Considerations for Planning and Scheduling

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Introduction

Planning and scheduling tasks tend to be based upon fixed times in both the internal and contracted maintenance arena. This can lead to inefficient or ineffective use of resources and the decline of the maintenance department towards reactive maintenance, further reducing the efficiency of the program. There are a number of ways to not only ensure proper completion of maintenance tasks, both scheduled and reactive, but also to improve wrench time.

In the production and operations arena, there are a number of methods of scheduling production for maximum efficiency. The method for getting the most out of the process is by determining, first, if the production method is a job shop, batch, assembly line or continuous flow. Once operations has determined the type of process, scheduling can be performed using simple methods, with unknowns including suppliers and uptime. In fact, some planning methods review production and take into account reduced throughput due to improper maintenance without realizing it.

Maintenance is slightly different in that it can be a combination of all four systems. For instance:

1. Reactive Maintenance (RM): This is a job-shop process where each repair and return to service is handled on a case-by-case basis.
2. Preventive Maintenance (PM): Depending on the type of PM, this can be job-shop, batch or assembly.
3. Predictive/Condition-Based Maintenance (PdM/CBM): These are generally batch or assembly with continuous monitoring falling under continuous flow.

Add in the variable of individual training, experience and aging of the workforce, planning and scheduling can become quite complex, with the added issue of production and operations departments that may not turn over equipment for maintenance. As a result, many planning and scheduling philosophies take the easy way out and over-schedule work. This leads to frustration on the part of the workforce from never being able to catch up to their daily workload. The result tends to be falling back on performing tasks in the exact amount of time outlined by the task and a growing lethargy, or even unnecessary overtime to meet PM task completion.

In this paper, we will discuss how to bring these different issues in line in order to develop a consistent strategy to improve your wrench time. The improved efficiency and effectiveness of your maintenance department will provide additional resources from your existing assets, or will help identify the lack of assets that is impacting your company.

The Workflow Concept

The Workflow Concept (WFC) is derived in the same way that workflow is determined for production, including the methods of Design for Manufacturing and Assembly (DFMA), in which our concept is Design for Maintainability (DFM). Does this refer to changing the design of equipment when it is purchased? Somewhat. However, it also refers to designing the maintenance process around the actual maintenance requirements. In effect, a part of DFM includes such processes as Reliability-Centered Maintenance (RCM) which is a tool used to determine the optimum maintenance for a system.

The concept of RCM provides the information of what the optimal maintenance requirements are, with evidence for that maintenance. The concept of DFM provides the methods for assisting the RCM process in determining budget requirements while also providing information on individual manpower requirements based upon the resources available. It is much like a sports team in that if you coach to a strategy, then your season will be poor; if you coach and develop your strategy to the capabilities of your players, you will do very well. In this case, we are going to look at the capabilities of our personnel and resources and match them to the maintenance development process strategy.

The concepts of WFC and DFM are not unique. They were born of the efforts of production and operations sciences and industrial engineering. The primary difference is we are going to match these traditional manufacturing principles to the application of maintenance scheduling and planning. This is not a significant leap nor is it particularly complex.

Components of the WFC:

1. Determining the maintenance task requirements through processes such as RCM;
2. Performing time and training studies in order to determine the time necessary to perform tasks and to determine optimal methods for performing the tasks;
3. Development of best practices to match the optimal task methods. These should be created in terms of processes and may include times for actual steps;
4. Determine qualifications of individual maintenance personnel for these practices;
5. Benchmark existing or similar best practices and determine the gap between these benchmarks and existing personnel capabilities;
6. Develop goals for the individual personnel based upon the gap; and,
7. Schedule according to the capabilities of personnel.

For the purposes of this paper, we are going to assume that the RCM process has been completed and we are determining the DFM.

