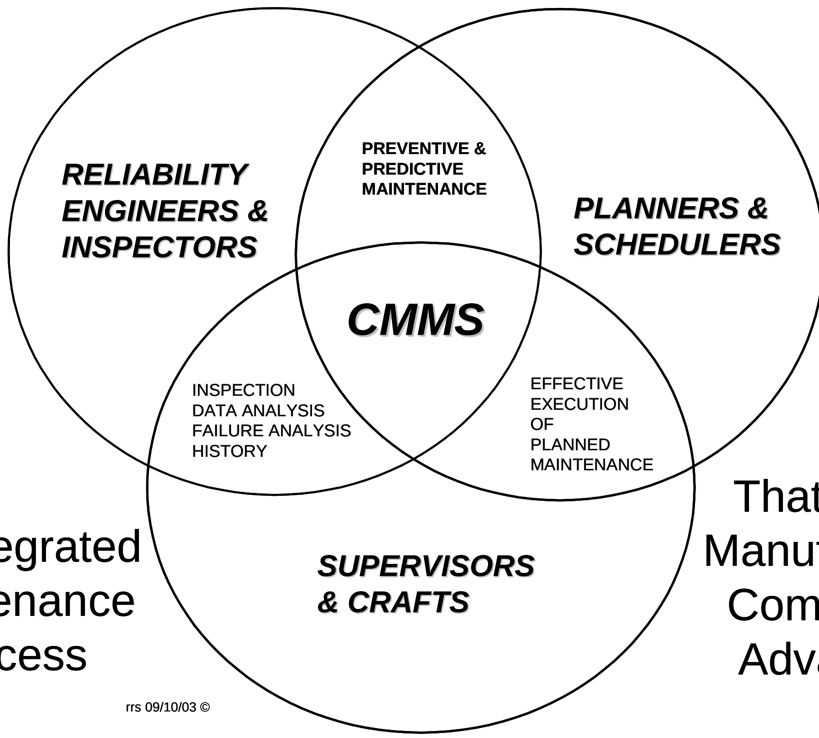
Modern Maintenance Management

For the 21st Century



An Integrated Maintenance Process

That Builds Manufacturing Competitive Advantage

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• INTRODUCTION

Maintenance has long been defined as a “process” by most experts in the maintenance field. These experts have further defined maintenance as delivering a product called capability, that is, the capacity to produce the product(s) the manufacturing facility delivers to the business. In today’s business environment, the manufacturing capability must be highly reliable and competitive on a global basis to remain a viable contributor to business success.

Traditionally maintenance has been viewed as a cost and a service to manufacturing, with any number of attempts being made to gain cost advantage from the maintaining function. These attempts have been considered as a “manufacturing” effort as well as an independent “maintenance” effort. However, most of these initiatives have met with only limited success.

As a result, maintenance today represents **the last frontier** to make a significant contribution to throughput, quality, yield and profit in modern manufacturing.

This discussion will explore the **Dynamic Maintenance Management System** as a continuous performance improvement process, based on a business management model. Additionally, maintenance will be introduced as a **business within a business** and examined from the perspective of delivering equipment uptime at a competitive cost to the manufacturing environment.

• OVERVIEW of DYNAMIC MAINTENANCE

Dynamic Maintenance Management System – In order for maintenance to successfully contribute to manufacturing efficiency, it must be worked as a business process within the manufacturing process -- a **business within the business**. Maintenance has its own set of business needs complete with products, measures and costs. It is also a closed-loop process which, when implemented and managed correctly, will deliver continuous improvement in manufacturing reliability and uptime as well as improvement in unit manufacturing cost through lower maintenance cost.

Figure 1 represents a simplified view of maintenance as a process. When implemented holistically it integrates a series of functions that in today’s organizations are often worked separately or included as part of the generic “manufacturing” process.

Planning and **Scheduling** is the most widely used “maintenance best practice” in the current manufacturing environment. It is intended to be the chief means of improving maintenance productivity. Yet it has failed to deliver sustainable results. It is most often implemented as merely a scheduling exercise without the appropriate emphasis on the thorough and detailed job-step planning required to deliver quality results.

Backlog management is the most important element in the maintenance process. It is the order book of the **Business of Maintenance**. Backlog management is the means by which a maintenance organization delivers capability with the appropriate focus and priority to effectively support the manufacturing process.

Maintenance Materials are often treated as a “procurement” initiative or a separate “stores” project to gain value from excess inventory or unused parts. **However, as can be seen in Figure 1, the materials function exists to provide parts and materials for planned, ready-to-schedule maintenance work.**

Work Execution is often measured by "schedule compliance" without respect to "productivity" or value of the work performed. In the **Business of Maintenance** the biggest component of maintenance cost is craft labor, sometimes as high as two to three dollars for every dollar spent on materials. Contract labor costs as well as internal labor costs need to be considered when addressing productivity as internal craft resources succumb to attrition and are replaced by contract maintenance or purchased services.

