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Maintenance Work Order Backlog and the Six-Sigma Process

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ABSTRACT: Paper manufacturing is a very capital and labor-intense process with an end product commodity sold in an elastic market. Emphasis on manufacturing costs is a must. In the Pulp and Paper Industry, maintenance is a service to the operating departments and is a cost captured on the financial report. However, this service is often ignored as a cost to operations (and manufacturing) when not completed and the maintenance orders are placed on “work order backlog.” A small percentage of backlog work orders levels out the swings in the maintenance’s daily work schedule, but a disproportionate number over a time period may indicate significant problems in the maintenance area. Using the Six-Sigma Process Improvement Model, a framework is developed to identify causes that allow for a disproportional number of backlog work orders and to develop solutions to solve and prevent excessive backlogs which directly or indirectly constrain an operation/machine and operations’ costs.
placed on “work order backlog.” A small percentage of backlog work orders levels out the swings in the maintenance’s daily work schedule, but a disproportionate number over a time period may indicate significant problems in the maintenance area. The determination of what constitutes a disproportionate number and the possible corrections demand a logical approach. The six sigma five phase model provides a framework with proven success.

Operational effectiveness is a major consideration when determining whether or not an organization has the ability to survive in the global competitive marketplace. Maintenance is a key component in the operational effectiveness equation and it a service agency within the manufacturing organization. Effective and efficient planning, scheduling, and execution of maintenance plans are important activities that work to ensure resources are allocated in the right areas and the sequence in which those resources are needed and used minimize production losses. A high priority is placed on being able to complete as many activities as possible (meeting quality standards) in the shortest amount of time at minimal cost. A major reason for being interested in initiating improvements in the maintenance area is that studies show a majority of the maintenance departments in the United States and Canada operate at between ten and forty percent efficiency and most equipment failures are self-induced. In many organizations the costs associated with direct maintenance activities are captured as line items on monthly financial reports but, often the long-term impact of day-to-day maintenance-work-not-accomplished is not fully recognized or understood. Work-not- accomplished is categorized as the work backlog and includes all jobs; regardless of status, that are not
completed. These jobs include daily and weekly corrective repair work, preventive and predictive routines, and jobs planned for scheduled equipment outages! In the pulp and paper industry the traditional role of maintenance is portrayed as a service organization that supports operating departments. While a small percentage of work order backlog is necessary for leveling out the swings in the craftsmen's daily work schedules, a disproportionate number of backlogged work orders over a lengthy time period may indicate significant problem(s) in maintenance management, especially in the areas of resource availability and distribution.

Research Issues and Objectives

To illustrate the importance of maintenance work order Backlog and the application of the six sigma process, a specific firm is researched and its maintenance process analyzed. The firm under research is a world’s preferred marketer and manufacturer of papers for communication. It manufactures 6 million tonnes of newsprint, 1.9 million tonnes of value-added papers, 2 billion board feet of lumber, and recycles over 3 million tonnes of paper. The firm has a major capital asset, Paper Machine, Alpha, (P/M Alpha) that is less than two and a half years old and is experiencing difficulties in its operations due to the maintenance process. The number of items on the maintenance work order backlog list has continued to increase steadily over its short life span. The backlog of incomplete maintenance work is directly and indirectly constraining the production capabilities of P/M Alpha. The focus of this research is on maintenance, specifically on the maintenance work order backlog issue on P/M/ Alpha. The primary objective is to determine if there is sufficient valid data to support the hypothesis that the maintenance
work order backlog on P/M Alpha is a real issue. If it is determined that the backlog is an issue the secondary focus will be to develop possible solutions to minimize the number and/or impact of backlogged work orders. The Six Sigma model will be employed.

The benefit of utilizing the Six Sigma Improvement model as a primary guide for research analysis is in its ability to provide large amounts of problem-solving structure for addressing a very complex issue. The power of Six Sigma lies in its focus on processes that create products or services, not simply the outcomes. Mapping the process using a model such as Six Sigma, results in greater understanding of the link(s) between steps. With this knowledge comes the realization that the greatest opportunities for improvement are not always in the teeth but in the gaps between the teeth. Using numbers to measure the organization’s capabilities facilitates clarity and enables selection of one problem to address at a time as a project instead of trying to fix everything at once.

The key to the Six-Sigma Process Improvement is the five step Model: Define – identify the problem, define the requirements, and set a goal, Measure – validate the problem/process, refine the problem/goal, and measure key steps, Analyze – develop causal hypothesis, identify vital few root causes, and validate the hypothesis, Improve – Develop ideas to remove root cause(s) in defining problem, measurement, and analysis, Control – establish measures to maintain the performance/correct problems as needed.