Time Studies

The idea of the time study goes back to the early days of Scientific Management. The idea is to break up a task into manageable chunks and determine the times for each step. The result of a time study can provide the following information:

1. Which tasks, or combination of tasks, can complete the steps the fastest while maintaining quality of work and safety;
2. What resources are required for each portion of the task, including personnel requirements; and,
3. The total man-hours and linear man-hours required to perform the tasks by individual or by projecting based upon experience and training.

Time studies are often seen in a negative light by personnel, leaving it up to the individual manager, or team, to determine the best way to approach this most important step in the maintenance management process. The tools of the trade, from a technical standpoint, however, are a timer and a notepad. As we are assuming that such a study has not previously been performed, the notepad should be used to take notes on the individual steps and the times to perform each one. Observations by the analyst should also be noted including the quality and safety aspects of the work being performed.

The analyst must have experience in the types of tasks that are being performed with the optimal person having actually performed the tasks in the past. All records developed must be kept for future analysis to assist in review of the maintenance process through such programs as the Maintenance Effectiveness Review (MER).

A proper time study includes the development of a sampling strategy which includes the number and experience/training of the personnel and the number of task cycles to be studied. This can then be used to develop a minimum, maximum and average task time which is necessary to understand task flow and for scheduling purposes.

The number of task observations, per task, across the experience/training of personnel should be broken into increments and the percentage of each group to the population of personnel should be determined. The number of task observations can be determined as shown in Equations 1 and 2, where:

- ☑ E = Absolute Error
- ☑ p = Percentage occurrence of activity or delay being measured
- ☑ N = The number of random observations (sample size)
- ☑ Z = The number of standard deviations for the desired confidence of the study:
  - Z = 1.65 for 90%
  - Z = 1.96 for 95%
  - Z = 2.23 for 99%

Equation 1: Absolute Error

$$E = \sqrt{\frac{p(1-p)}{N}}$$

Equation 2: Required Sample

$$N = \left(\frac{Z^2 p(1-p)}{E^2}\right) \Big/ 2$$

For instance, if you have 120 maintenance personnel and you are examining a motor greasing program in which an average of 25 motors are greased in an 8 hour period and you know that the personnel performing the greasing are utilizing approximately 5 hours per day. When reviewed, you have 20 personnel who are fully trained with experience in greasing, 30 who are trained but with only a little experience, 35 who are familiar with motor greasing and 35 who are not. That would be 17% experienced, 25% with some experience; and 29% of each of the others, and then the number of samples would be spread across the appropriate personnel. The Absolute Error would be 9.8% (0.098), when considering all 25 machines and the required sample for 95% confidence would be 49 tasks. If reviewing all 120 personnel, the 49 tasks being studied would be extended as follow:

- ☑ Experienced: 49 * 17% = 8
- ☑ Some Experience: 49 * 25% = 12
- ☑ Familiar: 49 * 29% = 15
- ☑ Unfamiliar: 49 * 29% = 14

The analyst will have to determine which mix of personnel are selected for each of the time studies. This particular approach will also provide us with an estimation of the training gap time from each of the levels to the next, along with training and experience records for each level.

For the time study, itself, a linear breakdown, number of personnel and times for each step of the task should be described and diagramed by the analyst for each of the tasks being reviewed. The actual times are multiplied by a performance rating that may be above or below ‘1’ depending upon the analyst’s observation that the observed personnel are working faster or slower than normal.