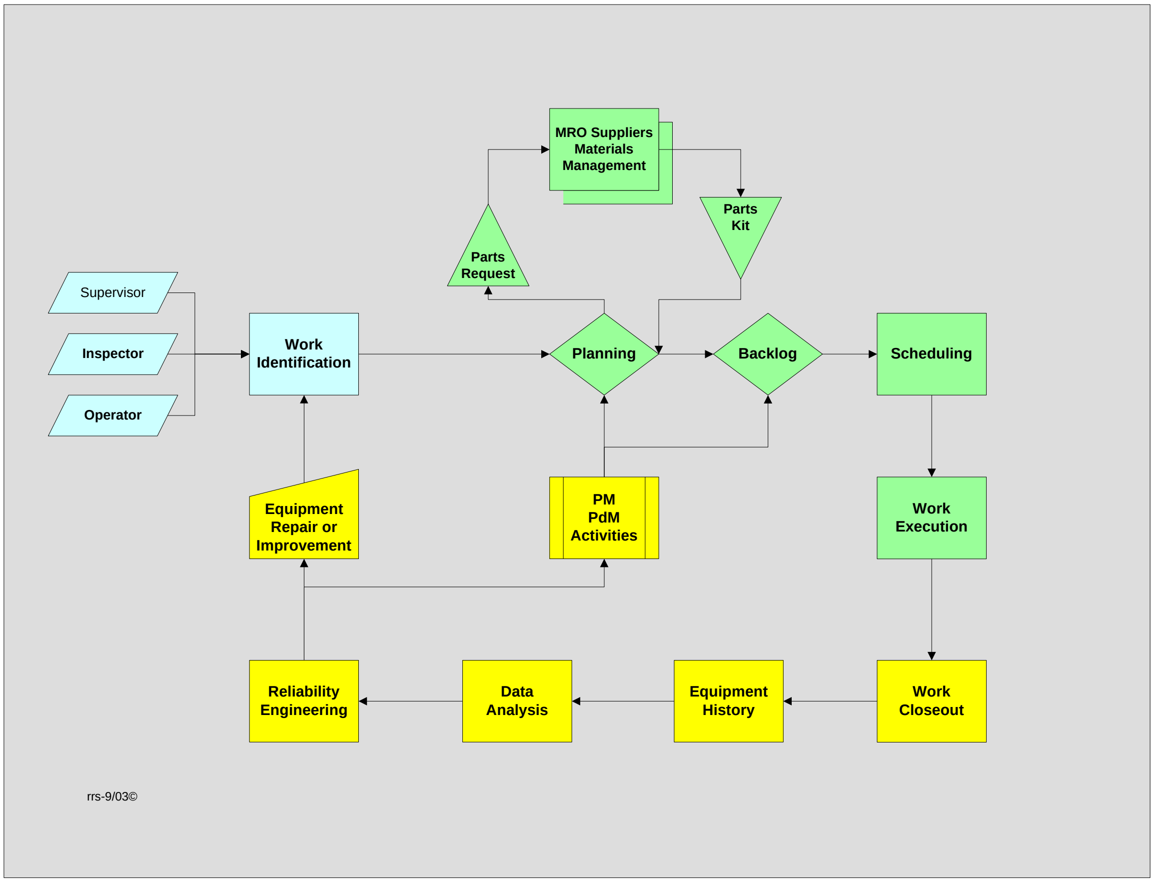

Figure 1: Dynamic Maintenance Management System

In the contemporary integrated manufacturing model, **work execution** is often the endpoint of the process. Production needs have been satisfied, the identified work is complete, and the focus is moved to the next production-defined equipment problem or issue.

However, in the **Dynamic Maintenance Management System**, work execution is just the beginning of the continuous improvement process. The **Computerized Maintenance Management System** (CMMS) is designed to support and stimulate continuous improvement in maintenance. Unfortunately, it is often highly underutilized for the purpose for which it was designed.

Equipment History and Data Analysis are the tools used to define the opportunities for maintenance improvement. Hours of crafts worked, repairs made and processes used, parts and materials consumed, all provide a history and database that form the basis for evaluation of the effectiveness of the maintaining function. Add to this the cost to maintain, equipment failure frequency and duration, and the business plan goals of manufacturing and we have now defined the appropriate and timely contributions that maintenance can make to the success of manufacturing.

Reliability Engineering is the vehicle by which maintenance defines its performance and expectations. The Reliability Engineer has many tools at his disposal to inspect, monitor, analyze, measure and improve the performance of maintenance. This process starts with **Equipment History and Data Analysis** and integrates its engineering tools into **Predictive** and **Preventive Maintenance** activities designed to deliver manufacturing process reliability, thereby reducing maintenance workload. This systematic analysis defines and indeed encourages corrective work meant to improve the life of the equipment as well as preventative or predictive maintenance activities to insure the health of the manufacturing process.

Preventative Maintenance Compliance becomes the tool with which the base work load of the maintenance organization is defined. Reliability Engineering owns this critical measure and monitors it on a weekly basis to insure that the PM activities that have been entered in the work order system are being completed in a timely fashion.

Closing the loop on the maintenance process enables the **Business of Maintenance** to provide a sustainable and reliable manufacturing capacity while delivering it at a competitive manufacturing unit cost. The business processes incorporated in the **Dynamic Maintenance Management System** include elements of measurement systems monitored by the Reliability Engineer. By monitoring the health of the equipment, complementing the robustness of the maintenance process, the Reliability Engineer can steer the maintenance process in the proper direction for delivery of its two important missions: **Maintenance Efficiency and Maintenance Effectiveness**.

• Dynamic Maintenance Management System

Effective implementation of the **Dynamic Maintenance Management System** principles can only be achieved within a framework of appropriate control and monitoring by management. There are two principal process outputs, (**Maintenance Efficiency and Maintenance Effectiveness**) which define the **Business of Maintenance** with all other measures being subsets of these two. Equipment uptime and maintenance cost are the result of the how effectively Maintenance Managers and Reliability Engineers manage these two principles.