Methodology
Sources of information come from analyzing P/M Alpha historical maintenance records and documents, from independent technical and trade journals, and the Internet. The trade and technical journals were researched to determine if there are established industry standards for determining whether or not an organization's work order backlog is in or out of control. Additional baseline information in maintenance areas such as: number of craftsmen required for paper machine maintenance, crafts involved, percentage of overtime, percentage of work completed versus work planned, percentage of break-in work, and maintenance man-hours per tonnes of production were noted. A comparison was made between P/M Alpha information, industry standards, and opinions of maintenance subject matter experts and consultants.

Research Discussion

The current status of the maintenance organization has 128 hourly maintenance craftsmen organized into two unions, the International Brotherhood of Electrical Workers and the International Association of Machinists and Aerospace Workers (AFL-CIO). The maintenance organizational strategy is one of area maintenance versus a central shop. Therefore, the 128 craftsmen are distributed across 5 area shops including the key paper machine (P/M). The P/M Alpha is a major aspect of the total process and due to its abilities and capacity is its own area shop. These area maintenance shops support their assigned operational groups and are the permanent work areas for craftsmen assigned to them. However, some craftsmen are often assigned temporarily on a day-to-day schedule to other areas (i.e., machine outage days).
The Mill operates on a 24 hour/7 day a week/365 days a year schedule. The majority of the craftsmen (104) are assigned to the Monday thru Friday day shift schedule (1am to 3:30pm). They are paid for 8 hours of work and they take an unpaid 30-minute lunch break. Contractually there are no other "break" periods. The remaining 24 craftsmen are divided into four rotating (southern swing) shifts: days, evenings, graveyards, and off shift. There are six craftsmen assigned to each shift. Management decides how many craftsmen and what craft skills are needed in each area. The shift-craftsmen do not have pre-assigned work in specific areas but are primarily responsible for covering emergency work throughout the mill. The operational area supervisors decide what work and the priority of that work for the maintenance shift craftsmen.

The total available hours craftsmen are directly involved in maintenance work is from an efficiency perspective, a theoretical number. A craftsman's time can be taken up by a multitude of activities that take away from actual wrench time (the actual time it takes to perform the maintenance activity, hands-on-time). At this facility serving the five areas the day for a craftsman can be divided accordingly; 6% AM shop time, 37% AM work time, 3% AM break-time, 37% PM work time, 3% PM break-time, 6% PM shop time, 4% travel time, and 4% other. The corporate standard has labor productivity - total work order hours spent on "wrench time" versus all other time - targeted at (60%+). This target number is a key element that impacts the reality of what is actually taking place on the shop floor versus the perception of what is being accomplished.
The specific information about this service is dependent on the accuracy of the repair activities. To this objective, the Mill utilizes a computerized maintenance management system (CMMS) to collect data and generate reports. This system is a fully integrated business system that is electronically tied into the stores, purchasing, and payroll entities. From a purely maintenance perspective the primary purpose of the CMMS is to capture and build useful equipment histories. These data histories are critical for yielding specific information about operations that in-turn can be used to generate analysis through statistical methods. The workhorse that captures the majority of the planned and unplanned work information within the CMMS is the work order. The work order template for the CMMS is comprehensive in providing an environment for data entry. It has twenty-nine separate data fields for capturing information. The maintenance planner, from work order information, plans the daily and weekly work schedules. The template for the weekly schedule is detailed and the information is incorporated into the daily work schedule.

The Work Request/Work Order flow within the CMMS can be compared to an in/out bin. Work Requests can be rejected (for one or more reason codes) or accepted and bumped up to the next level, the Work Order. The maintenance Work Order for the Lufkin mill is the document on which all work requiring more than two hours of labor and/or over $100 in materials is recorded. Although multiple data fields can be built into the work order template, the basic repair data fields come in four categories: origination, planning, scheduling, and results. It is important to get all data consistently and correctly entered into each field. Most problems occur at the work order origination and multiply as the
A work order is simply a work request that has been given approval and has had its status code advanced. Within this system there are four types of work orders (Type 1 - Corrective Maintenance, Type 2 - Preventive, Type 3 - Standing Work Orders, Type 4 - Capital & Expense) and four priority categories (1 - Emergency, 2 - Urgent/same day, 3 - Regular, 4 - Normal/ASAP). Status codes provide the structure for the work order life cycle and are designed in logical progression from work request, to work order, to work history. One of the interesting points about this data is that five months ago, the maintenance and P/M Alpha operation groups meet to review and reconcile the work order backlog. As a group they agreed to purge 228 work orders from the backlog, leaving 268 remaining. Since then the backlog has climbed back to 479 work orders.

