Industrial and Facilities Maintenance Management: Opportunities for Economic Growth In Milwaukee

by

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A Research Paper

Submitted in Partial Fulfillment of the

Requirements for the

Master of Science Degree

in

Training & Development

Approved: 4 Semester Credits

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The Graduate School

University of Wisconsin-Stout

May, 2010

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Title: ***Industrial and Facilities Maintenance Management: Opportunities for Economic Growth In Milwaukee***

Graduate Degree/ Major: MS Training & Development

Research Adviser: Dr. Katherine Lui, PhD.

Month/Year: May, 2010

Number of Pages: 51

Style Manual Used: American Psychological Association, 6th edition

Abstract

Industrial and Facilities Maintenance is required of any business that operates out of corporate offices or produces material goods. This study reviews and assesses themes present in the literature that promote and obstruct the adoption of recent performance improvement strategies in this field, and relates them to current practices in the Milwaukee area as viewed by several experienced practitioners.

This study recommends that educational initiatives for promoting awareness and practice of these function-based strategies are in order. Professional, educational, civic, and government organizations would do well to bring successful practitioners together with the recalcitrant, in a variety of arenas that promote mentoring and coaching opportunities. It also underscores the

literatures' call both for maintenance professionals to partner with their business office colleagues to learn business case presentation, and for executives to recognize the role asset management/maintenance plays as a core business strategy and the necessity of their taking the lead in promoting organizational cultures of ownership.

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Acknowledgments

Many people have played a significant role in making this research possible. Foremost among them has been UW-Stout's MS Training and Development Program Director, and my thesis advisor, Dr. Kat Lui. Her calm and excellent advice encouraged me at every turn and kept me focused on a small enough theme to actually accomplish the task. I have to thank Andrea Beilfuss, an exceptionally able and inspirational Workforce Development Center counselor, for setting me on the journey this has become, and Rachel Reinders, whose support and encouragement helped see me through to its completion. Professional associations have always been a source of wisdom and enlightenment for me, and among the members of the Plant and Facilities Maintenance Association (PFMA), the Wisconsin Vibration Institute, and the Association for Facilities Engineers (AFE), I have to thank Gerry A. Olson, Jim Rescheske, Dean Schill, William (Bill) Mazur, and John Skadahl for their guidance and/or inspiration.

Mr. David M. Draper and my fellow University of Wisconsin-Stout MS Training & Development Cohort classmates stimulated and challenged me throughout my studies, and for this I am grateful. I would be remiss if I did not express my appreciation (and awe) for Ken J. Kieck, former PFMA President and (retired) Production Manager of the Milwaukee Journal-Sentinel, whose career accomplishments exemplified every principle of World Class Maintenance & Reliability, and inspired this research. Last, I am indebted to Sue and Ruth Lampi for the love, sacrifices, and long-suffering support they provided throughout so many of these college years

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Chapter I: Introduction

Humans have frequently been differentiated from other animals by their use of technology, among other behaviors. Since the invention of the wheel, technology has been rolling right along to the extent that we refer to the "wheels" of commerce and sagely advise that others not "re-invent the wheel". We want to keep moving forward to our organizational goals as smoothly and reliably as possible, without any sudden stops, delays, or unforeseen calamities. Yet despite all these prosaic references to this mechanical wonder, what regard do we give towards insuring that the wheels keep rolling? Why is it that only "the squeaky wheel gets the grease"? What esteem do we place on those who "grease the wheels" in the most literal sense, and what place do these people and their ever-so-necessary tasks have in our organizational strategies?

Simply-put, maintenance deserves special and highly-focused attention from Management and Organizational Development professionals for two major reasons; first, maintenance technicians will be the last humans working in the "totally automated" factory of the future, and more immediately, how effectively and efficiently maintenance technicians work determines whether your company gets to its destination smoothly and on time, or late, frazzled, and broke. Furthermore, would you tolerate a personal vehicle (your car) maintenance "system" that was always ready to get you back on the road whenever your vehicle (frequently) broke down, or one that always ensured your vehicle was available when you wanted it and that it would take you to your destination flawlessly?

While keeping "things" running has been the watchword since technology began, a new maintenance philosophy has sprung into existence over the past 40 years, and is slowly transforming the focus of Industrial Maintenance from simply maintaining things to maintaining the function of whatever process the equipment supports. The "customer" is no longer Operations, but the end user of the product being made. This change has been driven by economic conditions, legal liability, and, as facilities become more automated, the ever larger threat to the environment and people's safety when something does fail.

Statement of the Problem

Reliability, as an Asset Management strategy and practice, has driven organizations to profitability and competitive advantage as reported in countless case studies over the past 30 years. It has been codified in engineering and military standards, and yet appears to remain largely a mysterious and costly techno-babble to the average maintenance manager and technician. This is compounded by an ages-old "invisibility factor" of the maintenance field and its practitioners alike. This study will assess the spectrum of maintenance practices in the Milwaukee business region and inquire as to what initiated and drives organizations' practice of Reliability and/or other asset performance improvement practices, what prevents the adoption of these practices in others, and whether there is any correlation, or lack thereof, with Organizational Development initiatives within these organizations.

Purpose of the Study

The purpose of this study is to identify the range of maintenance practices and knowledge in the Milwaukee Metro area and inform educational and professional organizations regarding any need for (continuing) education and training activities to enhance the area's economic health and productivity.

More specifically, this study may serve to inform management science regarding the immense significance appropriate maintenance management practices now play in productivity and associated performance improvement initiatives. It may also identify any need to inform organizational development (OD) practitioners regarding modern Asset Management practices and their role as a physical counterpart to OD initiatives.

Finally, it may identify any need for the promotion of Reliability and related maintenance management practices to the maintenance trade in the Milwaukee area.

Assumptions of the Study

This study proceeds on the following assumptions:

1. That quoted case studies are factual.
2. That books, articles, and whitepapers published by trade periodicals and consultants to the profession, and further supported by professional on-line discussion and dialogue are accurate and authoritative for this field.
3. That the responses of those interviewed is genuine.

Definition of Terms

BSI PAS55:2008. Two-part British Publicly Available Standard (PAS) defines measures and practices that integrate 28 key aspects of the asset management/life cycle process. (IAM, 2008)

Corrective Maintenance (CM). The performance of *unplanned* (i.e. unexpected) maintenance tasks to restore functional capabilities of failed or malfunctioning equipment or systems. p.20 (Smith, RCM Gateway to World Class Maintenance, 2004)

Maintenance. "The combination of all technical, administrative, and managerial actions during the lifecycle of an item intended to retain or restore it to a state in which it can perform its required function." (BS EN 13306:2001)

"Ensuring that physical assets continue to do what their users want them to do". (Moubray, 1997)

Maintenance, Repair, and Operations (MRO). "Fixing any sort of mechanical or electrical device should it become out of order or broken (repair) as well as performing the routine actions which keep the device in working order (maintenance) or prevent trouble from arising (preventive maintenance)." (Life Cycle Engineering, 2008)

Preventive Maintenance (PM). The performance of inspection and/or servicing tasks that have been *preplanned* (i.e. scheduled) for accomplishment at specific points in time to retain the functional capabilities of operating equipment or systems." p.20 (Smith, RCM Gateway to World Class Maintenance, 2004)

Terotechnology. Multidisciplinary approach to obtaining maximum economic benefit from physical assets. ...systematic application of engineering, financial, and management expertise in the assessment of the lifecycle impact of an acquisition (buildings, equipment, machines...) on ... revenues and expenses ... terotechnology is a continuous cycle that begins with the design and selection of the required item, follows through with its installation, commissioning, operation, and maintenance until the item's removal and disposal and then restarts with its replacement." (terotechnology, n.d.)

Methodology

This study will incorporate a literature review and qualitative analysis of Industrial Maintenance management practices in the Milwaukee area with attention to their relationships with organizational development and performance improvement initiatives. It will compare and contrast these in an effort to identify the current role of maintenance/asset management in regional productivity and economic health, and suggest areas for action and further study.