• Maintenance Efficiency (Craft and Maintenance Productivity)

Maintenance Efficiency is defined by how productively the maintenance system utilizes available resources. Those resources include crafts, internal and contractor, and maintenance parts and materials. Much as manufacturing productivity is measured by delivering more units of production with fewer resources, **Maintenance Efficiency** can be looked at in a similar manner. In fact, measures of maintenance man-hours per unit produced or maintenance cost per unit produced serve to give the Maintenance Manager a lagging indicator of how successful he has delivered on the **Business of Maintenance**. Although leading indicators of **Maintenance Efficiency** are beyond the scope of this discussion, any number of measures exist to allow the Maintenance Manager to gauge progress toward delivering his contribution to manufacturing productivity. The important concepts revolve around what are the key influential variables impacting these resources and how these variables are implemented for maximum success. This discussion will focus on how these concepts are organized to work together and provide a synergy for efficient maintenance management.

Figure 2 defines the segment of the maintenance process that is designed to deliver **Maintenance Efficiency**. When integrated effectively, maintenance planning and scheduling can and will deliver the appropriate resources to the most critical of maintenance work.

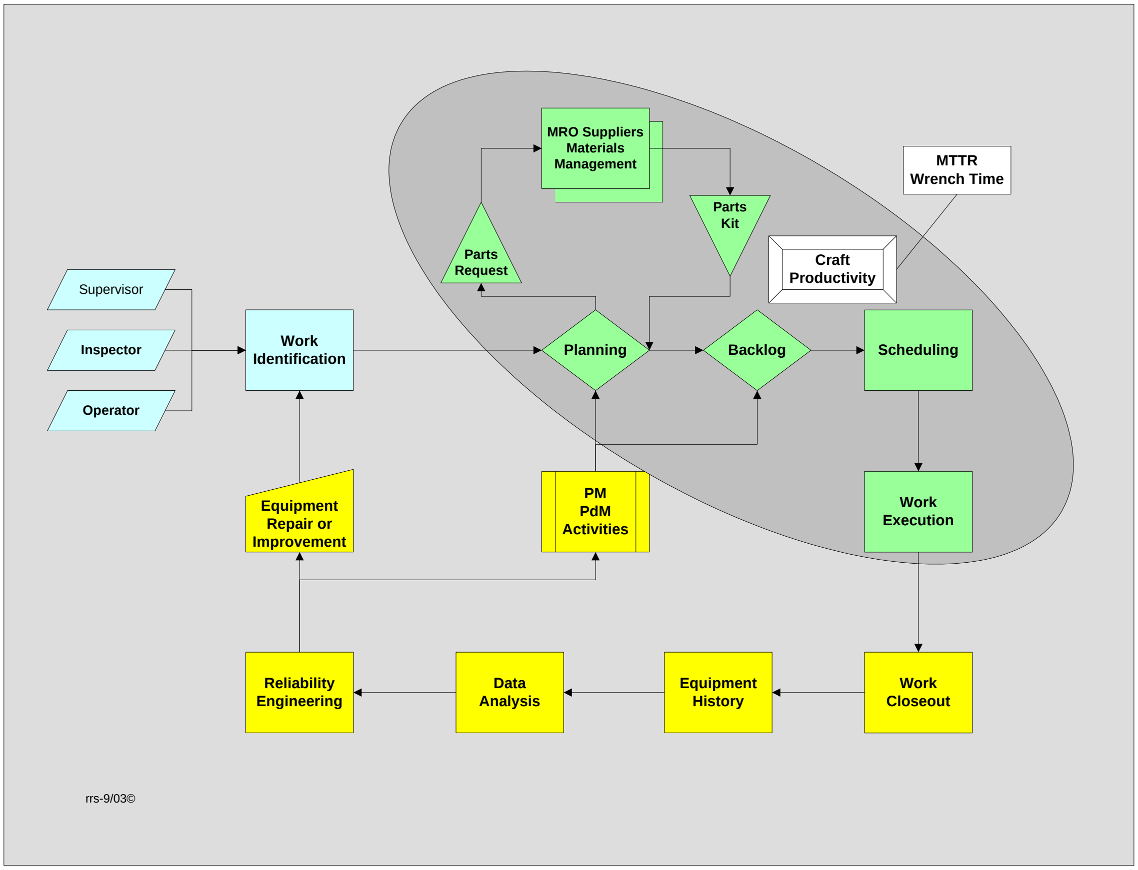

Figure 2: Maintenance Efficiency

The focal point of the planning and schedule process is the **Ready-to-Schedule Backlog**. This represents the "order book" of the maintenance process and is much the same as the order book of the manufacturing process that maintenance supports.

Maintenance planning and scheduling becomes, in effect, the "operations planning" department for maintenance. Maintenance Operations Planning's job is to deliver the most efficient utilization of resources to meet the production need. It is also designed to deliver maintenance required by the operation(s) it supports and work dictated by the preventive maintenance work orders automatically generated by the Computerized Maintenance Management System. Mean Time To Repair (MTTR) is a common measure of maintenance efficiency and can be used as a measure of how the process of efficiency improvement is progressing.