This information is significant when comparing the number of weeks in the P/M Alpha work order backlog with world class and corporate targets. Opinions may vary on what is a healthy amount of backlog, but a general rule of thumb is that two to four weeks will provide a balanced workload for maintaining facilities. Doing a simple calculation for the mechanical daily/weekly backlog, 985 hours/(10 employees x 40 hr/wk), the results will be a backlog of 2.46 weeks. But, is this a real number? As discussed that a target for labor productivity (actual hands-on) is 60%. 400 hours for the labor productivity calculation becomes 60% of 400 or 240 hours. Furthermore, subtract from this 240 hours the time craftsmen spend working on outage work orders, vacations temporary set-ups into salaried positions, sickness, absenteeism, training, special assignments, and etc. This calculates into approximately 40 hours a week. Now 200 hours becomes the labor
productivity number and the resulting work order backlog for the daily/weekly schedule increases to 4.9 weeks. For the scheduled equipment outage backlog, the results are more dramatic. The major point to remember about scheduled equipment outages is the attempt to get the maximum amount of work accomplished in the shortest period of time. The paper machine in question is scheduled for 20 hours of outage time per month. However; operational shutdown and startup times are included in that timeframe so the actual window of opportunity for maintenance work is reduced to 14 hours. For scheduled outages, the planning includes additional craftsmen borrowed from other areas and an increase in the use of outside contractors.

It is important to understand the role of Preventive Maintenance (PM) because its activities are included in the calculation for determining weeks of backlog work. PM is best described as routine repetitive work designed to eliminate breakdowns and unscheduled or emergency repairs. Most maintenance experts agree that PMs are planned work but, because of their routine and repetitive nature, do not require planning beyond their initial setup phase. Examples of PMs would include meter readings, inspections, nondestructive testing, and cyclical or repetitive events. Routine PMs, such as lubrication, cleaning, inspections, adjustments, and minor parts replacement are the first steps in beginning a preventive maintenance program. Predictive PMs are a more advanced form of routine inspections. Using present day technology inspections can be performed that detail the condition of virtually any component of a piece of equipment.
Examples of this technology would include vibration analysis, spectrographic oil analysis, and infrared scanning. The benefit resulting from these proactive activities can pay considerable dividends to both maintenance and operations. A timely PM program usually uncovers problems before they become serious enough to cause equipment failures. Routine adjustments and minor repairs take the place of failures. The potential for reducing breakdowns may be as high as 50%. Preventive maintenance inspections usually uncover major jobs that require planning with sufficient lead-time to allow planning to be done. With maintenance and operations looking for things that cause problems fewer problems escape detection. This, in turn, reduces the potential for emergency situations. The goal of a Preventive/Predictive Maintenance (PPM) program is to impact the cost of corrective maintenance in a positive way by reaching a point of equilibrium in spending between PMS and corrective maintenance. Whether daily/weekly or outage work, typical maintenance delays occur. These delays can be categorized into five main areas: material, prints/manuals/procedures, coordination, tools/equipment, and job interferences. Material related issues revolve around pre-determination of what parts are needed before the job starts, finding the symbol number of needed parts so they can be ordered out of the storeroom, waiting for parts delivery, finding (non-stock) direct ordered parts for the job, using inferior parts, finding out required parts are not available after the job has started, and finding additional parts after the scope of the job has been expanded. Prints/manual/procedures has to do with to locating drawings, equipment manuals, missing or inaccurate information, and having adequate direction on how to lockout. Coordination delays emphasize the importance of pre-planning. Delays in this area are usually around unclear description of work to be
performed, equipment is not available as scheduled, waiting for work priorities to be set, waiting for job assignments, waiting for additional craft support, waiting for job site to be prepared, too many or not enough people assigned to the job, and not knowing the job steps or having instructions on how to perform the job. The tools and equipment delays include tools that are missing, special tools that are misplaced or not available, hoists and cranes not available when required. Job interferences can include anything from the weather, to not having ready access to job site or equipment, to the scheduling of too many jobs at the same place at the same time.

Analysis of Research

All systems exhibit variation and reducing variation in the resources will reduce variation in the outputs. The work order backlog issue on P/M Alpha requires looking at all the resource components that impact the outputs in the maintenance system and reach conclusions based on a balanced set of measures. Complex issues are not often resolved through the identification of one specific root cause. In many instances the focus on variation reduction versus root cause elimination will result in faster, attainable improvements. Probable cause areas include the CMMS and its supporting networking systems, the process and procedures associated with the initial identification of needed work to the actual work completion, equipment reliability, and the human element (craftsmen, operators, supervisors, managers, outside contractors).