Chapter 2: Literature Review

Many books, studies, and detailed articles have been published about each facet of Maintenance and Reliability. Theories, models, and comparative and case studies abound, when one searches for them. There are a prolific number of professional associations, and even certifications, available for those who want to learn more, or develop their skills. Consultants appear around the globe, hawking their version of best practices and decrying the others, with many proprietary, trade publication, and association web sites (ranging from very active to virtually dormant) discussing these issues as well as immediate needs for operational advice. This literature review seeks to provide a generalized overview of the current "condition" of Maintenance. We will look at how modern management theories and concerns for environmental and safety issues have profoundly impacted its function and practice within organizations, and its value to them and the world at large.

Please note that this study will use the term "functionally-based" when categorically referencing Reliability-centered Maintenance and its many derivatives.

Asset Management

Appreciating the value of maintenance in the organized business world first requires an understanding of its key role within asset and risk management. Asset management, or terotechnology (n.d.), is optimizing the usefulness of any and all physical assets from both functional and economic perspectives. Effective asset management requires alignment with organizational policy and strategy, with all assets designed and acquired to achieve specific goals with consideration of complete life-cycle costs including operational, maintenance, renewal, redesign, and disposition expenses. Accomplishing this demands the close cooperation of executive management, financial officers, production and design engineering, operations, and maintenance management. The BSI PAS55:2008-compliant Institute of Asset Management (IAM) model, Figure 1, identifies seven functional roles required to fulfill this cyclical mission. (IAM, 2008)

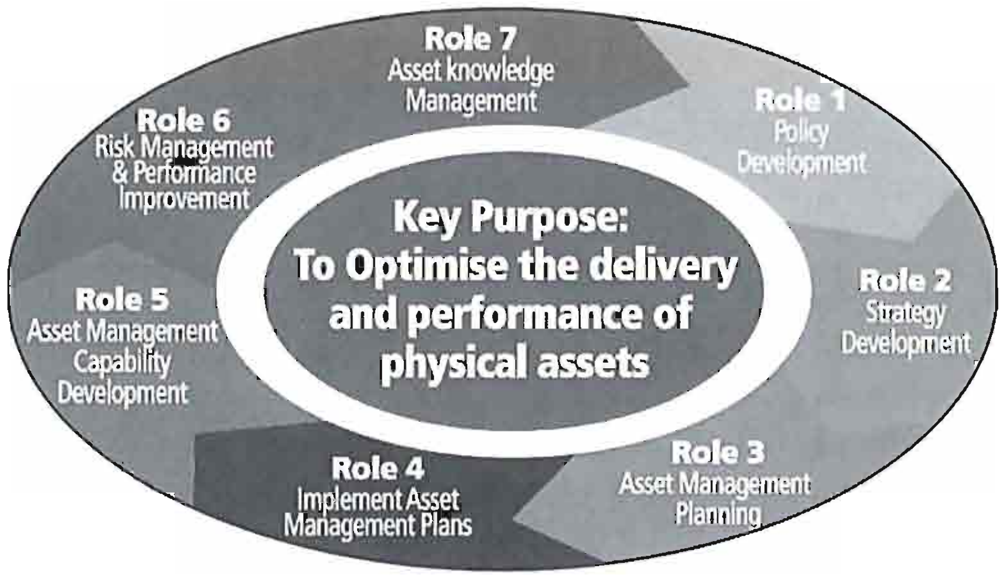

Figure 1. IAM Asset Management Model

Ideally then, equipment should safely and consistently produce the desired quantity of quality product(s) using the least amount of resources (material, human, and utilities) while requiring minimal maintenance, and signal when inexpensive and easily performed maintenance is required. Maintenance is integral to asset management.

Historical Development

The European Federation of National Maintenance Societies (EFNMS) (2010) states that:

> The role of maintenance and asset management has been changing significantly during the past couple of decades. The profession, which was previously considered a support function for production, has recently become the key factor for the competitiveness of companies. Today maintenance is a profession of its own and for more and more companies it is the core business.

Moubray (1997), in his definitive book *Reliability-Centered Maintenance*, identifies 3 generations in this recent evolution of maintenance management practices as represented in the reconstructed Figure 2.

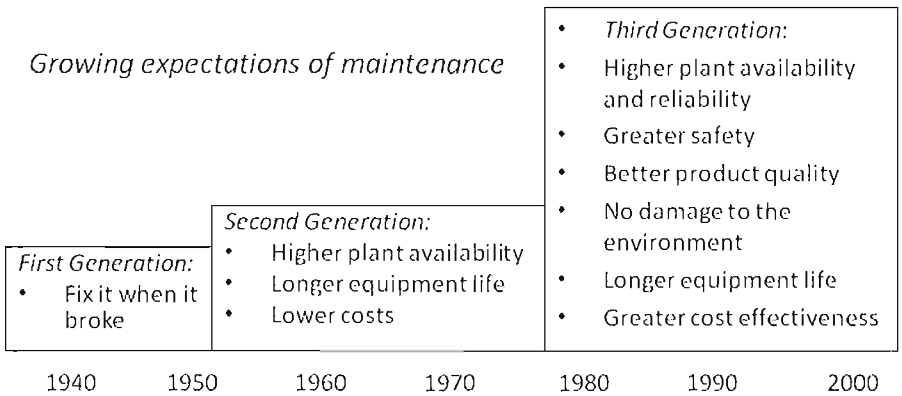

Figure 2. Evolution of Modern Maintenance

Levitt (2008) describes these 3 generations of maintenance as typified by the "(older) super fix-it guy" up through the mid 1960's, the "young computer guy" into the 1990's, and the "'equipment fixes itself' of the next millennium."

Organizational Function

"Maintenance is a critical business process and a key to the company's success…an investment in productive capacity. (Not)… *a necessary evil – a cost center."* Campbell's (2006) words are fitting, given the research published and practices observed. Wireman (2005) echoes Campbell's sentiments:

> Although many companies believe that maintenance is not a core competency, it fits all definitions of core competencies…. There are several definitions of core competencies, but all of them focus on processes that allow a company to differentiate itself from its competitors. A core competency may have an impact by lowering costs,

increasing profits, providing improved service to a customer, improving product quality, and improving regulatory compliance.

Wireman continues by referencing Richard Schonberger's *Operations Management* (1997) text which "defines a core competency as a key business output or process through which an organization distinguishes itself positively" and identifies examples, "expert maintenance, low operating costs, and cross-trained labor".

Maintenance (traditionally) has primary and secondary functions, according to Higgins (2002), these are listed as:

Primary -

- Maintenance of existing plant equipment
- Maintenance of existing buildings & grounds
- Equipment inspection & lubrication
- Utilities generation and distribution
- Alterations & new installations

Secondary -

- Storekeeping
- Plant protection
- Waste disposal
- Salvage
- Insurance administration
- Other services

Mobley (Higgins, Maintenance Engineering Handbook, 6th Edition, 2002) writes that there are 3 types of maintenance tasks in the performance of these functions: "(1) breakdown, (2) corrective, and (3) preventive", breakdown maintenance being "repairs (that) do not occur until the machine fails to function", preventive tasks those performed "before a problem is evident", and corrective tasks those "scheduled to correct specific problems". The main differentiation between these is whether a task is performed before, at the onset of, or after, functional failure. Mobley states that "A comprehensive maintenance program should use a combination of all three. However, most domestic plants rely almost exclusively on breakdown maintenance to maintain their critical production systems."

This observation perhaps illustrates why there are such divergent views of the value and function of maintenance, when Mobley continues "This approach … is both ineffective and extremely expensive." Ineffective, due to (lost) production time constraints leading to poor planning, and incomplete, due to addressing only immediate symptoms and not investigating/addressing the root cause of the failure. He notes that this generates 3 to 4 times the cost of well-planned repair and perpetuates the cycle of breakdowns. (Higgins, Maintenance Engineering Handbook, 6th Edition, 2002) Maintenance is a paramount example of the adage, "an ounce of prevention is worth a pound of cure".

