Developing and delivering a maintenance plan: the basics

By Malcolm Hide, Senior Consultant, Strategic Maintenance Ltd.

Introduction

So how do you go about setting up all of the maintenance requirements for several thousand discretely maintainable assets? This was the challenge facing us when we needed to set up the maintenance requirements package for a baggage handling system at a new airport terminal in a major international airport. From previous experience, and the Airport requirements, we had a good idea of what needed to be done. The challenge was about the sheer size of the system - with a total asset base of over 28,000 discretely maintainable assets, we needed to find a more efficient way of doing things. As a result of this we applied a three-step process that delivers a robust maintenance plan, based on a clearly defined strategies, which is easy to review and enables the implementation of changes when necessary. We have found that the principles hold well irrespective of the size of the system.

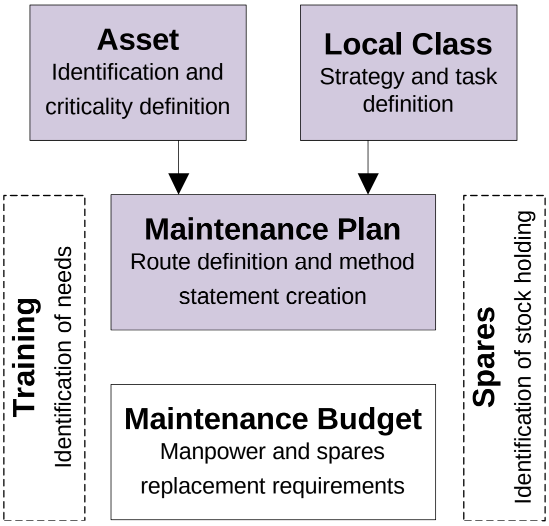

Image 1 - Showing the three step process and additional knock-on information.

Methodology

<u>Phase 1 – Identify Assets and Define Criticality</u>

Assets are assets, what can be difficult about identifying them? Well that depends entirely on how far you might want to go down the asset tree. Take a conveyor for example, do we take the asset structure down to component level, such as the drive motor, or do we leave the asset at conveyor level and take the motor as a component? We defined a maintainable asset as a piece of equipment that can be isolated individually, and as a result we opted for the latter. This did, in some instances, create some exceptions; for example a vertical sorter unit (see Image 2) was taken as a single asset, even though it clearly contains three individual conveyors as they were all isolated by a single source. In another instance a pneumatic conveyor extender at a fire break, was taken as a discrete sub-asset of a conveyor, to simplify the development of the maintenance strategies.

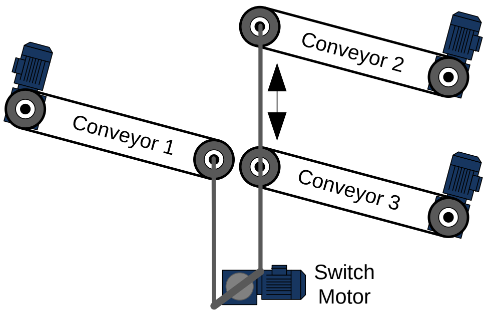

Image 2 - Showing a vertical switch conveyor.

Ultimately, asset identification becomes a fine balance between the identification of local classes (similar equipment) and discrete equipment. This may sound simple, but there is an art to doing it in a way that helps to simplify the development of your overall maintenance strategy. We will clarify what local classes mean in Phase 2.

Once you have identified all of the discrete assets in your system, you will need to define how critical they are to the performance of your business. To do this you might want to take a process layout of your system, and mark off large areas such as "Check-In Island A" or "Picking Floor C", which has a measurable impact on your business. Now define a series of business-related questions with five possible realistic answers for your business, such as:

1) What would happen to our business if the identified section was out of operation for 24 hours?
   a) Production loss of over €1 million
   b) Production loss of over €500k
   c) Production loss of over €100k

   d) Significant production loss which could be supplemented by another site
   e) Minor production losses which could be supplemented by another area on our site
2) How would our customers react to the identified section being out of operation for 24 hours?
   a) Losses in sales in excess of €1 million
   b) Losses in sales in excess of €500k
   c) Losses in sales in excess of €100k
   d) Significant losses in sales which could be supplemented by another site.
   e) Minor losses in sales which could be supplemented by another area on our site.

You need to make sure that the several aspects of your business, such as environmental impact, media coverage, customer perception, reputation and any other issues that have a direct impact on your business and its ability to function and operate in future are addressed. You need to be aware that both the questions and their relevance might change over time, as the business and its environment changes.

Once the business criticality for an area has been determined, you need to consider the failures that could take place on the equipment in that area, and the frequency at which these failures might occur. These should not be operational issues such as bag jams, but rather equipment failure issues that would require component replacement or adjustment, such as motor failure or belt adjustment. At this stage you should ignore the length of time it takes to repair the failure - we are more concerned at this stage with the frequency of maintenance-related disturbances.

