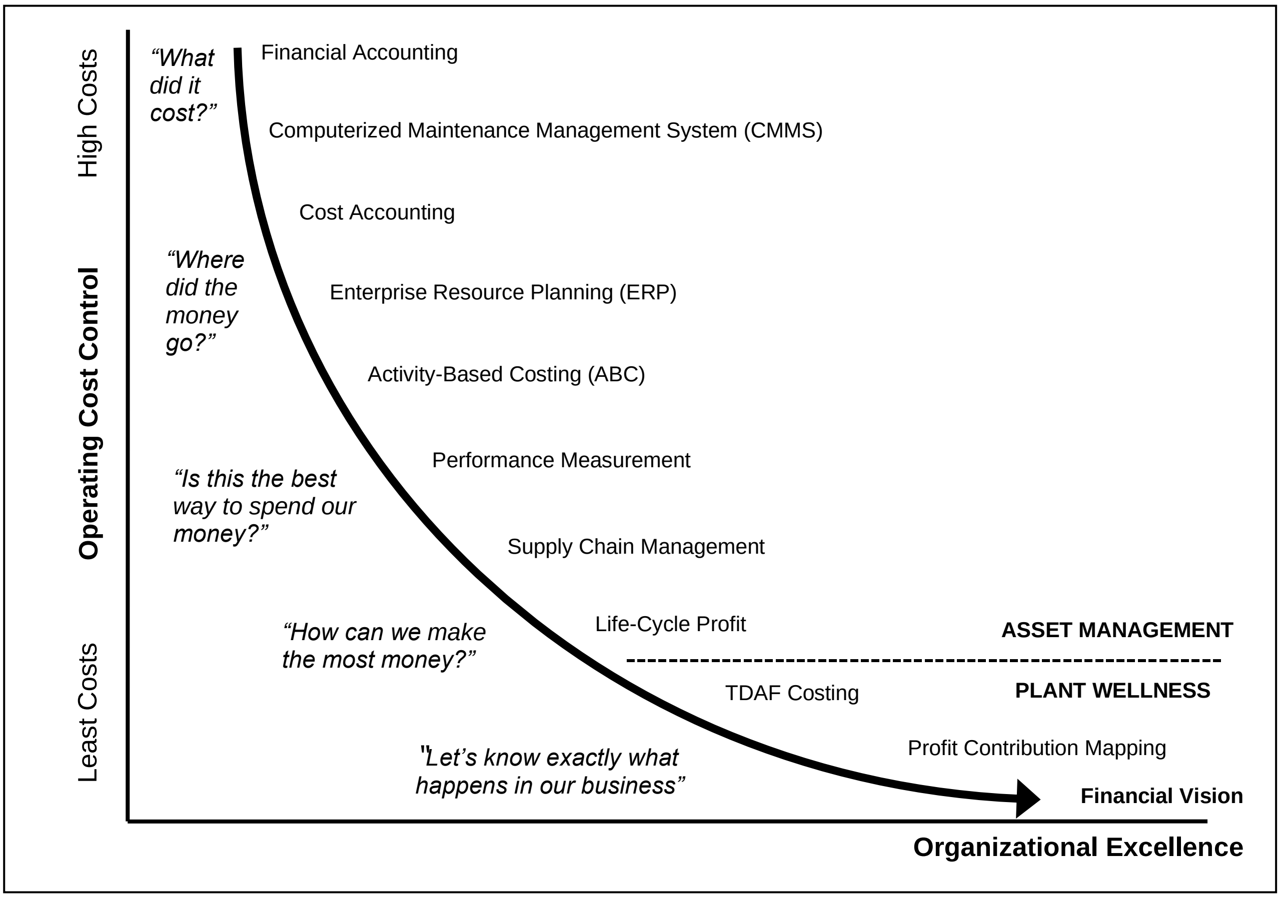

Figure 7.7—Enterprise Asset Management with Plant Wellness Way Cost Control

Introducing Enterprise Asset Management and Plant Wellness into Organizations

Enterprise asset management the Plant Wellness Way collects the key methods required for plant and equipment integrity and performance excellence into an optimizing life-cycle profit philosophy. The Plant Wellness Way provides enterprise asset management with the risk-elimination and reliability improvement techniques and tools for the selection, use, and care of plant and equipment to achieve production and business goals year after year. The Plant Wellness Way gets physical assets performing at optimal operating profit by doing the following:

1. Controlling the inherent variability in business, engineering, maintenance, and operating processes within the limits that produce excellence
2. Reducing risk by eliminating the chance of adverse incidents and minimizing the consequences of any remaining risk
3. Preventing equipment failure by setting and adhering to high-quality standards for parts health throughout their life, starting from capital equipment acquisition
4. Creating a supply chain that delivers correct, reliable inputs for use in the organization
5. Ensuring the accuracy and precision of human intervention and work activities
6. Maximizing total life-cycle profits with proactive, fact-based financial modeling to justify eliminating failure, waste, and loss
7. Bringing management, staff, and the workforce together to work cooperatively as a team of experts building a business that will secure their communal future

The Plant Wellness Way adds to enterprise asset management the specific methods to sustain equipment working parts in perfect health for a lifetime of reliability. It maximizes an organization's chance of reaching Operational Excellence. When you put a critical equipment part at risk of a bad outcome, you put the equipment at risk of failure. When your equipment is at risk, so is your operation and its future. All bad operating risks become production losses or harmful incidents when luck runs out.[6] Organizations that do not give priority to creating parts health and wellness in their equipment can never be world class—they will have too many failures and losses. Operational success needs healthy parts that do not fail, because when a part breaks, a machine dies, and then your business will instantly lose fortunes.

The introduction of change into organizations and the success of a change program require determined senior management commitment and leadership. The launch of a corporate-wide initiative as large as the Plant Wellness Way requires a solid appreciation by senior management of the principles and practices that must be applied if the business is to reap the maximum benefits most quickly. With a detailed understanding of the Plant Wellness Way, senior managers comprehend its effects on the organization and the benefits that result. To prevent the Plant Wellness Way from becoming a "business fad" that is quickly dropped if improvements are not swiftly generated, companies introduce it through a pilot program. A representative portion of the business proves that the concepts and practices deliver improved operating performance and profits. Once the pilot program is successful, it is rolled it out progressively to the rest of the operation.

Asset Management and Plant Wellness Policy

An asset management and plant wellness policy is used to make sure that the right business decisions are made to support the well-being and long-term health of your plant and equipment. The policy drives the engineering, project, production, maintenance, and finance groups to improve equipment health and wellness. A successful business needs plant and equipment that makes on-time, least-cost, quality product that its customers will buy willingly. Because an industrial operation's future depends on equipment working accurately and reliably, the finance, engineering, operations, and maintenance groups need to protect and improve the wellness of their machines' parts, so their business has a highly reliable and trouble-free operating plant.

It is important to ensure that an asset wellness policy meets all the requirements that make it a useful and valuable document for guiding plans and practices. Within it are the organization's purpose and core goals, along with how its physical asset management efforts help goal achievement. A policy needs to be inspirational to the people it applies to. A limp policy does nothing for its readers or the company. The final published policy may need to be injected with energy by a writer who can bring it to life. Table 7.2 lists the quality, risk, and asset management policy requirements of some internationally recognized standards. The comparison is intended to help you build into your asset management and wellness policy those things that are considered important to note in such documents. The checklist will help you get useful content into the policy so that it focuses on business benefits. This does not mean that an asset management policy must comply with every requirement in the table. The most important factors are the amount of "life" the policy breathes into the people and the business, along with its ability to produce good decisions for equipment parts' health and promote proactive actions that reduce life-cycle operational risk.

An example of an asset management policy for plant and equipment wellness is as follows:

We recognize that our plant and equipment are the foundation on which the livelihoods, plans, and dreams of us all depend (shareholders, staff, employees, suppliers, customers, and community). Without sure and certain competitively priced, quality products from our operation, we put our collective and individual futures at grave risk.

Because our business and individual success depends on the reliable and faithful production of 100% quality products that satisfy our customers' requirements, we will adopt and use those proactive asset management, engineering, project, operational, maintenance, and financial practices, methods, and business systems that minimize operating risks and prevent failure of our plant and equipment during its operating lifetime.

Starting from the conception of a business idea through to the decommissioning of a plant, we will work together in cross-functional teams to seek ways that maximize the safety, productivity, and value added in every part of our operation while assisting our supply and distribution chains in doing the same. Included is the need to constantly minimize and eventually eliminate our business losses, waste, accidents, and incidents so that we do no harm to our planet, our people, and our community.

All our people continually seek and learn better ways that improve their productivity and minimize the risks in every task. We encourage their learning with both formal methods and by controlled experimentation. Through the ongoing drive of our people to seek excellence and mastery, we will become and remain a best-in-class asset management performer.