Maintenance Models

Many specific maintenance models, or perhaps better, modalities are discussed and promoted throughout the literature. The main features of each are highlighted in this next section. Typically several are combined into a unique blend based on an organization's strategies, leadership, culture, and experience, leadership. Implementation of each can be strategic, tactical, or both, to suit business organizational and cultural realities, and evolved as conditions call for, or drive, change.

Reactive Maintenance

Reactive Maintenance is essentially a strategy of repairing equipment failures as they occur, or "fire-fighting". Run-to breakdown can be a legitimate asset management strategy if resultant equipment failure will not do any harm or disrupt production significantly while it is repaired or replaced.

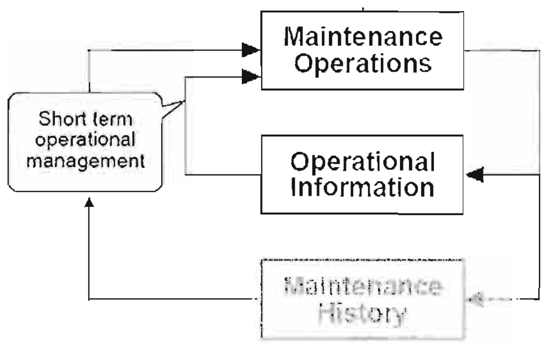

Figure 3. Reactive Maintenance Operations Model

Adapting Coetzee's (1999) model (Figure 3), we see that Reactive Maintenance is simply a reflexive cycle of Operations experiencing breakdowns, calling for immediate repairs, and Maintenance responding, with minimal attempts to record activities and equipment history.

Proactive Maintenance

Proactive Maintenance methods and strategies are those which seek to maintain and or extend the operational life of mechanical and electrical devices. They include Preventive Maintenance (PM) and Predictive (PdM) Maintenance tasks. While the actual tasks are the same under all maintenance management strategies, their tactical use and application is what differentiates each of the Proactive Maintenance Strategies. Adapting Coetzee's (1999) model, once again, Figure 4, we add a tactical planning loop for Maintenance History to inform

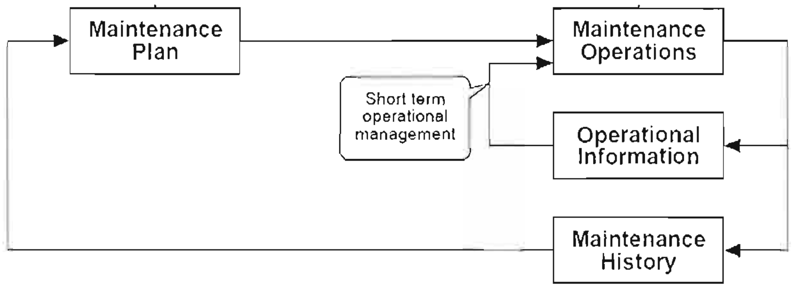

Figure 4. Proactive Maintenance Operations Model

Maintenance Management, allowing for planned and scheduled time and/or condition- based preventive maintenance activities. Maintenance can then begin addressing issues before they seriously affect production, even effectively prioritizing and planning corrective work, Figure 5.

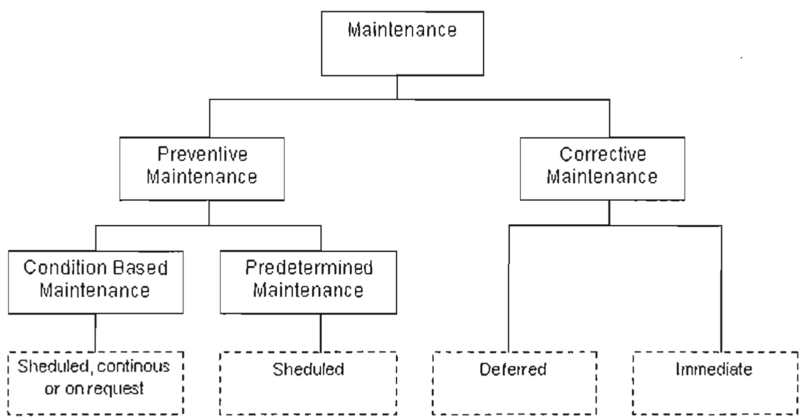

Figure 5. Scheduled Maintenance Activity

Looking at Coetzee's complete Holistic Model (Figure 6) we observe the addition of a strategic planning loop.

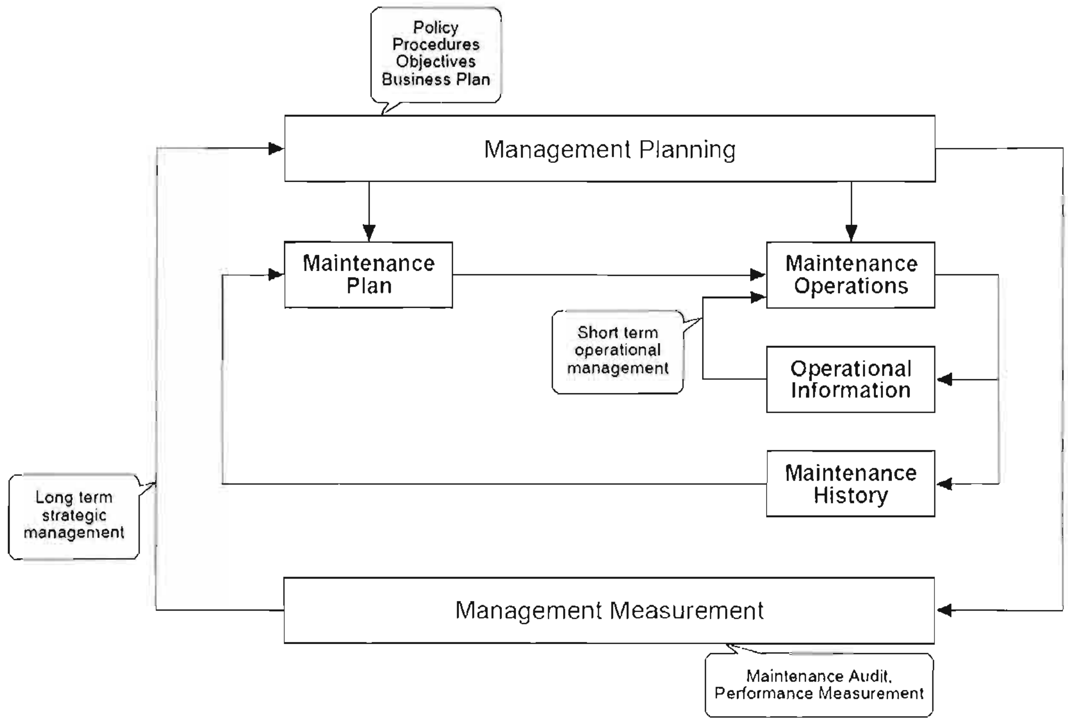

Figure 6. Holistic Maintenance Operations Model

Recognizing Maintenance as an integral part of overall strategic planning and asset management allows full implementation of Total Productive (TPM)/Total Quality Maintenance (TQM), Lean Maintenance, and Function-based Maintenance Models.

Preventive Maintenance (PM)

Preventive Maintenance and its associated tasks is possibly best illustrated by the US Navy's maintenance handbook, Figure 7. (NAVSEA, 2007)

Task	Condition-Directed	Time-Directed Life-renewal	Failure Finding	Servicing	Lubrication
Action	"Renew life" (restore or replace) based on measured condition compared to a standard	"Renew life" (restore or replace) regardless of condition	Determine whether failure has occurred	Add/replenish consumables (e.g. windshield washer fluid)	Oil, grease or otherwise lubricate
Circumstance	Equipment characteristic corresponds to failure mode	Imminent wear out	Failure of off-line or hidden" function (e.g. Safety/protective devices)	Reduced level of operating consumables	Accelerated wear
Typical Tasks	Diagnostic Test, Material Condition Inspection	Discard and replace with new item	Inspection, Functional Tests	Top off consumables (e.g. fluids)	Lubricate

Figure 7. Five Types of Preventive Maintenance Tasks

Predictive Maintenance (PdM)

Predictive Maintenance, also referenced as Condition-based Maintenance (CBM), typically involves the use of fluid/chemical spectral analysis and vibration-sensing, sonic, and/or infrared technologies to evaluate equipment condition. Baselines are established for selected measuring points and monitored on a schedule that matches the potential nature of its failure, accounting for adequate lead to effect timely repairs without interrupting production.