Planning is the Achilles heel of the maintenance process. Improvements in craft productivity can only be achieved if each maintenance task is described in sufficient detail to create an effective execution plan for a typical crafts person to deliver the expected results at the required level of quality. This includes all the critical job steps in their proper sequence with precise specifications and expectations defined, proper and special tools to perform the work, the correct parts and materials specified and available for use when required, plus the equipment available to be maintained when the crafts person arrives to perform the service. Absent these criteria, the crafts person is often left to his own devices to make decisions that might and often will produce unsatisfactory outcomes.

Selection by managers of the best planners, and the managers' subsequent unwavering dedication to the efficient scheduling of 100% of craft persons time is the critical factor in achieving maximum maintenance efficiency. Without this commitment, the process has proven to produce less than acceptable results.

Backlog Management, as described by Maintenance Activity Type, Work Group (craft), Manufacturing Process, or Equipment Type becomes the driver for delivering the appropriate services in the most efficient manner. ***Figure 3*** describes a typical way of looking at backlog to assist operations and maintenance in defining how and when to schedule work which will impact operations in the most positive manner. **Figure 3** looks at "Ready to Schedule Backlog" in man-hours required to complete these types of work, irrespective of the craft type required. When looking at this information on a weekly basis, it gives the Maintenance Manager a convenient picture of how he needs to deploy his valuable human resources. For each class of work, he sees the number of man-hours of "Ready to Schedule" work available to be scheduled for the coming week. He can see the delta, or change, from the previous week, what the average man-hours of this work has been for the last three months and how many man-hours have been deployed on average over the last for week to retire the backlog in each category. Finally, he can understand how long it will take his organization to retire a work order in any given class of work based on how resources have been deployed in the recent past.

For example, this chart indicates that a safety work order entered today would typically take 18.9 weeks to complete under the current maintenance management process and resource allocations. The last four weeks have seen only 16 man-hours, on average, dedicated to that category of work, hence management might think that rate of work completion needs to be accelerated by assigning more people, contractors or overtime hours to facilitate more action in that critical category of work.

This particular approach is also used to effectively look at distribution of craft type or outside resources available to the Maintenance Manager. By looking at the distribution of backlog work by craft (mechanic, electrician, carpenter, instrument tech, etc.) or physical equipment or area, the Maintenance Manager can begin to predict his need for outside resource support, increased or decreased overtime or reallocation of any of his craft resources.

Although this method is not a direct measure of wrench time, or craft productivity, looking at backlog in this manner, over time, will begin to paint a picture of where initiatives to improve productivity will provide benefits in **Maintenance Effectiveness**.

Wrench Time defines the essence of craft productivity and as such cannot be ignored in managing maintenance cost. Although it may have a bad connotation among the crafts, implying that there will be force reductions or stricter work rules, it does not necessarily mean that company crafts need to feel threatened. The focus of the Planner is to convert support activity and task delays into direct maintenance activity. ***Figure 4*** describes the categories of wrench time and those responsible for managing the activities to improve productivity.

The chief benefit of wrench-time improvement is that more maintenance work can be accomplished with the same amount of craftsmen. Improvement in this critical area means that some work currently "contracted out" or "outsourced" can be recaptured and performed by company crafts, often with better inventory management, quality control and closer management of costs and cash flow.

Work Type or Class	Current Week	Change from Prior Week	3 Month Average	4 Week Avg. Hrs Worked	Number of Cycles
Safety	302	38	400	16	18.9
Routine	1860	(375)	1700	235	7.9
Rebuild	777	(578)	500	40	19.4
Environmental	100	(8)	150	8	12.5
Administrative	244	200	312	30	8.1
P.M. Work	489	(50)	525	225	2.2
Result of Inspection	1478	75	1200	76	19.4
Sub Total	5250	(698)	4787	630	8.3
Capital Projects	1500	0	3500	200	7.5
Expensed Projects	1010	300	898	80	12.6
Sub Total	2510	300	4398	280	9.0
TOTAL HOURS	7760	(398)	9185	910	8.5
Standing or Blanket				434	
Total Resource Load				1344	

Figure 3: A typical weekly predictor of crew size and labor distribution requirements.

Scheduling now becomes the means by which the available resources are allocated to the highest priority "Ready to Schedule" work. With the more clearly defined parameters around job scope and duration, the maintenance schedule can be one which truly becomes a "contract with operations" to complete the required work in the time frames required.

Categories of Craft Productivity

- Direct Activity (Wrench Time)

Planner works to maximize these elements

- Support Activity
  - Get Equipment or Tools
  - Travel with Equipment
  - Get Material
  - Travel with Material
  - Travel other than above
  - Planning

Planner works to turn these activities into Direct Activity

- Delays
  - Wait on Equipment
  - Wait on Material or Parts
  - Same Crew Delay
  - Other Crew Delay
  - Supervisor Delay
  - Miscellaneous Delay
  - Personal Activity

Planner and Supervisor work to minimize these activities providing more opportunity for Direct Activity

Figure 4: The Maintenance Efficiency focus

Although it can deliver improvements in **Maintenance Efficiency**, "Planning and Scheduling" alone does not address the issue of why manufacturing needs maintenance in the first place. With obvious limitations, "Planning and Scheduling" does provide delivery of a more reliable manufacturing process in that it can allow for the selection of the appropriate maintenance work to be done at the appropriate time. However, **Maintenance Effectiveness** as part of the **Dynamic Maintenance Management System** will define more accurately and in greater detail the true value of maintenance work.

- **Maintenance Effectiveness (Improved Uptime & Maintenance Work Elimination)**

The purpose of maintenance is to deliver the capability to produce the products the business is selling. In order to do this effectively, maintenance must have its finger on the pulse of the equipment. Only then can maintenance perform the correct and timely tasks designed to optimize the performance of the equipment and the manufacturing process.