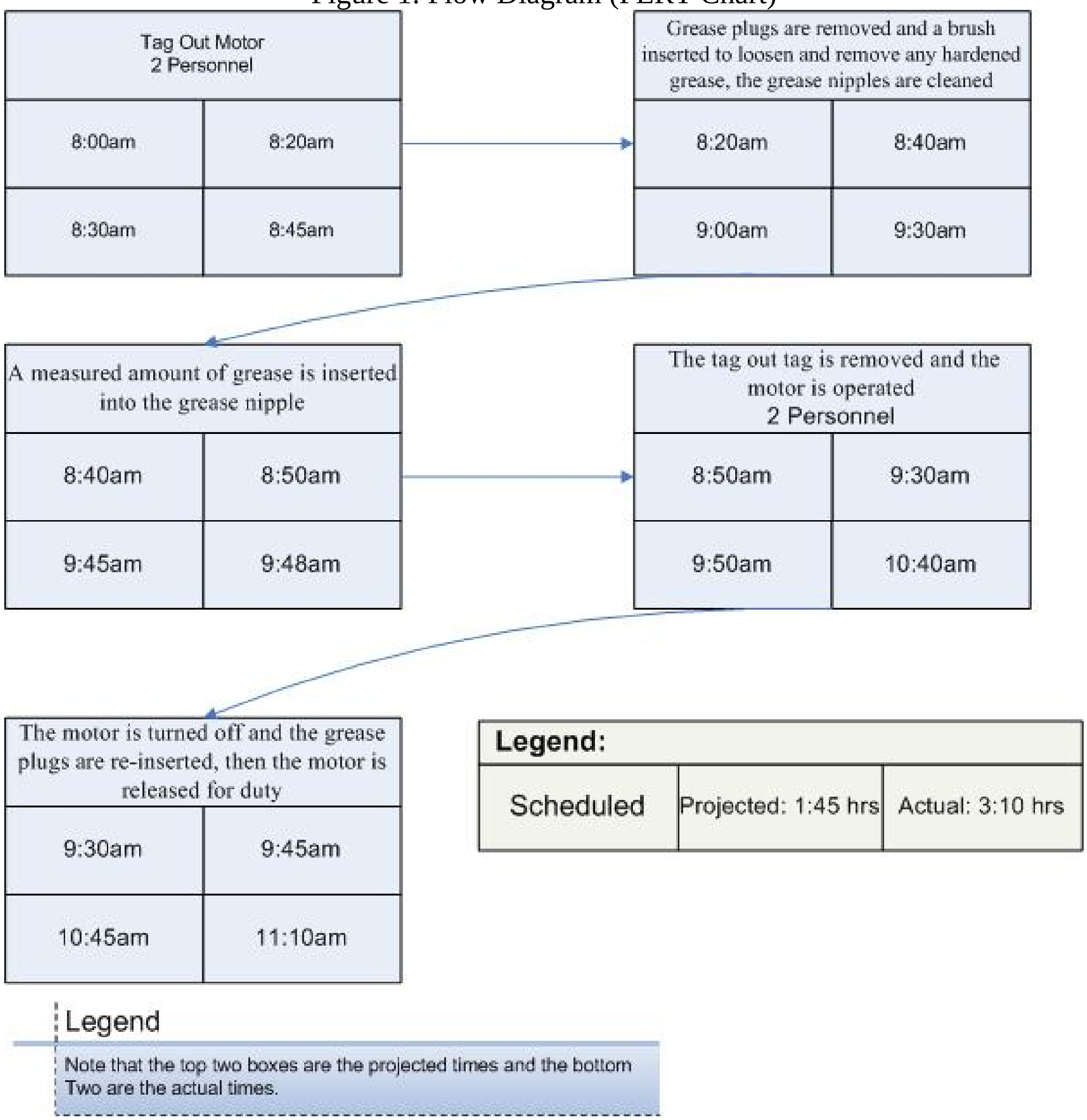
Using the above example, the tasks for the first experienced maintenance person are determined as follow:

1. The equipment to be greased is tagged out;
2. Grease plugs are removed and a brush inserted to loosen and remove any hardened grease, the grease nipples are cleaned;
3. A measured amount of grease is inserted into the grease nipple;
4. The tag out tag is removed and the motor is operated;

5. The motor is turned off and the grease plugs are re-inserted, then the motor is released for duty.

The times and personnel involved are diagramed as shown in Figure 1.