Total Productive Maintenance (TPM)

TPM is a maintenance strategy primarily known for its focus on the Operational Equipment Effectiveness (OEE) KPI, and on its criteria that operators, in fact all production employees, assist in the maintenance function as they are able.

Lean Maintenance

Lean Maintenance has its roots in the Toyota Manufacturing System and is more a philosophy than model. Its main focus is to examine any practice for wasted effort or resources, and to make the elimination of that practice as natural as possible. It has three levels of practice, with initial efforts best known as the 5S method employed in general manufacturing. It can be applied with great effect to any practice.

Function (Performance)-Based Maintenance

Function-based maintenance has its roots in the airlines' industries growing frustrations in the 1950's with mounting maintenance costs and the apparent futility of proactive/preventive maintenance in efforts in making aircraft significantly reliable. (Nowlan, 1978) Nowlan and Heap's report goes on to detail that a joint airline/FAA work group formed in 1960 found time-based preventive maintenance had no observable effect on an airplane's reliability, posing "a direct challenge to the traditional concept that the length of time between successive overhauls of an item was an important factor in controlling its failure rate." A second major finding that came from their work was that "There are many items for which there is no effective form of scheduled maintenance."

Their work culminated in a maintenance steering group's (MSG-1) drafting of a handbook for (scheduled) maintenance evaluation and program development, first applied with great success to the (new) Boeing 747. Further refinements led to a revision (MSG-2) and a European counterpart that were used with continued successes on commercial and military aircraft. Nowlan and Heap (1978) note that United Airlines, using these new reliability guidelines saw 98% reductions in the number of overhaul items and manhours accompanied by reductions in spare parts inventories of 50%, literally saving millions of dollars in several instances. Aside from the incredible cost savings these new reliability principles engendered, airline safety became relatively stellar, as Moubray (1997) observed in Figure 8 below.

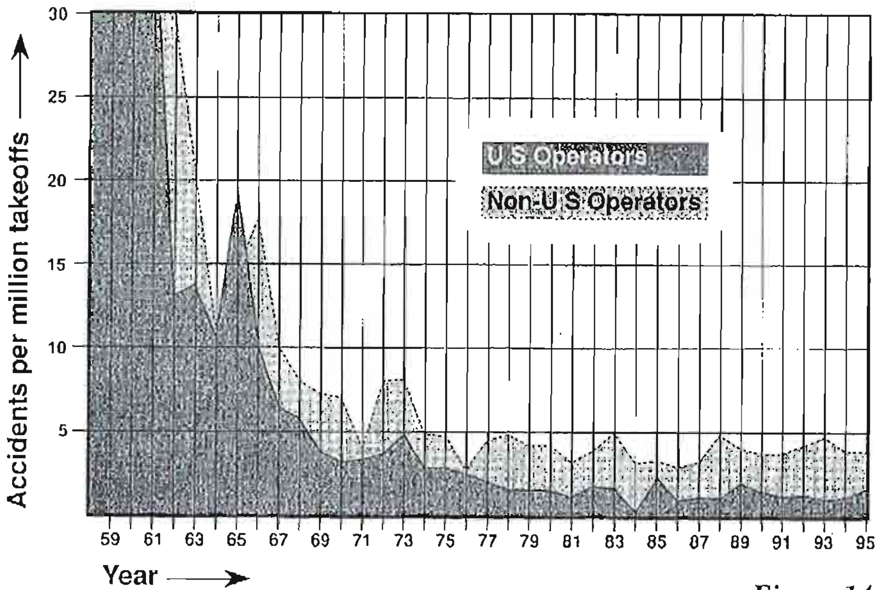

Figure 14.2:
Safety in the civil aviation industry
Source: C A Shifrin: "Aviation Safety Takes Center Stage Worldwide"
Aviation Week & Space Technology: Vol 145 No 19: Pp 46 - 48

Figure 8. RCM Effectiveness in the Airline Industry

Reliability-Centered Maintenance (RCM)

The success of these developments culminated in the now-famous "Reliability-Centered Maintenance" (RCM) report commissioned by the US Department of Defense, and produced by United Airlines' Nowlan and Heap in 1978, in an effort to examine how these reliability principles might be applied to the maintenance of military assets. This resulted directly in the development of separate RCM processes for each of the military branches, and eventually two general approaches to commercial and industrial maintenance improvement, "classic" RCM and planned maintenance optimization (PMO). (Netherton quoted by Moubray)

Reliability Centered Maintenance 2 (RCM2)

Working from the aircraft-centric reliability principles detailed by Nowlan & Heap, and working under Stan Nowlan's mentorship, John Moubray and his associates began developing mining and manufacturing models that also took safety and environment concerns into account and engendered their decision to revise the name of their practice of these principles to RCM2 in 1990. (Moubray, 1997)

The RCM process centers on the answers to seven questions relative to an asset or system's functions, possible failures and resultant consequences, and potential solutions. (Moubray, 1997) The comprehensive answers are obtained through facilitated review team efforts involving personnel throughout the organization including at least one maintenance and one operations person. A thorough review may also involve the application of statistical probability and risk analysis.

"Functions" considered range from such primary ones as production of product to secondary ones like being showcase models of company brand. "Failures" can range from cessation of production and poor quality/scrap issues to "hidden failures" such as faulty safety devices that don't affect ordinary operations. "Consequences" can be as simple as requiring overtime operation to make up for inefficiency, to catastrophic loss of life or irreparable environmental damage. Solutions can include proactive maintenance strategies, machinery/equipment redesign, or even a deliberate decision to run the equipment to failure.

RCM Variants

Given the tremendous success of aviation's RCM process, a variety of maintenance consultants began offering their own versions of "RCM". These are variously referenced as "Streamlined" RCM, "Backfit" RCM, or "Reverse" RCM. Most of these are frequently referred to colloquially as RCM "lite". The main advertised differences are that these new processes supposedly require less study and paperwork, cost less to implement, don't require cultural change, are faster to implement, and so on. These benefits are hotly disputed in books, articles, and on internet maintenance discussion groups by the "classic" advocates, who contend that these also do not offer the safety or reliability, much less the liability protection, of full-fledged RCM.