In this context, the concept of maintenance-work elimination takes on an important role in contributing to manufacturing productivity and corporate profit. By monitoring the health and performance of the equipment on an ongoing basis, the **Dynamic Maintenance Management System** can deliver the appropriate levels of maintenance at the appropriate intervals. The result of this approach insures that equipment always functions at its optimum level, providing predictable operating performance. When this condition occurs, the cost to operations becomes more stable with less costly repairs required to correct the collateral damage and loss of production incurred by unanticipated or even catastrophic failures.

The **Reliability Engineering** function serves to define the maintenance program in our **Dynamic Maintenance Management System**. ***Figure 5*** illustrates the portion of the system where we look at how to identify the appropriate work for our maintenance organization to perform. Much as manufacturing has Process Engineers who sort out the numerous quality, yield and throughput issues of the manufacturing process, maintenance has a similar function in the Reliability Engineer.

The Reliability Engineer begins his quest for maintenance effectiveness with a routine analysis of available maintenance information. This information can come from any number or sources. In most manufacturing settings, some form of "lost production" data base exists. In many of these systems, causes for lost production are recorded and may or may not be attributed to maintenance issues. In any case, the Reliability Engineer will strive to identify relevant maintenance issues as a hidden production "cost" and begin to evaluate and understand what the impact of maintenance is on the manufacturing process.

Numerous other sources of maintenance information also exist. High on the list is the CMMS and its wealth of information on where the maintenance resources are being utilized. Financial cost information, operations and maintenance log books, DCS system monitoring, inspection reports, predictive maintenance results all provide essential information in determining the maintenance contribution to the success of the manufacturing process.

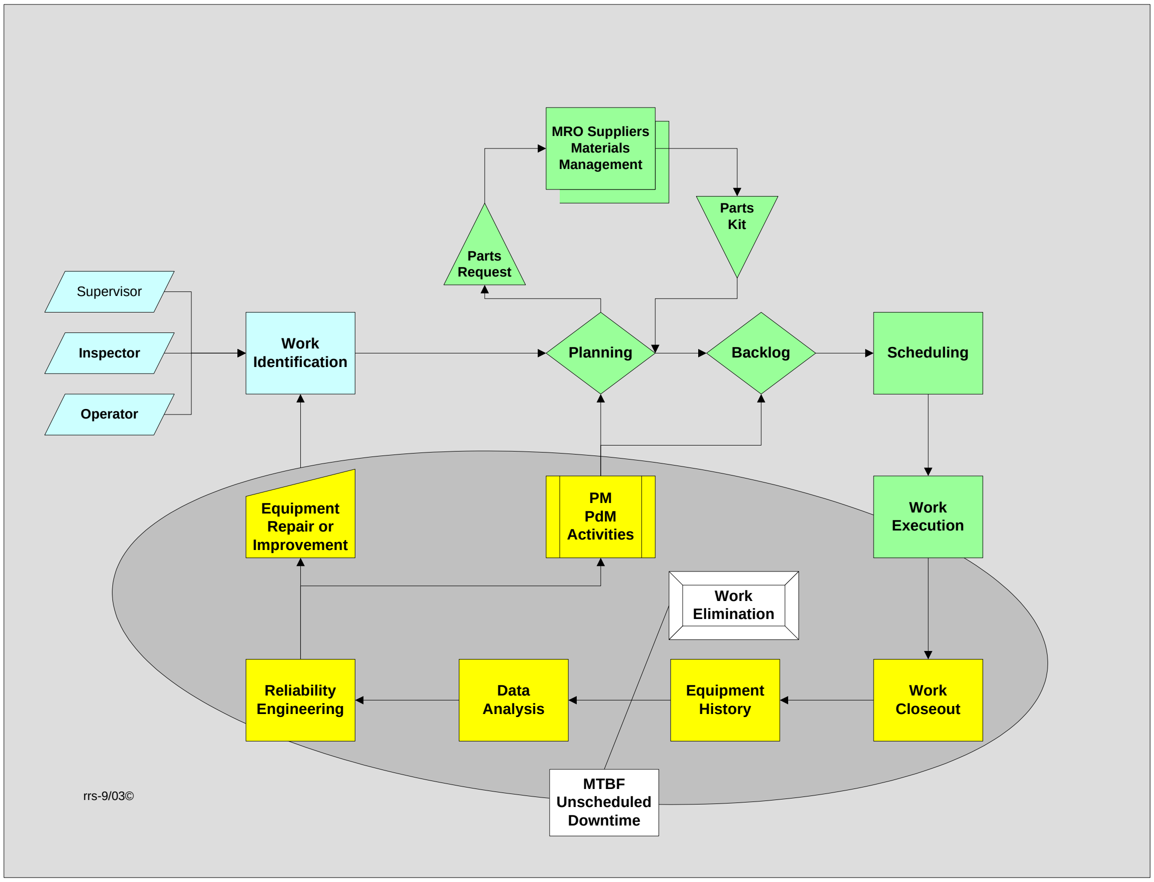

Figure 5: Work elimination and continuous improvement.

When a Reliability analysis of these sources of data is done on a monthly and quarterly basis, we now have the foundation required to recommend specific equipment improvement initiatives or refine the maintenance strategies of the Predictive and Preventive Maintenance programs. In either case, the effectiveness of the maintenance system is enhanced to deliver improved operating performance at better overall costs to the business.