Figure 1: Flow Diagram (PERT Chart)



The total linear time is 3 hours and 10 minutes which deviates significantly from the projected 1 hour and 45 minutes. When the notes from the analyst are reviewed, it is determined that the maintenance person was called away for other tasks and meetings during and between tasks. In the task blocks in Figure 1, the top row is the projected time for each task and the second row is the actual time in linear hours. The actual man-hours for this task can be determined as 2 hours and 3 minutes for one person and 1 hour and 5 minutes for the second person. In maintenance reviews, this particular experienced maintenance man was determined to be slow.

A second experienced maintenance person is studied. In this case, the maintenance man does not tag out the electric motors or run them after greasing. Instead, his tasks read as follow:

1. The motor is left energized;
2. Grease plugs are removed;
3. Grease is pumped into the bearings until fresh grease shows from the grease plugs;
4. The grease plugs are replaced and the motor is returned to service.

The total time per motor is determined to be 25 minutes and only one maintenance person required. The times across all experienced personnel average out to 1 hour and 46 minutes, close to the original time projected. However, the greasing practices vary between the two extremes noted above. This is also observed with all the other levels, whose times run as shown in Table 1 (Note that normally the average should be weighted but is not in this example).

Table 1: Direct Calculated Man-Hour Totals

Type of Personnel	Max Total Man-Hours	Min Total Man-Hours	Average
Experienced	3:08 hours	0:25 hours	1:46 hrs
Some Experience	3:15 hours	0:40 hours	1:57 hrs
Familiar	3:45 hours	1:00 hours	2:22 hrs
Unfamiliar	4:00 hours	1:30 hours	2:45 hrs

Because of the dramatic variation in hours, deviation from 9.8% error and steps at each level, a review of industry practices is performed and it is determined that the first example, above (Figure 1) follows the industry best practice. It was also noted that the fastest time (25 minutes) also resulted in the greatest number of bearing failures following greasing PM's. However, the total man-hours benchmarked is the original 1:45 minutes. The analyst reviews the notes and observations and makes the following calculations:

- ☑ Step 1: 0:15 hours * 1 = 0:15 hours
- ☑ Step 2: 0:30 hours * 0.85 = 0:25 hours
- ☑ Step 3: 0:03 hours * 2 = 0:06 hours
- ☑ Step 4: 0:50 hours * 0.85 = 0:42 hours
- ☑ Step 5: 0:25 hours * 0.85 = 0:21 hours

It is also reviewed and determined that the lockout/tagout procedure only requires one maintenance personnel. The same review is given to the rest of the experience levels and the results are shown in Table 2.

Table 2: Modified Man-Hour Totals With Best Practice (3% Error)

Type of Personnel	Max Total Man-Hours	Min Total Man-Hours	Average
Experienced	2:05 hrs	1:35 hrs	1:49 hrs
Some Experience	2:15 hrs	1:40 hrs	1:57 hrs
Familiar	2:45 hrs	2:00 hrs	2:22 hrs
Unfamiliar	3:10 hrs	2:20 hrs	2:45 hrs

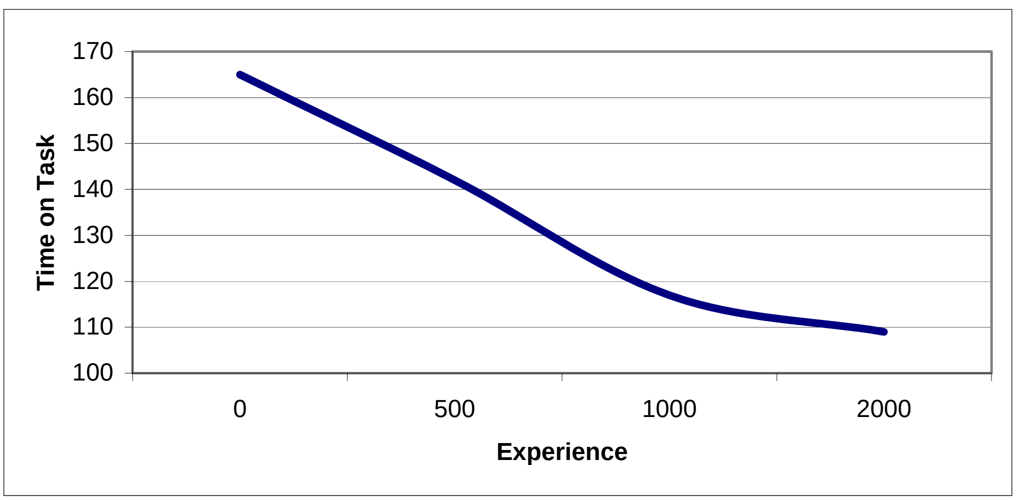
As noted, the actual average hours were equal, or close, to the original average hours. This allows the planner/scheduler to view each level of experience with set Upper and Lower Control Limits (UCL/LCL).