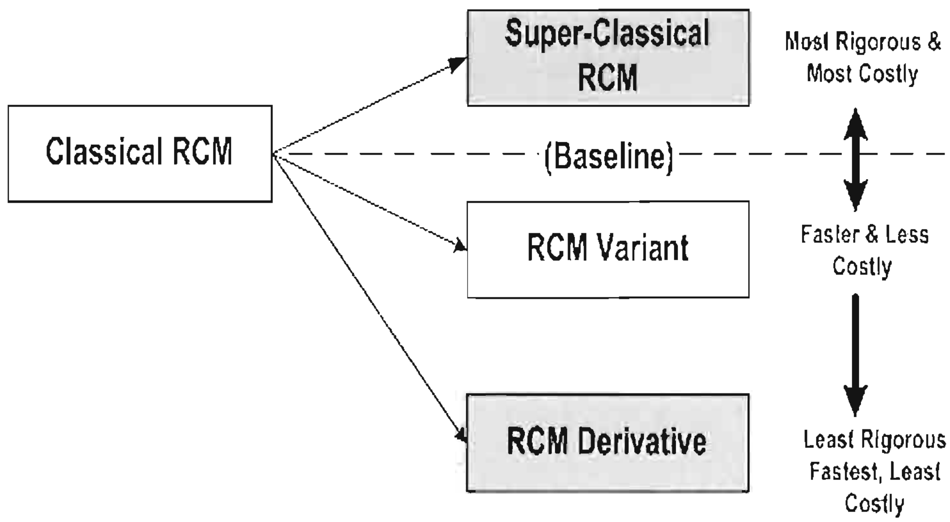

Figure 9. RCM Developments (Reliabilityweb)

Planned Maintenance Optimization (PMO)

While Moubray et al. transformed RCM into a more rigorous process in terms of reliability and safety, the Electric Power Research Institute (EPRI), applied RCM to the nuclear power industry believing that they had safety and reliability well-covered, but were over-maintaining their equipment and facilities. Rather than beginning with an examination of functions and failure modes, they applied the RCM "action" methodologies based on past performance records and known failure modes. This RCM derivative was subsequently adopted by the electric utilities in general and parts of the oil industry, and many concerned RCM proponents protest that "it should be more correctly described as planned maintenance optimization, or PMO, rather than RCM". (Netherton, quoted by Moubray, 1997)

Steve Turner and other maintenance consultants have actually developed PMO as a practice and a lively debate has ensued ever since, and some will argue that PMO is not properly a function-based maintenance management strategy.

Maintenance and Reliability Standards

Given the diverse interpretations and practices that have developed from the original RCM report, several government agencies and professional associations have developed standards to define, clarify, and govern their expectations of Reliability and those who offer "reliability' services.

Aircraft

The commercial aviation industry's RCM programs, which began the reliability revolution, now operate under MSG-3 guidelines. These are the current revision of MSG-2 and were strongly influenced by the Nowlan & Heap report. (Netherton, quoted by Moubray, 1997)

Military

The US Naval Air Command rapidly responded to the airlines' success by adopting its own version, "Guidelines for the Naval Aviation Reliability Centered Maintenance Process" (NAVAIR 00-25-403). The British Royal Navy similarly adopted the RCM-based Naval Engineering Standard (NES45).

Society of Automotive Engineers (SAE)

Moving into 1990's, the US Navy soon found that it was not able employ its own RCM standards when awarding contracts to commercial industry, due to changes in Federal procurement processes. Its response was to form a study group with industry representatives, under the sponsorship of the Society of Automotive Engineers, to develop industrial RCM standards. This effort produced "Evaluation Criteria for Reliability-Centered Maintenance

(RCM) Processes (SAE JA 1011)" in 1999. This is not an RCM process, as such, , but "presents criteria against which a process may be compared" (Netherton, quoted by Moubray, 1997). This was closely followed by "A Guide to the Reliability-Centered Maintenance (RCM) Standard" (SAE JA 1012) published in 2002 and which "amplifies and clarifies each of the key criteria listed in SAE JA 1011.... And summarizes additional issues that must be addressed in order to apply RCM successfully." (SAE, 2010)

The seven basic questions (criteria) that any true RCM process must respond to are (Wikipedia)

1. What is the item supposed to do and its associated performance standards?
2. In what ways can it fail to provide the required functions?
3. What are the events that cause each failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure?
7. What must be done if a suitable preventive task cannot be found?

Professional Associations

There are a myriad of professional associations that are involved peripherally or integrally with maintenance, its management, and asset management (terotechnology) in general. (See Appendix E, which includes their acronyms). Many are devoted to a science or technology, such as the tribology or fluid power associations, that maintenance technicians utilize in the course of their duties. Maintenance personnel must be aware of changes in these technologies and their associated standards, and may even hold proficiency certifications offered by these associations. The same is true for industrial standards-setting associations such as the ANSI, ASTM, SAE, and SME.

Most professional membership-based associations directly involved with Maintenance in the United States and Canada are either regional, such as the PFMA and IMI, or thinly scattered and primarily located in heavy manufacturing or processing regions, such as the AFE and SMRP.

On an international level the IFMA has 126 chapters around the world and COPIMAN brings many South and Central American countries together. The IAM spans a number of countries throughout the world and the EFNMS brings 21 of Europe's national organizations together, publishing "Maintenance World" to address maintenance and asset management issues. The SMRP in the US has partnered with the ENFMS to share standards and training while the IAM has also partnered with the ENFMS, MESA (Australia), IET, and other organizations in promoting international acceptance of the BS PAS 55:2008 asset management standard. A similar alliance is promoting the European standard prEN 15341 "Maintenance Key Performance Indicators" to establish commonly-defined measures.

Informal web communities have also formed to share information, experiences, and opinions about every maintenance topic imaginable. These are sponsored by a variety of organizations ranging from professional associations and individuals to consultants and trade publications.

Certifications

The primary, and only legally required Maintenance certifications, are those required by federal agencies such as those established under the Occupational Safety and Health Act (OSHA). These pertain to generic employer training about such things as Blood-Borne Pathogens and Hazardous Materials, or job-specific activities like Confined Space Entry.

Additional codes such as the National Fire Protection Association NFPA 70E (Electric) Arc Flash Standards similarly call for certification of training.

Several maintenance organizations have developed certifications, primarily for Maintenance Managers, at one or more levels, a few have technician or Engineer certifications, and several of these association certifications feature Reliability as a component to greater or lesser degrees. Related associations each have their own certifications for such things as Hydraulic or pneumatic mechanic/technician/specialist, Vibration Analysts (Levels 1-4), Infrared analysts, etc.

At the moment the main value of any of these appears to be the assurance that the certified party can do well on cognitive tests. Since most of these also require documented employment and/or education in the respective occupation, the main proof of functional capability is the longevity and recommendation of the employer.

Chapter III: Methodology

Introduction

Milwaukee has a significant history of growth and development in technology-driven manufacturing and food processing industries. While this focus has changed along with the United Sates as a whole, numerous companies continue to compete with a global economy, seeking to achieve profitability and competitive advantage through a variety of means.

This study will undertake a qualitative analysis of Industrial Maintenance management practices in the Milwaukee area with regard to the efficacy of recent Reliability and similar functional-based strategies in enhancing productivity. Pertinent literature will be selected by review from among government reports, scholarly journals, on-line discussions between practitioners, and trade publications including books, white papers, and periodicals. Interviews of trade practitioners will be conducted in person and by phone, with representative candidates selected by recommendation from several professional trade associations operating in the Milwaukee geographic area. Additional observations and commentary will be made and collected from members of these organizations as they engage in pertinent discussion.

Literary themes, responses, commentary, and observations will be compared and developed, suggesting areas for action and further study.

Subject Selection and Description

Interview respondents were selected to represent as wide a cross-section of business/organizational category and/or size as possible. They were either recommended by officers of the Plant and Facilities Maintenance Association, the Association for Facilities Engineering, and the Wisconsin Vibration Institute, or chosen from membership lists of these same associations. Four people were interviewed with maintenance management experience in manufacturing, public utilities, processing, printing, and facilities operations with plant sizes ranging from 110 to 230 and maintenance staff ranging in size from 6 to 150. The respondents' education levels ranged from non-degreed (with lots of formal coursework at the technical and university levels) to full Bachelor of Science degrees, with all expressing that they made personal educational and skill advancement a priority throughout their lives. Each had direct maintenance experience ranging from 25 to 37 years.

Instrumentation

Many generic cognitive surveys have been administered by trade publications and made available to the public. The six questions utilized for this study's interviews, listed in Appendix B, were created with intent of discovering the effects of education, experience, organizational size, departmental size, and the presence and/or activity of organizational development initiatives on the various maintenance management practices employed, and the net results thereof.