The computer maintenance management system (hardware and software) being utilized is reliable and incorporates additional enhancements above and beyond the necessary components of a basic CMMS. The mill network on which it runs has insignificant
unscheduled downtime. The planned network downtime averages ten hours or less per quarter and is scheduled during off-peak hours on the weekends. There are approximately 210 individual computer workstations located throughout the mill and ninety percent of them are running the CMMS software. This means availability for user (operations, maintenance, supporting areas) access and data input does not seem to be a significant problem. However there seems to be weak spots in the area of consistency of data input and utilization of work order status codes, report writing, requesting reports from the database, generation of reports, and a software limitation. The report areas require additional specialized skill sets, other than those needed for data input. There are a limited number of people with these skills in the mill. This is a bottleneck that creates delays in the distribution of basic information and diminishes the motivation for people to request additional information for analysis. The software limitation is in the inability of the system to subtract partially completed work from a work order. For example, if a work order has an estimated time of 64 man-hours and 32 hours are completed, the system will continue to show 64 hours of work needed until the work order is 100% completed. Even though the planner can manually access individual work orders and re-enter new estimates this is not done on a regular or consistent basis. The CMMS is a powerful database that is supporting the maintenance effort in many areas. However, the system is being underutilized for some activities and improperly utilized for others (i.e., work order information and correct priority and status coding).

The current process and procedural areas for getting work identified and completed seem to need further tweaking for improvement in communication agendas rather than on
partial or total restructuring of the planning process. The number of people who enter work requests into the CMMS is steadily increasing, operators, craftsmen, supervisors, managers, etc. These work requests go directly to the designated maintenance planner. Every weekday morning at the maintenance planner meets with the area maintenance supervisors and operations management to: 1) review emergency and corrective work requests that have been entered into the system from the previous sixteen hours and determine if they are complete or incomplete, 2) determine if priorities have changed on the daily work schedule (do we have to break into the daily schedule and postponed work already scheduled in order to make craftsmen available to work on higher priority items?), 3) review maintenance manning and work schedule for the next eight hours. Each Tuesday the maintenance planner meets again with this group to plan out the weekly work schedule for the up-coming week. On Thursdays this group meets again to plan work for scheduled equipment outages. These meetings are opportunities for resource negotiation with operations providing information on priority of work and possible consequences if work is not accomplished and the planner providing information on availability of maintenance resources.

In the area of equipment reliability the first question that needs to be answered is whether or not the maintenance department is in control of the equipment or the equipment is in control of the maintenance department. Stable systems produce consistent, predictable outputs and allow planning for future improvement. One of the interpretations of the paper machine planned and unplanned downtime trend charts might be that the machine, although it has been operating for two years, is still in the late stage of a start-up curve.
The importance of this insight is that the maintenance organization is not in a start-up support mode. They are in a production mode and organizational resources are allocated from this perspective. The inability to meet target activities associated with planned and scheduled outages as a result of unplanned and unscheduled events is apparent. This is a direct correlation to equipment reliability issues. Two areas that seem to have a direct correlation on equipment reliability are the percentage of scheduled compliance and percentage of break-ins to the daily/weekly schedule. We can readily see a low percentage of scheduled compliance and a high percentage of break-ins. These numbers would indicate that there is a lot of emergency work coming into the system. Emergency work is a priority that applies to work that must be done immediately to prevent or correct serious safety hazards, environmental hazards, or loss of production. Emergency priority work starts immediately, bypasses the CMMS approval process, and is worked straight through until completion. Within the emergency priority are five criteria: 1) production is stopped, 2) production is going to stop, 3) a serious injury will result, 4) an environmental impact will result, and 5) catastrophic loss of capital equipment will result.

In the first quarter of the year, fifty percent of the work orders were coded as emergencies. Another indication of unstable operation results from a review of the trends for the percentage of Preventative/Predictive (PMs) being performed and the percentage of planned jobs being completed as planned. The interpretation of this information can go in many directions but it seems apparent there is a domino effect on the work order backlog as a result of equipment reliability issues. If the magnitude of emergency work is so great that maintenance facilities cannot complete a majority of planned work then there is no other option but for the backlog to increase. Also remember that the PPM
work is a part of the planned daily work. The organization’s ability to identify equipment related trouble before it happens is further limited if it cannot accomplish the PPM work. The effect of excessive backlog is higher overtime use and higher cancellation of valid work. Higher overtime in most cases results in the company paying fifty percent more for those hours and only getting a seventy percent return in productivity. The cancellation of valid/required work is a risky option. When an organization is so overworked that the daily and/or weekly PMs are not completed or, are cancelled due to lack of resources, a greater possibility exists that a particular PM will not be performed for a much longer period thereby increasing the risk of unscheduled/unplanned downtime and subsequent corrective maintenance work.