The objective of the Reliability Engineer is to eliminate or minimize maintenance work. This serves to address the two primary needs of the **Dynamic Maintenance Management System**.

First – Eliminating unforeseen, repetitive or obsolete maintenance work means that the equipment is operating at a more reliable level. The Mean Time Between Failure (MTBF) is greater and therefore the equipment is running longer between equipment failures or required maintenance interventions. Operations have the equipment available for longer production runs and greater throughput. Better running equipment also means less yield losses from production stoppages and restarts.

Second – When the equipment runs with a greater MTBF, less labor is required to service the equipment, thereby freeing up internal labor to do work which would otherwise be contracted out or outsourced. Maintenance costs are reduced on both an absolute level and as a portion of manufacturing unit cost.

The Reliability Engineer has numerous tools available to help him meet his objectives.

Data Analysis – A great deal of information exists today for the Reliability Engineer to analyze in his pursuit of maintenance-work elimination. In a "brown field" environment, priorities are set for maintenance dictated by the performance of the equipment and manufacturing process. Quarterly Pareto analysis of equipment failure causes, maintenance costs and process performance serve to direct the Reliability Engineer towards addressing the issues most critical to manufacturing success. This analysis provides for numerous applications of Six Sigma problem-solving principles and techniques.

Predictive Maintenance Technologies – Probably the most common tools are the predictive maintenance technologies used to monitor equipment condition.

- Oil and fluid analysis is a valuable early predictor of equipment health. Much as a medical doctor uses blood testing to determine a patient's medical condition, fluid analysis, on a routine basis, provides important information and early indications of internal wear characteristics on many types of equipment.
- Vibration Analysis is the most common and widely used predictive technology. Routine examination of rotating equipment provides the Reliability Engineer with a great deal of information on specific condition and early warning of deterioration and misalignment on a variety of equipment components.
- Infrared Thermography has numerous applications for routine inspection on electrical distribution equipment. It also has great application to thermal process equipment or anywhere heat control is important to process equipment integrity.

Management of these and other routine predictive inspections and the data that they provide give a clear picture of the health of the equipment on a regular basis.

Inspection Method of Maintenance (IMM) – The routine inspection route, performed by a technician or craftsman, gives ongoing visual feedback on equipment performance. Combined with predictive technology routes, routine inspection followed by actionable work orders provides a corrective action process to identify, record and follow up on known equipment deficiencies.

Root Cause Failure Analysis – This technique allows equipment failure or chronic maintenance intervention causes to be positively identified and dealt with in a proactive fashion. Led by the Reliability Engineer, this investigation process reveals maintenance, design or operational deficiencies that can be identified and corrected. Appropriate preventive maintenance strategies can also be identified, modified or adjusted to the correct frequency using the results of these exhaustive investigations.

Reliability Centered Maintenance – An excellent technique to deal with chronic failures or excessive service requirements. This analysis will produce activities to address design deficiencies and/or enhance the preventive maintenance program in support of equipment reliability.

All of these tools, and others, assist the Reliability Engineer in improving the performance of the maintaining function. Often promoted as "the" solution to the maintenance problem, none of them in isolation will deliver the results required of the maintenance process by manufacturing. Only when Reliability Engineering, and its entire tool kit, is engaged in monitoring, measuring, and defining improvements in the maintenance process will the needs of the **Dynamic Maintenance Management System** be met.

Preventive and Predictive Maintenance Compliance is the primary measurement which concerns the Reliability Engineer. It is a well know fact that PM work is less costly and less time consuming than corrective or breakdown work. Only when PM Compliance is at or above 95% of all the PM and PdM activities complete by their due date can the Reliability Engineer be confident that the measures he is putting in place will be effective in delivering the required manufacturing process performance. If, at minimum, 40% of the craft hours worked on a weekly basis are not spent on this category of work, he can be reasonably assured that he has much more to do in defining those kinds of preventive maintenance activities. Less than 40% of craft hours spent on the PM / PdM category are an accurate indicator that the high cost corrective and reactive work is dominating the maintenance process.

If the Reliability Engineer is not engaged in the **Dynamic Maintenance Management System,** the loop is not closed and maintenance becomes a series of seemingly random and therefore uncontrollable events. With the inclusion of Reliability Engineering in the process, continuous improvement in the maintaining function becomes a way of life. Maintenance now looks like the Quality process known as PDCA (plan, do, check, act).

The Six Sigma world targets the vital few causes of the preponderance of problems. The Reliability Engineering analysis and data inputs of the **Dynamic Maintenance Management System** provides many opportunities for Process Improvement projects for the Six Sigma Black Belt and Green Belt.

- **Maintenance Cost**

It is appropriate at this time to understand the essentials of maintenance cost. In today's manufacturing environment manufacturing cost is a focal point for Executive Management in its quest to deliver products at a competitive price. Maintenance cost is always a significant contributor to that cost equation.

Maintenance cost is a combination of direct and indirect costs. Direct maintenance cost falls into one of three categories: Internal Maintenance Labor, Maintenance Parts and Materials, and Purchased Maintenance Services. ***Figure 6*** provides a breakdown of total maintenance costs.

Craft labor appears in two different areas of maintenance cost when looking at monthly cost control reports. Conventional accounting methods typically separate out maintenance labor as a unique category in monthly financial reports. Often, however, contractor craft labor is hidden under the "Purchased Services" heading in the purchased material category and, consequently, gets lost in an understanding of maintenance cost control.