More specifically, the questions were designed to capture:

1. Relationships between age, experience, education, and level of maintenance practice. (Questions 1, 2, and 4)
2. Overall awareness of Asset Management/Reliability Theory and practices. (Questions 4 and 5)
3. Relationship of organizational size to the level of maintenance practice. (Questions 3, 4, and 5)
4. Types of Reliability initiatives/programs in use in the area. (Questions 4,5, and 6)
5. The functional reality, if any, of reliability initiatives. (Questions 4 and 5)
6. Information regarding the types of Maintenance (Management) Technologies in place. (Questions 4 and 5)

7. Any connections between Maintenance and Organization-wide Performance Improvement/ Organizational Development initiatives. (Question 6)

The use of open-ended questions was intended to capture greater depth of response than that allowed by a multiple response survey and enabled the respondent's sharing of uniquely customized management strategies. The questions were submitted for, and received, approval from the University of Wisconsin – Stout's Institutional Review Board (IRB) (Appendix A).

Data Collection

Respondents were approached variously by telephone, email, or referral through network contacts, and informed of the study's purpose, interview format, and their participation options relative to established university research policies. (Acknowledgement of which was confirmed by signing a Consent Form, Appendix C, prior to commencing the interview.) An appointment was made to meet with each respondent, and the interviews ranged from 20 minutes to 2 hours with responses recorded in writing. Each respondent welcomed the opportunity to share their experiences and current management practices, per the structured format, and all enthusiastically offered to make themselves available should any further information be required.

Data Analysis

The respondents' answers were collected by question/topic and compared to the range of responses within the group, and as a group to themes found in the literature. The arbitrary definitions listed in Appendix D were used as an aid in categorizing responses for comparative purposes. These responses and themes were then compared and contrasted to observed and recorded (written) commentary made by professional association members in open discussions regarding maintenance management practices and observational comments offered by vendors to the trade.

Limitations

The primary limitations of this research are the small sample size of the population, and the fact that each of those who chose to participate in the interview process was either an active practitioner of Reliability-based management practices, or a strong proponent thereof. These limitations, strangely enough, lend credence to the findings, albeit in a negative mode, when one learns that several practitioners who were approached had no available time to share their responses, and expressed even more disinterest in participating on hearing that it was a study relative to the function of Reliability strategies in Maintenance, Repair, and Operations (MRO).

Chapter IV: Results

Introduction

This study proposed to identify the range of maintenance practices and knowledge in the Milwaukee Metro area in order to better inform educational and professional organizations regarding any need for education and training activities to enhance the area's economic health and productivity. It conducted formal interviews of several maintenance management practitioners utilizing open-ended interview questions to capture the effects of education, experience, organizational size, departmental size, and OD activities on maintenance management practices and their net results.

The respondents' answers were collected by question and themes, with additional commentary included when pertinent to themes discovered in the literature. Current literary themes were similarly reviewed and organized. Records of dialogue and interactions observed during discussions held in local maintenance-related professional settings were also gathered. These sources were then compared thematically to provide the basis for the ensuing discussion.

Item Analysis

All of the respondents had significant maintenance work experience, ranging from 26 to 35 years (Table 1). Education spanned from one with simply a mixed conglomeration of technical college, and university courses to the most educated with a BS in Electrical Engineering, with each attending numerous job-related specialty training activities. Job titles reflected responsibilities from maintenance management through two with predictive technologies responsibilities to the last with capital projects management duties.

Table 1

Respondent Demographics

Respondent	Experience	Job Title	Education	Daily activities
A	32	Capital Projects Manager	Technical college & university courses	(3) Planners schedule, plan & "kit" PM's and PdM activities. Evaluate technicians' PM recommendations
B	35	PM/PdM Trainer	B.S (Engineering) & miscellaneous PdM/PM training	Prioritize maintenance requirements. Keep critical systems running
C	32	Maintenance Manager	Technical college diploma, professional certification courses	Purchasing, CMMS entry, scheduling, report writing, supervise 3 shifts
D	35	Predictive Technologies Manager	Associate degree, & technical certifications	Manage PdM technicians, develop PdM technologies/ strategies for cost avoidance

Daily management activities ranged from one with general oversight of six personnel, personally ordering parts, making computerized maintenance management system (CMMS) entries, scheduling, and report writing to the other end of the spectrum, where three full-time maintenance planners are engaged in performing these activities, with management oversight, for a department of 150 maintenance technicians.

All four were employed by "Large Corporations" with total employees ranging from 5,000 to 100,000. The number of total employees on site, however, ranged from 110 to over 230, with site maintenance workforce to employee ratios of between .05 and .65 (Table 2).

Table 2

Company and Maintenance Department Size Comparison

Company	Corporate Employees	Site Employees	Maintenance Employees	Site Maintenance - to - Employee Ratio
A	100,000	230	150	.65
B	5,000	1,200 /9	165/9	.14
C	70,000	110	6	.05
D	12,000	---	1,000	.08

The respondents' maintenance programs ranged from self-determined undefined mixes of Reactive (RM), Preventive (PM), and Predictive (PdM) tactics through strategic implementations of these, to one with a full-scale corporate executive-driven RCM program (Table 3). Company B utilizes corporate asset management to a large degree, even to the point of re-establishing a significant maintenance training department to prepare for replacement of its aging workforce, yet continues to under-fund its decentralized and (primarily) tactically –focused managers who

Table 3

Maintenance Program Comparisons

Company	Defined Model	Exec. Support	Maintenance Practice	Maintenance Planning	Org. Dev./ Integration
A	RCM	Yes	Reliability	Strategic	No
B	No	No	PM/PdM	Strategic/tactical mix	No
C	No	Yes	PM/Root Cause Analysis/Redesign	Strategic/tactical mix	No
D	No	Yes	Reliability	Strategic	No

are "buried" in breakdown repairs to the point that PM routes and issues are falling seriously behind.

Company C was operating in a totally reactive mode with outsourced technicians in 2008. A new maintenance manager convinced executive officers to hire company technicians and implemented Preventive Maintenance and Reliability techniques, notably root cause analysis (RCA) with accompanying equipment redesign, by leveraging vendors' sales engineering expertise to perform these functions.

The results of these efforts, in terms of planned maintenance activities versus (unplanned) Reactive Maintenance, can be seen in Table 4. Companies A & D, with highly structured, executive supported, and strategically-driven Reliability-based maintenance programs have reduced their "unplanned" breakdowns to such a low level that they refined their definition of "reactive" maintenance to include any work scheduled with less than three-days' notice.

Table 4

Maintenance Department Activity Ratios

Company	Reactive Maintenance	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance
A	---	30%*	65%	5%
B	45%	40%	10%	5%
C (2008)	70%	---	30%	---
C (2009)	30%	---	70%	---
D	---	27%*	66% (PM & PdM)	

Company C's basic RCA efforts have reversed the percentages of Reactive to Preventive work, nearly cutting their maintenance costs in half (from $7 per ton of processed product to about $3.65 per ton). It is quite notable that company C's Reactive work level is at an unacceptably high 45 percent, with downtime reportedly increasing each year.

All the respondents stated that they were not aware of any links between their company's maintenance/asset management and organizational development/performance improvement efforts. Companies A and D did promote company "reliability" cultures in which everyone was made aware of the necessity of their stewardship for all the company resources, and integrated several strategies to develop close teamwork between executives, operations, and maintenance. Company D is widely known for its innovative employee engagement and support efforts.

Themes

A number of themes in support of the literature became apparent through the interview process. First, it became very clear that the literature's proclamation of a "pot of gold" at the end of the rainbow appear true. Maintenance, more specifically reliability, done well, can radically decrease costs and drive performance improvements. Second, the maintenance manager 's knowledge and comprehension of reliability principles and measures, his ability to build a business case and successfully present it to upper management, and executive buy-in and continued support both in budgeting and in transforming the company culture over a period of years appear critical to this transformation. Third, additional components for successful transformation are developing maintenance staff engagement and skills, acquiring CMMS and PdM technologies appropriate to the facility, and vigilant monitoring and reporting of essential KPI's.

The respondents all noted that outsourcing was, at best, a necessary evil to be contemplated only when unfamiliar technology or peak demands required it. All reported frustrations with outsourced staff's motivation, knowledge, and skills.