Maintenance Vision, Policy, and Strategy

With the importance of maintenance to production success firmly placed in a business context through the asset management and wellness policy, it is necessary to decide how to use maintenance to maximize operational productivity. This is the role of the maintenance policy. It contains what to achieve with maintenance, why it is necessary for the business, and how it will be done. It explains the maintenance vision and strategy to ensure the necessary production performance from your plant and equipment.

Table 7.3 is a maintenance capability hierarchy to help identify the maintenance vision and policy. Plot where your operation is in each column and then decide where you want to go over the next three to five years. Plotting on the table helps you develop a maintenance vision to guide the drafting of the policy. With the policy decided, work can start on the strategies and actions that will achieve the vision.

A sample maintenance management policy for plant and equipment wellness is as follows:

Maintenance is fundamental to successful production. The reliability of our plant and equipment assets are dependent on our production and maintenance people doing the maintenance function effectively in a timely manner.

Our maintenance activities support the asset management and plant wellness strategies in producing products that our customers want, with well-planned and well-executed delivery of the most economic maintenance strategy and best reliability practices that eliminate component risk so that we get the plant performance needed for on-time delivery of quality product at optimal operating profit.

We seek the most successful equipment performance through the cooperative teamwork and knowledge of maintenance, operations, engineering, and finance in relentlessly preventing operating risk by proactively introducing defect prevention and failure removal and by conducting responsible and controlled business process improvements.

Policy Requirements	Quality Management System ISO 9001:2008	Physical Asset Management System ISO 55001:2014	Risk Management System ISO 31000:2009
Responsible for developing policy	Top management (board or chief executive officer)	Top management	Board or executive
Obligatory policy content inclusion	• Commitment to comply with the requirements of the Quality Management System • Commitment to continually improve the effectiveness of the Quality Management System	• Overall physical asset management objectives • Physical asset management is directed at achieving the organization's strategic plan • Commitment to continually improve the physical asset management process • Commitment to comply with current applicable legislation, regulatory, and statutory requirements and with other requirements subscribed to by the organization	
Recommended policy content inclusions			• Objectives of risk management • Commitment to risk management
Possible policy content inclusions			• Objectives and rationale for managing risk • Links between policy and strategic/corporate plans • Guidance on extent and type of acceptable risks taken and ways to balance threats and opportunities • Processes to be used to manage risk • Accountabilities for managing specific risks • Details of support and expertise available to assist those accountable for managing risk • Level of documentation required • Statement of how risk management performance will be measured • Commitment to periodic review of risk management system • Statement of commitment to the policy by directors and executives
Organizational context	• Appropriate to the purpose of the organization • Equal to and consistent with organization's overall policies and strategy • Provides the framework for setting and reviewing measurable quality objectives	• Appropriate to nature and scale of the organization's physical assets and operations • Derived from how the management of physical assets will help achieve the organization's strategic plan • Consistent with other organizational policies • Provides the framework for setting physical asset management strategy, objectives, targets, and plans • Consistent with the organization's risk management framework	• Create linkages to other corporate strategies
Showing commitment to policy	• Visibly endorsed by top management • Communicated across the organization • Understood by everyone within the organization • Reviewed for continuing suitability	• Visibly endorsed by top management • Documented in suitable media • Implemented as standard practice • Maintained in condition to meet purpose • Communicate individual physical asset management obligations ▪ To relevant employees ▪ To relevant third parties • Published to stakeholders where appropriate • Reviewed periodically for relevance to and consistency with the organization's strategic plan	• Publish policy • Communicate policy ▪ Establish management team to communicate and involve staff across the organization ▪ Raise awareness across the organization of the risk management process ▪ Risk management is in the organization's culture