When this contractor cost category is examined it is generally in the comparison of labor rates between various contractors. This comparison disguises the fact that all this work could be done internally if the company craft resources were managed efficiently and trained with the skills to perform it.

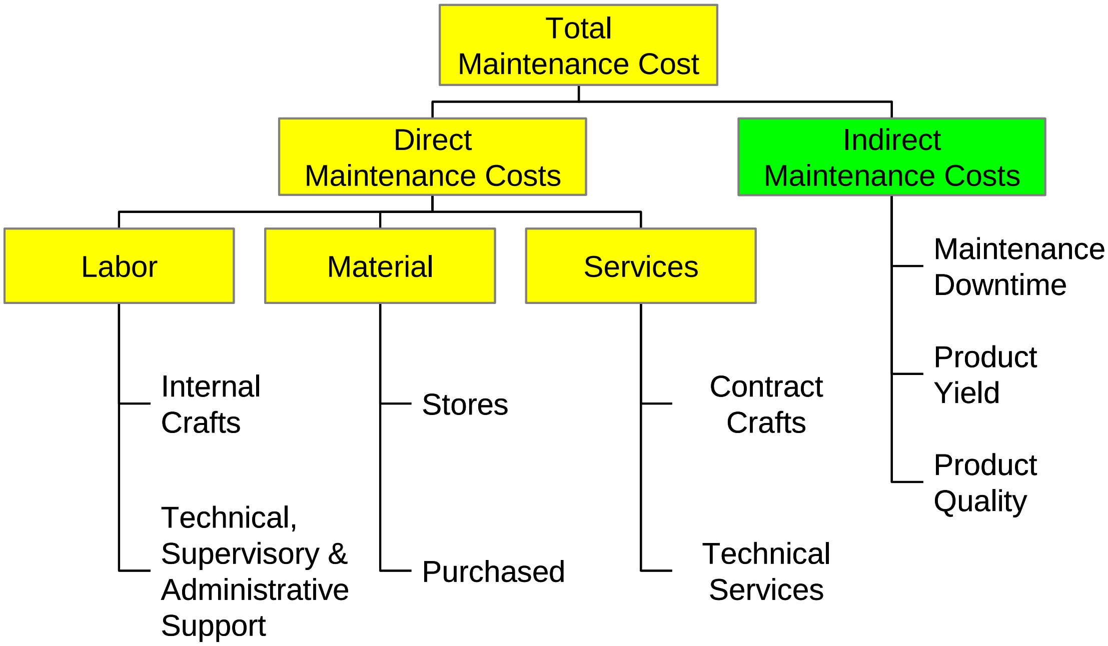

Figure 6: Distribution of Maintenance Costs

Figure 7 looks at the make-up of maintenance costs as defined by a number of cost categories. Conventional thinking revolves around spare parts and materials being the major contributor to maintenance cost. From this example, it becomes clearer that labor is the biggest slice of the maintenance-cost pie from the standpoint of internal labor costs. It also represents the most significant opportunity when looking at maintenance cost control.

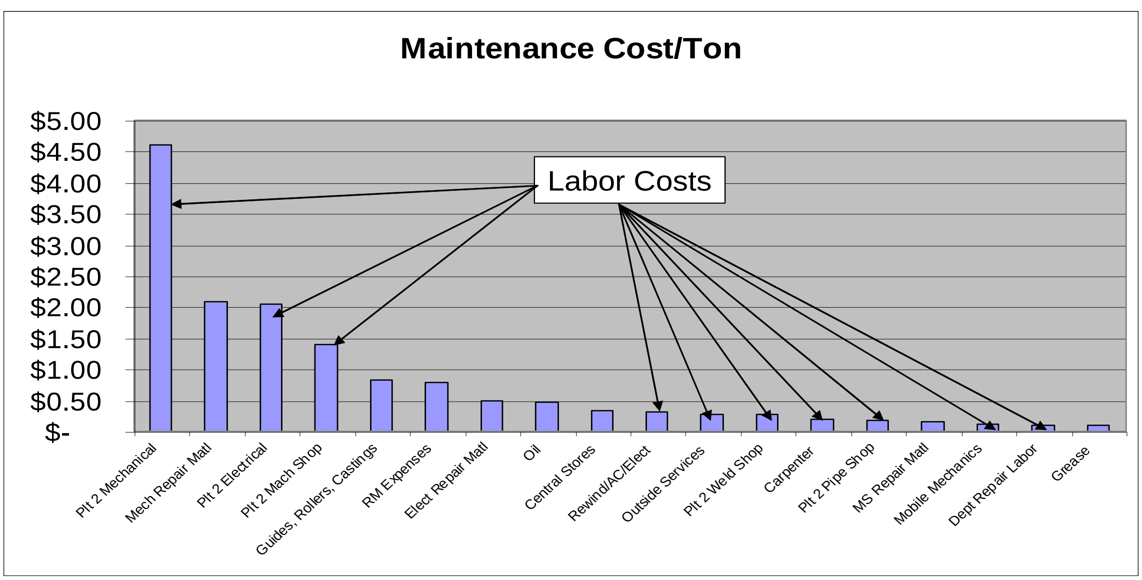

Figure 7: Typical Maintenance Cost Distribution

What isn't clear from this example is the impact that the reduction of labor cost will have on manufacturing process reliability, throughput and yield. In the current manufacturing environment, little is understood about this relationship between reducing maintenance cost and its impact on manufacturing. The **Dynamic Maintenance Management System** is designed to optimize the impact of **Maintenance Efficiency and Effectiveness** on cost and manufacturing production. This represents a true win – win situation in the real sense of manufacturing performance. That such a large portion of maintenance cost is labor (as shown in **Figure 7**) has made it **the last frontier** for corporate executives in their never-ending battle to reduce fixed costs. The good news is that through backlog management, a tool exists to predict future requirements for maintenance labor.