Each respondent reinforced the literature's notation that instituting reliability practices required investment, that initial efforts would uncover more needed repairs and accomplish them at a faster rate, requiring more money than usually budget for materials. They also noted that this always resulted in long term savings, but with the observation, that most companies were averse to this, as demonstrated by our company B, much to that respondent's frustration.

This amplified respondents' comments about the need for Maintenance Mangers to understand executive-level business measures and present a compelling case for their efforts. One felt that this was exacerbated by the fact that Maintenance was deprived of the knowledge needed even to develop a business case, stating "Maintenance cannot contribute to company productivity if it doesn't have a place at the table."

Chapter V: Discussion

Introduction

We have reviewed what the academic and trade literature tells us about Maintenance practices, and seen that the study and implementation of World Class Maintenance Management practices can be crucially important to the world's environmental integrity, public safety, and economic growth. We have also learned that it is the last frontier for significant performance improvement initiatives in capital-intensive organizations, and that there is lively debate about the most effective models. We have also made inquiry into maintenance and reliability practices in various organizations in the Milwaukee economic region, and found a wide diversity in philosophy and practices.

Limitations

The scope of this study was restricted to a review of the literature and the Maintenance practices of several organizations in the region in and around Milwaukee, WI, USA, with a focus on capital-intensive entities dependent on machinery and mechanical equipment for their operations. Only one of these organizations has significant exposure to the public relative to health & safety.

Our review of various literature resources assumes that quoted case studies are factual and that interview responses were open and genuine. We have also assumed that books, articles, and whitepapers published by trade periodicals and consultants to the profession, and supported by professional on-line discussion and dialogue are accurate and authoritative.

The small number of interviews conducted severely limits our ability to generalize or extrapolate the results, and serve primarily to illustrate the diversity of practices and resultant effects discovered in our search of the literature.

Conclusions

It appears, from the literature, that maintenance management throughout the world is a mix of reactive, proactive, and functionally-based practices, with interviews of, and discussions by, practitioners in the Milwaukee area suggesting little difference.

The relative levels of resource inputs for the given outputs in terms of productivity and product quality, by types of general maintenance strategy, might well be modeled by a funnel, Figure 10.

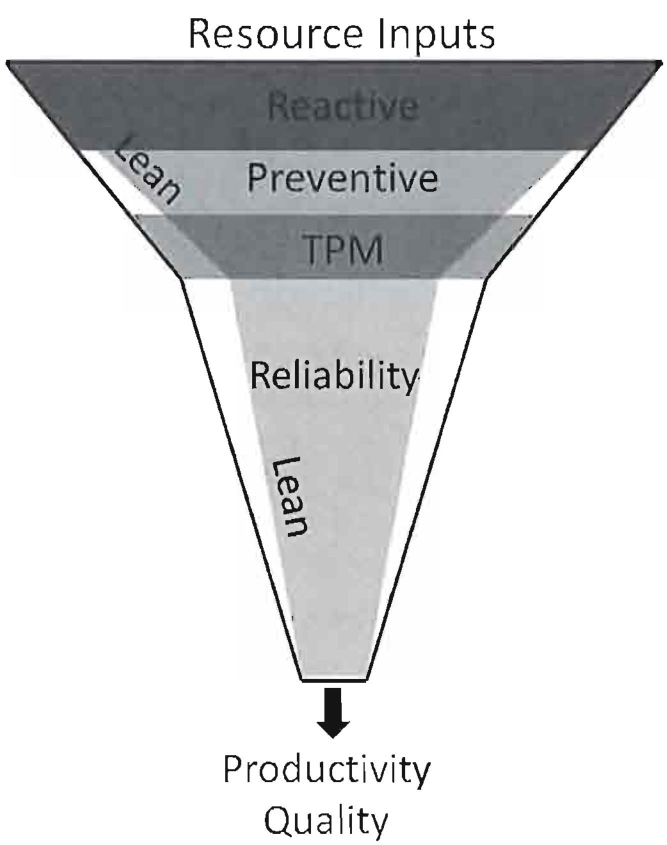

Figure 10. Maintenance Resources Funnel

This "funnel" model graphically represents several of this report's findings. It shows the relative amounts of resource "inputs" required for a given productive uptime "output" when applying each of the given maintenance strategies. Pursuing a "reactive" strategy (or following no strategy whatsoever) - simply fixing things when they break and doing preventive and predictive tasks when time becomes available consumes the most amount of resources. This is, essentially, the "pound of cure" required if one fails taking the "ounce of prevention" Reliability and other function-based strategies require to obtain the same healthy productivity. The smaller "Lean" funnel indicates how various Lean activities can be implemented at any level and with any strategy to effectively reduce the amount of resources required. The increasingly darker color gradations represent how organizational culture change is critical to effecting results with each strategy. This model is only a tool to help visualize the results one can expect when these strategies are fully supported. It does not indicate the reality of mixed modes found in a typical plant, or how various "mixes" might interact to produce results.

We have seen that the Reactive Maintenance consumes vast amounts of resources over time. Adding in or even adopting Preventive Strategies and devoting resources for their accomplishment reduces the net amount of resources required, while changing the organizational culture (TPM, etc.) to effect a sense of engagement and equipment "Ownership", with greater focus on (maintenance) performance measures, will be even more cost effective. Finally, both case studies, and interviews witness that Reliability-centered initiatives employing an organizationally-appropriate mix of cultural change, technologies, and proactive strategies can have dramatic impact in reducing the resources required to achieve productivity and quality, profoundly increasing a company's bottom line while reducing its exposure to safety and environmental risks.

Recommendations

It is fairly obvious by this point that Reliability holds great promise for Industry and Commerce in general. The reluctance of many to pursue it appears to be largely based on ignorance and inertia. It is quite possible that educational seminars and workshops, led by local Reliability practioners, might serve to dispel the images of reliability as cumbersome and "high tech". They certainly would pique the interest of many.

While this study does not conclusively answer the question "Are Organizational Development practitioners aware that there is a form of OD for machines?" a "mechanical" or asset-based OD, if you will. When an OD program is put in place, how successful is Maintenance in ducking this perceived additional workload, and remaining invisible? Similarly, if it does include asset management and maintenance processes, are the personnel aware of the current best practices unique to asset management, are they given the resources to feed-back to the organization the necessary cultural shifts that will enhance the reliability of plant and equipment, synergistically blending the two streams of performance improvement into a harmonious and powerful river (of change)?

One might ask this from the other point of view, "Do Reliability campaigns (ever) attempt to include partnership with OD?" I believe that this would be really rare, given the necessity of executive support for effective OD and the observed issues with simply getting executive buy-in for maintenance improvement initiatives. I suspect that a productive blend of these two performance improvement practices would have the economic equivalent of a nuclear bomb, and certainly deserves further study.

References

BS EN 13306:2001. (2001, June 15). *What does EFNMS stand for?* Retrieved April 18, 2010, from European Federation of National Maintenance Societies: http://www.efnms.org/What-EFNMS-stands-for/m1312/What-EFNMS-stands-for.html

Campbell, J. D.-P. (2006). *Uptime: Strategies for excellence in maintenance management, 2nd edition.* Portland, Oregon: Productivity Press.

Coetzee, J.L. (1999). A holistic approach to the maintenance “problem”. Journal of Quality in Maintenance Engineering, 5, 276-281. doi:10.1108/13552519910282737

Dunn, S. e. (n.d.). *Maintenance task selection*. Retrieved November 4, 2009, from Plant Maintenance Resource Center: http://www.plant-maintenance.com/articles/maintenance_task_selection.shtml

Higgins, L. R. (2002). *Maintenance engineering handbook, 6th Edition.* New York, New York: McGraw-Hill.