Table 7.2—Asset Management Policy Content Comparison

	Leadership and Capability					Systems and Processes				
	Maintenance Vision & Strategy	**Performance Measures**	**Organization Structure**	**Human Resources**	**Knowledge Base**	**Maintenance Strategy**	**Materials Management**	**Planning & Scheduling**	**Contractor Management**	**Reliability Engineering**
Mastery	Quality system managed, accuracy-controlled enterprise in which everyone in every department works to 3T (Target-Tolerance-Test) error prevention procedures; effectiveness philosophies improve processes	Business strategy focus; maximizing life-cycle profit; TDAF cost database. Process step contribution monitoring across all processes	Integrated cross-functional teams incorporating financial, engineering, operations, and maintenance	Empowered, flexible, cross-functional teams of experts working to scientific discipline	Continually learning, pushing the boundaries of human knowledge, and understanding; Six Sigma discipline is normal	Precision domain drives all engineering, installation, operations, and maintenance work; risk analysis and management normal	Materials problems designed-out, OEM monitors real-time information on critical parts' condition and carries necessary spares	Maintenance reduced as continual improvements extend time between outages; continually reducing time to repair with lean philosophies	Small teams of experts servicing entire local industry delivering precision maintenance and design-out maintenance with profit sharing	Design and Operations Cost Total Optimized Risk (DOCTOR) is used to minimize all operating risks throughout the facility's life; reliability growth pervades thinking
Excellence	Personnel action plans; appraisals are clearly tied to the maintenance strategy	Ongoing benchmarking of metrics and processes; full cost database	Total productive maintenance in which operators drive reliability, fault-find, and maintain equipment; root cause failure analysis by operators and maintainers	Empowered, flexible, world-class workers; self-managed teams	Expert systems used; fully integrated CMMS common database	Preventive and predictive plans continuously optimized; the "right" maintenance tactic is applied based on analysis	Stores system integrated to CMMS and accounting system; bar coding or radio frequency tags of all stores items; World-class Stores Management	More than 90% of all maintenance is planned and more than 95% first-time schedule compliance; rolling schedule fixed for the week ahead	Small numbers of contractors on long-term sharing partnership agreements with high innovativeness	Risk and unplanned failure reduced to best in industry by analysis and modelling
Competence	Reliability-focused maintenance improvement action plan is linked to the maintenance management strategy	Statistical process control applied to maintenance process measures; equipment-specific maintenance costs available	Established teams for achieving key objectives in the maintenance management strategy	Multiskilled trades with process capability analysis and basic operating skills	Easy access to knowledge bases for all employees at all times	Preventive and predictive plans exist for all maintainable items; emphasis on PdM; all tactics understood	Single-source supplier partnerships established and effective; area stores with visual controls; reliability of spares maintained; suppliers provide technical expertise	Long-term asset planning established; critical path analysis used for all rebuilds and shutdowns	Contractors are established based on principle of risk sharing; contractors provide technical expertise	Effective root cause analysis applied to equipment problems to extend life
Understanding	A clear maintenance vision and strategy is documented and communicated to all employees	Input/output process measures reviewed and displayed; downtime by cause; segregated maintenance costs reviewed	Decentralized with central support; clearly written mandates/roles for each maintenance function and group	Trades have problem identification and solving; team dynamics and training skills	Document control system established; CMMS installed and used to manage knowledge bases	Preventive and predictive plans exist for key equipment; compliance with scheduled plan is more than 95%	Spares classified with separate strategies; spares linked to bills of materials/equipment drawings; standardization polices exist; A-B-C spares priority management with vital "A" spares protected	All but unexpected failures planned; all planned jobs specify safety, labour, materials, tools, technical details	All contractors repairing rotables are capable of original equipment manufacturer's testing	Basic equipment conditions established; good failure databases; all major failures investigated; PM modified based on site experience
Awareness	No clearly documented role of maintenance; no maintenance vision or strategy	Some downtime records; maintenance costs regularly available but not segregated into area/line	Centralized maintenance group with alignment to production; team approach to technical problems	Trades have Operational Health & Safety and maintenance support (inspection, reporting) skills	Plant register established and useful data collected; central technical library; all drawings and equipment information identified	System to identify all maintainable items exists; emphasis on time-based overhauls and inspections	Stores catalogue established; Inventory accuracy is greater than 95%; goods receiving practices in place	Work request/work order system established; major rebuilds, shutdowns fully planned and programmed	Contractors used for peak loads and noncore maintenance work	Collect the failure data; equipment histories occasionally reviewed for failure analysis
Innocence	The main role is to fix it when it breaks/fails	Incomplete or no maintenance downtime records; maintenance costs not readily available	Centralized maintenance group with no alignment to production; command and control approach	Trades have their basic trade skills, but little or no technical knowledge or support and training is given	Ad hoc records kept for purchasing; no plant register or control of drawings	"If it isn't broke, don't fix it"; annual shutdown and inspections only	Ad hoc stores; no costing or control of spares	No planning function; planning done on the run; short-term focus	All maintenance carried out by in-house team, which may include individual contractors	No failure records

Table 7.3—The Climb to Reliability and Maintenance Mastery

FOOTNOTES

1. Ron Moore, *Making Common Sense Common Practice: Models for Manufacturing Excellence*, revised and updated ed. (Boston: Butterworth-Heinemann, 2002).

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