Recommendations

CMMS

The electronics system recommendations focus more on performance management of human resources rather than any major changes in hardware or software. Management reinforcement of expectations for consistency of data input and proper coding, as well as providing additional training to close skill and knowledge gaps would not only improve the validity of raw data input but would also minimize the time spent in analyzing, planning, and scheduling work. The immediate focus group would be training for the maintenance planners, especially in reinforcing the need for consistent status code entry. The second focus of training focus should be on the craftsmen in the area of entering the correct work order type for needed maintenance work discovered during routines. The
reports issued may be improved by initiating a meeting with stakeholders to begin the process of developing a strategy to address *adhoc* requests for reports.

**Processes and Procedures**

In this area there are two recommendations. Number one is to designate a gate-keeper(s) in the operating department to review all work requests (except for emergency) before they are forwarded to the maintenance planner. This would centralize the process. Centralization would reduce the number of duplicate work orders, reduce the variation in the amount and content of information placed on the work order, and contribute to a more efficient communication exchange between operations and maintenance on work order status and priority during their daily maintenance planning meeting. The second recommendation would be in the area of forecasting outage work. Since we know that the paper machine has scheduled long (12 to 16 hours) and short (6 to 8 hour) outages each month, the outage work order backlog could be planned out for six to nine months. The first benefit of this would be that operations could see that although there is a substantial amount of work in the backlog, there is a schedule to get it accomplished. The second benefit would be in the effectiveness of the negotiations for resources between maintenance and operations during the outage planning meetings. There would be not be the unrealistic pressure of trying to get every work order completed during every outage and work orders could be systematically moved up or down in priority.

**Equipment Reliability**
This is an area that needs to be addressed from five perspectives. The first initiative is a proactive approach by top mill management to address equipment reliability issues by working with corporate entities in their interaction with equipment manufactures and vendors. Questions should be surfacing as to whether or not equipment performance guarantees are being meet and if not, what action plans are being implemented to address those issues. The second is a review of the skill and knowledge level of the mills in-house maintenance expertise as it relates to the new equipment and technology associated with this paper machine. Does the mill have the bench-strength (engineering and crafts) that is required to repair and maintain the equipment? Third is a review of the equipment bill of materials and spare parts. Have critical parts been identified and made readily available so that equipment can be fixed right the first time and reduce repetition of work? Number four is an in-depth analysis of the benefit being derived from the preventative/predictive maintenance routines. Are the routines focused in the right areas? Are they getting accomplished? Do we have the right craftsmen performing them? Is the documentation process complete and accurate? Number five is a review of the equipment operating procedures and validation that, on the operations side of the equation, the equipment is being operated (shutdown, started-up, monitored during operation) properly.

**MMI - Man- Machine-Interface**

The first recommendation in this area is to further analyze the labor productivity (actual hands-on) percentage and ways to increase it. Improvement in this area is like adding additional craftsmen to the workforce. The second area to analyze is the benefit of
further utilizing contractors. Although there is the issue of quality of work there may be methods to minimize this and in return realize the benefit of reduction in overtime as well as the $15 dollar difference in hourly cost/craftsman. Routines would be the third area to analyze. Can we find a way to be more effective and efficient? Can the operators become more involved? How can documentation be structured and communicated to ensure routines are not redundant.

**Research Conclusions**

The subject of work order backlog is complicated but along with other resources backlog information can be a guide to operational capabilities. However, like many other powerful tools, it does not give up answers easily or completely unless those analyzing its characteristics can fully understand how it is being measured and what the measurements mean. Currently the paper machine crew of the maintenance organization is primarily focused on keeping their heads above the water on a day-to-day basis. Although some attention is paid to long-term planning, the infrastructures already in place are not being fully utilized to improve work order backlog issues. The work order backlog has to be managed effectively in order to maintain the validity of the data.

The benefit of utilizing the Six Sigma Process Improvement Model as the primary guide for this research is in its ability to provide large amounts of problem-solving structure for addressing a very complex issue. The power of Six Sigma lies in its focus on processes that create products or services, not simply the outcomes. The mapping that occurs within the six sigma process helps identify and understand the steps within the problem
being addressed and the links between these steps. With this knowledge comes the realization that the greatest opportunities for improvement may be in the gaps and not in the obvious. Using numbers to measure the organization's capabilities facilitates clarity and enables selection of one problem to address at a time as a project instead of trying to fix everything at once.

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