Training/On-The-Job Training and the Gap

With the information shown in the example, along with information on training and experience of the associated personnel, the gap can be evaluated as well as the time to bring less experienced personnel up to speed. For the purposes of the example that we have been using in this article, we will assume that the average training and experience is as follows:

- ☑ Experienced: 2,000 hours lubrication experience and training. Some gap required for some of the personnel once the new greasing best practices have been put in place.
- ☑ Some Experience: 1,000 hours lubrication experience and training.
- ☑ Familiar: 500 hours lubrication experience and training.
- ☑ Unfamiliar: No experience.

Figure 2: Experience and Average Hours



Through the development of this curve, the learning gap can be estimated. This is extremely important as it provides evidence of the required training and OJT experience in order to improve times. When planning personnel, it also provides the information necessary to determine the gap between experienced personnel who may be retiring and new personnel hired. This learning curve and the time study should be re-performed at a scheduled point after the best practice has been in place, such as 6 months to a year, in order to measure the impact of the best practice procedure and to correct any errors in the time study.

Identifying Other Losses

There are a number of losses and concepts for improving the efficiency of tasks, such as the one used as an example in this paper. As part of the exercise of WFC and DFM, the lost time is reviewed and maintenance process design methods are investigated. For this we will introduce a second example before returning to our first one.

In this example, we will consider a motor repair shop department which is a job-shop scheduling environment. The initial study was performed in order to determine why the time per repair was increasing, wrench time was decreasing, on-time deliveries were non-existent and the warranty rate was also increasing. A new supervisor was introduced into the department who had WFC/DFM experience. During 30 days of observation, it was noticed that customer service personnel would bypass the supervisor and approach repair technicians directly throughout all departments, usually their favorite technician regardless of capability and training. The usual instructions were to stop work on one job and start another 'emergency' job at which point work would stop on the task that the technician was working on in order to start another job. In some cases, a few technicians would work on more than one job simultaneously because upper management would approach them directly on their increased times to complete work. The observation was that on 75% of jobs that were interrupted, additional work was missed on disassembly task reports, resulting in improper quotations, and steps were missed in the reassembly of motors resulting in warranty repairs. On jobs that were not interrupted, these issues occurred in less than 1% of the work. The average billable time per technician, in an 8-hour shift, was 4.5 hours, resulting in huge profitability losses and increased operating costs. During this time, the supervisor also evaluated the capabilities of the technicians and performed time studies based upon the time cards turned in for each job. There were 12 customer service reps and 45 shop personnel with 12 being in the supervisor's department.

The new supervisor implemented several best practices that had been observed in other repair shops. All repair requests had to be passed through the supervisor who would then schedule the appropriate personnel to perform the work. Emergency jobs would be scheduled as the next-in-line and/or spread between routine jobs, with past-due jobs receiving priority. No tasks would be interrupted for any reason and a second person had to sign off, as well as the technician, any quality control checks.

In this case, the primary gap had more to do with a culture change. It was also noted that the size of the jobs in the small/medium motor department caused the problems to be more noticeable because of the times and volume of work involved. The supervisor estimated three months to have all the kinks out of the new program during which time he had to deal with customer service personnel complaining to upper management in an attempt to return the environment to where it was. The primary complaint being that they did not feel they were able to meet customer expectations due to scheduling issues.