IAM. (2008, November 25). *BSI PAS 55:2008 brochure.* Retrieved 2010, from www.theiam.org: http://www.theiam.org/en/utilities/document-summary.cfm/docid/4B71D5F4-EB2A-4A4A-A3274EB9784C01D6

IAM. (2008, December). *The IAM competences framework, part 1: Asset management competence requirements framework. Version 1.0.* Retrieved from http://www.theiam.org/en/products_services/competences-framework/download-the-cf.cfm

Investopedia.com. (n.d.). *Investopedia.com.* Retrieved April 27, 2010, from Dictionary.com: http://dictionary.reference.com/browse/terotechnology

Levitt, J. (2008). *Lean maintenance.* New York: New York.

Life Cycle Engineering. (2008). *Reliability excellence (Rx) definitions.* Retrieved April 16, 2010, from Life Cycle Engineering: http://www.lce.com/Rx_Definitions_60.html

Moubray, J. (1997). *Reliability-centered maintenance, 2nd edition.* New York, New York: Industrial Press Inc.

Nowlan, F.S. & Heap, H.F. (1978). Reliability-centered maintenance. Springfield, Virginia: US Dept. of Commerce.

RP news wires. (2007, 01 23). *Article Archive*. Retrieved May 7, 2010, from Maintenance World: http://www.maintenanceworld.com/Articles/newswires/indicators-maintenance-performance.html

Smith, A. M. (2004). *RCM gateway to world class maintenance.* Burlington, MA: Elsevier Inc.

terotechnology, n.d. (n.d.). *BusinessDictionary.com*. Retrieved May 13, 2010, from BusinessDictionary.com: http://www.businessdictionary.com/definition/terotechnology.html

Wikipedia. (n.d.). *Three Mile Island accident*. Retrieved April 20, 2010, from Wikipedia: http://en.wikipedia.org/wiki/Three_Mile_Island_accident

Wireman, T. (2005). *Developing performance indicators for managing maintenance.* New York, New York: Industrial Press Inc.

Appendix A: IRB Approval

Research Services
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Date: March 3, 2010
To: John Lampi
Cc: Kat Lui

From: Sue Foxwell, Research Administrator and Human Protections Administrator, UW-Stout Institutional Review Board for the Protection of Human Subjects in Research (IRB) *Susan Foxwell*

Subject: **Protection of Human Subjects in Research**

Your project, "*Survey*" is **Exempt** from review by the Institutional Review Board for the Protection of Human Subjects. The project is exempt under **Category 2** of the Federal Exempt Guidelines and holds for 5 years. Your project is approved from **March 2, 2010** through **March 1, 2015**.

Please copy and paste the following message to the top of your survey form before dissemination:

> This project has been reviewed by the UW-Stout IRB as required by the Code of Federal Regulations Title 45 Part 46

If you are conducting an **online** survey/interview, please copy and paste the following message to the top of the form:

> **"This research has been approved by the UW-Stout IRB as required by the Code of Federal regulations Title 45 Part 46."**

Please contact the IRB if the plan of your research changes. Thank you for your cooperation with the IRB and best wishes with your project.

***NOTE: This is the only notice you will receive – no paper copy will be sent.**

Appendix B: Interview Questions

1. Please describe your position and role in this company?
2. How long have you been working in the Maintenance Field and what is your educational and work background?
3. How large is your company and maintenance department?
4. Describe your average workday tasks as a maintenance manager and your Maintenance Department's predominant activities.
5. How are Maintenance Department (& reliability) goals, activities, and budget planned at your site? Do you follow a formalized or commercial program/strategy?
6. How do Organizational Development/Performance Improvement initiatives play a role in your company and the maintenance department's activities? Are they aware of and take into account "Reliability" practices? What level(s) of real support do these initiatives receive?

Appendix C: Interview Consent Form
Consent to Participate In UW-Stout Approved Research

The State of Industrial Maintenance in Metro Milwaukee
It's Implications for Education and Training Initiatives

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Research Description:
This interview will require your honest and best-informed answers to 17 open ended questions pertaining to you and your company's maintenance practices and procedures. Your responses will not be published or divulged in any form that can be associated with you or your company/organization in any way.

Risks and Benefits:
The only significant foreseeable risk in participating in this study is realizing that there may be a need for further training or change in management practices within your organization. The results of this study will be used by educational institutions and professional associations to guide their professional development offerings. The benefits of your participation will be improvement in regional manufacturing productivity in general, and maintenance practices in particular.

Time Commitment, Right to Withdraw, & Gratuity:
This interview will take about ½ hour complete and your participation is entirely voluntary. You may choose not to participate without any adverse consequences. You are not required to answer any question(s), and also may terminate the interview at any time without incurring adverse consequences. You are entitled to a complimentary copy of the completed research study by emailing your request to: lampij@my.uwstout.edu before June 15th, 2010.

IRB Approval:
This study has been reviewed and approved by The University of Wisconsin-Stout's Institutional Review Board (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies. If you have questions or concerns regarding this study please contact the Investigator or Advisor. If you have any questions, concerns, or reports regarding your rights as a research subject, please contact the IRB Administrator.
I hereby consent to participate in this research.

(signed)____
Name____
Date:________________Company____

Appendix D: Comparative Definitions

Levels of maintenance practice:

- Breakdown
- Breakdown & (limited) preventive when time allows.
- Planned preventive (and predictive) maintenance based on OEM specifications and machine history with occasional breakdowns.
- Informal & targeted failure analysis combined with planned maintenance activities and some effort to incorporate Reliability culture.
- Rigorous employment of Reliability Analyses in determining planned maintenance activities and full executive support in changing organizational (asset management) culture.

Company/Organizational size:

- Small company 0 – 50 employees
- Medium Company 51-100 employees
- Large Company 101-300 employees
- Small Corporation 301-1000 employees (1 or more locations)
- Large Corporation 1001- 20000+ employees (Multiple locations)

Maintenance Department size:

- Small company department 0-3 employees
- Medium company department 4-10 employees
- Large company department 11- 20 employees
- Small corporate department 21-50 employees
- Large corporate department 51-200+ employees

Appendix E: Maintenance-Related Professional Associations

- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- American Productivity and Quality Center (APQC)
- American Society for Nondestructive Testing (ASNT)
- American Society for Testing and Materials (ASTM)
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
- American Society of Mechanical Engineers (ASME)
- Asset Management Council (AMC)
- Association for Facilities Engineering (AFE)
- British Fluid Power Association (BFPA)
- Canadian Machinery Vibration Association (CMVA)
- Pan-American Committee of Maintenance Engineering (COPIMAN)
- Equipment Manufacturers Institute (AEM)
- European Federation of National Maintenance Societies (EFNMS)
- Federal Facilities Council (FFC)
- Fluid Power Distributors Association (FPDA)
- Fluid Power Educational Foundation (FPEF)
- Fluid Power Society (IFPS)
- Global Forum On Maintenance & Asset Management (GFMAM)
- Human Factors and Ergonomics Society (HFES)
- International Council for Machinery Lubrication (ICML)
- InterNational Electrical Testing Association

- International Facilities Management Association (IFMA)
- International Maintenance Institute (IMI)
- Institute of Asset Management (IAM)
- Institute of Engineering and Technology (IET)
- Instrumentation, Systems & Automation Society (ISA)
- Machinery Information Management Open Systems Alliance (MIMOSA)
- Maintenance Engineering Society of Australia, Inc. (MESA)
- Manufacturing Skills Standards Council (MSSC)
- National Electrical Manufacturers Association (NEMA)
- National Fluid Power Association (NFPA)
- National Institute of Standards and Technology (NIST)
- Plant Engineering & Maintenance Association of Canada (PEMAC)
- Plant and Facilities Maintenance Association (PFMA)
- Power Transmission Distributors Association (PTDA)
- SIRF Roundtables (SIRF Rt)
- Society for Automotive Engineers (SAE)
- Society for Machinery Failure Prevention Technology (MFPT)
- Society of Manufacturing Engineers (SME)
- Society of Plastics Engineers (SPE)
- Society of Reliability Engineers (SRE)
- Society of Tribologists and Lubrication Engineers (STLE)
- Southern African Asset Management Association (SAAMA)
- Vibration Institute