• Conclusion

This discussion has examined the Maintenance function as a continuous performance improvement process, based on a business management model. The concept of maintenance as a **business within a business** is demonstrably an integral component of delivering equipment uptime at a competitive cost to the manufacturing environment. Importantly, gaining value from this approach requires each of the components of the system be implemented and integrated as described by the model.

Figure 8 represents such a model in the **Dynamic Maintenance Management System**. It is clearly a closed loop, continuous improvement process that delivers maintenance in support of manufacturing improvement. It supports sustained improvement in, not only the cost picture, but also the implied requirement of manufacturing, manufacturing process uptime, throughput, and quality that meet the enterprises annual business plans.

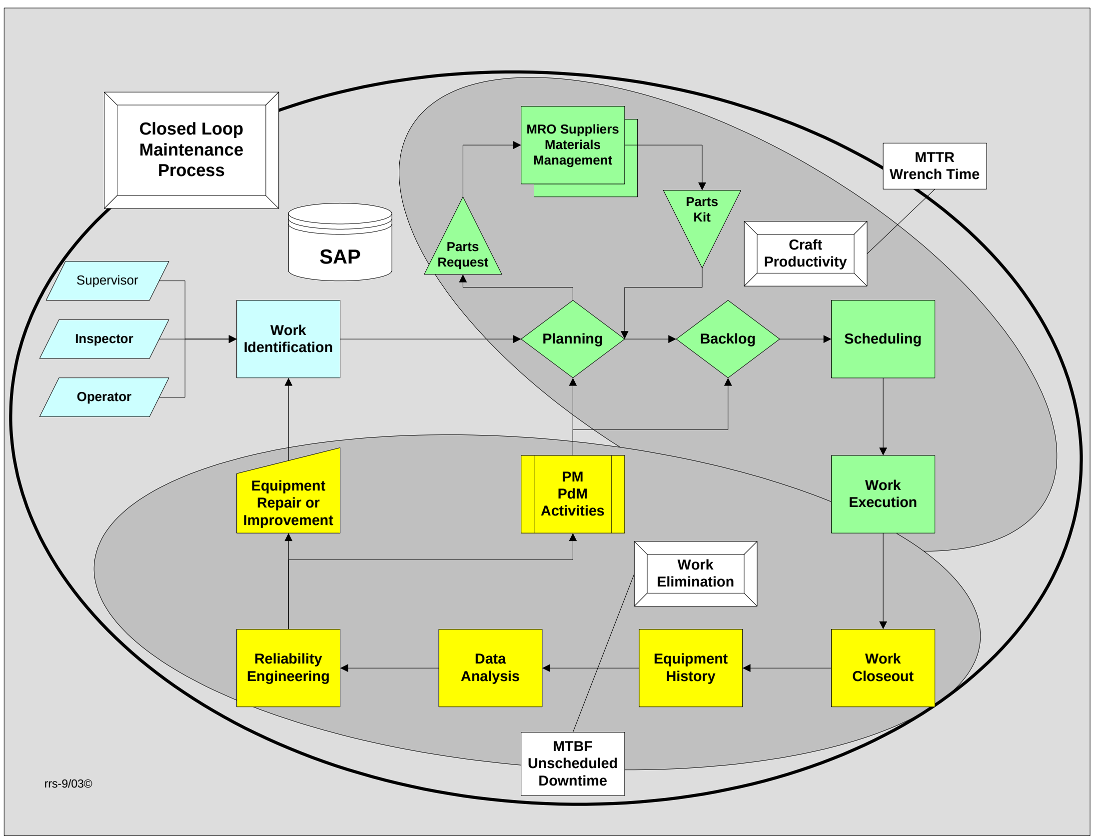

Figure 8: Dynamic Maintenance Management System.
The entire process must be followed to improve uptime and yield while getting the costs under control.

In the final analysis, today's world-wide economy is all about delivering a quality product at a highly competitive cost. Although conventional thinking holds that maintenance is mearly a subset of manufacturing, a comparative analysis of the contributions maintenance makes to a competitive business requires a much different conclusion. The business that is maintenance has a profound influence on many, if not most, of the important elements in a manufacturer's success. Improved uptime that comes with reliable equipment, consistently superior product quality that comes with predictable operating schedules, and competitive costs that come with optimizing the available resources are only a few of the benefits a well-managed maintenance program provides to the informed manager. When maintenance is carefully examined as a process that represents a "business within a business," the value proposition that emerges contributes to a significant competitive advantage in the world economy of the 21st century.

Implementing the **Dynamic Maintenance Management System** addresses **the last frontier** in the manufacturing environment. **The Business of Maintenance** is now poised to deliver the long sought after benefits of corporate management, improved maintenance costs **and** greater manufacturing uptime and throughput. The key to success is adopting the entire process with a commitment to implementation and improvement in **Maintenance Efficiency** and **Maintenance Effectiveness,** while integrating all available tools into the **Dynamic Maintenance Management System**.