At the end of the three month gap, the study was performed a second time over a one week period and warranty, time and wrench-time being re-measured. Another study was performed quarterly for the remainder of one year from the implementation of the plan. The first thing that was noticed is that the warranty rate dropped to zero almost immediately on jobs performed following the program implementation. The second thing noticed was that the average wrench time increased to 7.5 hours and average task times dropped by over 1/3rd during the first quarter and leveled off at 50% by the end of the year. In effect, throughput increased almost 400% within the first year, and warranty rates were virtually non-existent versus part of the workflow. The concepts gradually flowed throughout the rest of the repair shop departments during the first year and profitability increased dramatically while jobs were being completed on time, and frequently early. As a result, the next step in the process was to make improvements to the scheduling and communication systems between the shop and customer service and sales to improve quoting and delivery times.

Returning to our original example, there are a number of areas for improvement to the workflow to increase wrench time and increase throughput on this particular PM. When reviewing the linear time to correctly perform the best practice, it was determined that burdens were placed upon the individual technicians. While a daily meeting of about ½ hour was performed to communicate work, gathering equipment, travel and interruptions took up the remainder of the estimated 2.5 hours. In fact, it could be considered that the estimated 5 hours wrench time was overestimated.

The analyst reviews the workflow and notes taken during the 49 observations performed. In this, it is determined that maintenance personnel are contacted directly by customers and managers pull the technicians off of jobs, and they are sometimes made to wait, or are turned away, for production reasons. At the present time, individual machines are greased from start to finish before moving on to the next one, in a job-shop type process. The analyst reviews the list of work and determines the following DFM strategy:

1. Convert from a job-shop process and perform greasing from a batch process. This means that instead of tagging out and greasing one motor at a time, a group of motors is tagged out logistically close to each other, and the greasing procedure applied simultaneously on each batch. The number of motors for each batch is determined by location and availability to perform the tasks. Each group is broken out into individual work orders and the time to perform each group is monitored and scheduled for time study.
2. All communications with the maintenance personnel must be directed through the planner/scheduler. The planner/scheduler has access to the capabilities of each maintenance technician and their experience related to the training gap chart.

It is determined that there are ten machines in an average group. Time studies show that the average time to grease a batch of ten motors is four linear/man-hours for the experienced technicians. This reduces the number of technicians greasing motors from 3 motors per experienced technician per day, or an average of 6 experienced persons greasing motor per day, to an average of 2 experienced technicians per day (with variations due to batch sizes). Task completion improves dramatically and additional personnel are available for other tasks. With the reduction of interruptions, the average wrench time improves to 6.5 hours, or 30%, resulting in a wrench time of 81.3% up from 62.5% related to this task. The remaining time is dedicated to the daily meetings, travel and materials.

Conclusion

The philosophy of WFC/DFM will have dramatic immediate impact when the 'hanging fruit' maintenance opportunities are identified and improved first. However, most applications will have very dramatic results. It is also important to gage the required culture change as all new implementations will meet with resistance, especially in consideration of time studies and flow changes.

In the examples used in this paper, we covered job shop and batch approaches and standard PM's. However, the concepts related to WFC/DFM can be applied to all types of maintenance including emergency maintenance, or reactive maintenance. The average payback for a WFC/DFM study is measured in terms of days or weeks. The application of these concepts also bring maintenance that one step closer to the concepts utilized within the operations and production departments making communication between the two groups much improved. Planners/Schedulers can also use the result of the process in order to more accurately schedule work so that sloppy practices such as over-planning do not occur.

In a future paper, we will discuss the application of WFC/DFM to the reactive maintenance and PdM/CBM processes followed by a paper on using the method to develop your maintenance budget and improve planning/scheduling in combination with the RCM process.

About the Author

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