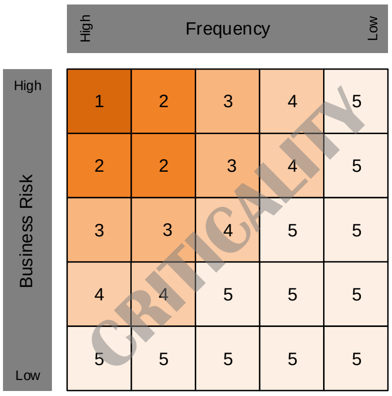

Image 3 – The criticality matrix.

The two values, Business Risk and Frequency are mapped onto the grid (see Image 3) to define the resulting criticality for the area. This process needs to be repeated for all of the areas you have defined on your process layout. Two items you will need to be aware of when performing this activity:

- If the business risk incorporates a question related to health and safety in relation to people performing maintenance on the equipment, these risks need to be carefully considered. While the resulting injury could be extremely serious, this risk of injury needs to be mitigated in the risk assessments and resulting method statements or redesign, not in increasing the business risk. The reason for this is if the business risk is too high, then you might consider doubling up on the equipment to reduce the risk, but this adds to an injury risk when maintaining the equipment
- All of the equipment and process routes in an area do not necessarily fall into the same criticality as the main routes for the area. You will need to identify the main process routes, secondary and tertiary process routes through the area and assign lower priorities based on their potential impact on the area.

This process needs to be kept as simple and flexible as possible, and ensure all decisions are well documented to eliminate the possibility of misinterpretation or to support any decisions made, should that become necessary. Remember that the business need and market forces will change over time and this criticality review will need to be re-evaluated fairly frequently (usually annually or in major shifts of the economy) to ensure you are still applying the correct strategies. Changes to your environment could quite possibly change the maintenance plan you have adopted for the equipment on site over time.

Phase 2 – Identifying Local Classes and Strategies

When looking through all of the equipment on your site, you will notice that there are several pieces of equipment that are very similar. The probability is high that the maintenance plan you want to apply to them would be the same, with minor allowances for various criticality levels. We identify these equipment groups by giving them a Local Class designation, and develop the maintenance strategies for each of these local classes, defining different frequencies (and strategies if necessary) for all five criticality levels at the same time. This process allowed us to reduce the baggage system quoted in our first example from 28,000 items to 122 local classes that we needed to define maintenance strategies for.

Based on your list of local classes, you will need to:

1) Draw up a list of every activity that you will possibly perform on this equipment/local class, including:
   a) Component Replacements, where you need to consider the level at which you want to carry out your maintenance (Level of Repair Analysis). For example, in a first world country if a bearing on a motor reducer unit failed, you may opt to replace the failed unit and either scrap the failed unit or send it for repair. Alternatively in a third world country you may opt to replace the failed unit and repair the failed unit in your workshop. In the first case there would be a single replacement activity, while in the second instance there would be two replacement activities. Each of these activities could have different skill levels to perform the task.
   b) Component Adjustments, covering activities where you may need to make minor adjustments such as belt tensioning, shaft alignment and defragmenting hard drives.
   c) Cleaning Activities, covering the equipment and the immediate surroundings should this be in a restricted-entry area. In many instances cleaning could fall to a lower skill level; however it should not be ignored from the maintenance plan as it forms part of a holistic approach to maintenance. At a food processing plant, we reduced downtime by 20% by introducing a cleaning regime on the system and as a result staff noticed potential future problems while cleaning – problems which were then averted by minor adjustments or component replacements prior to them failing.
   d) Inspections, covering visual inspections, stoppage inspections and statutory inspections as well as condition-based inspections such as Vibration, Thermography and Ultrasound. You may have in-house expertise to perform these activities, or you could contract them out to specialist companies who have the skills and expertise to perform the work. In our experience contracting out tasks that require a lot of experience and skill level can be beneficial if it is properly managed. Conversely keeping the work in-house could also be beneficial as long as the frequency of performing the task allows the people performing the activities to retain the skill and experience required.

   The identification of these tasks can be done using FMEA, RCM or MSG3. In our case we decided not to go to that extent on all of the local classes, but fashioned it on a refinement of the OEM requirements.
2) Define the attributes to each of these tasks:
   a) How long will each of the identified tasks take to complete (Mean Time to Repair [MTTR]).
   b) Identify how many people will be needed to complete the work.
   c) Identify the skill (trade or craft) required to complete the task at the required quality.

d) For adjustment replacement and tasks, estimate the interval between Mean Time between Failures (MTBF) for replacements and adjustments. To define the MTBF, you might want to look at the design or predicted life of a component that you intend to replace or adjust.

e) Decide if the work will require the equipment to be isolated in order to complete the work.

3) Select one of the following strategies for each of the criticalities you are using (see Image 4 – Strategy Sheet):

a) Time Based, where you define a set frequency to perform the maintenance activity. Some of the tasks are in themselves a strategy, such as a thermal inspection (Thermography) or vibration inspection (Vibration Monitoring), in which case you need to define a frequency based on an anticipated PF failure curve

b) Operational Based, which sets out the flow or operations required between maintenance activities

c) Condition Based, using an inspection or other strategy which will identify the onset of failure and allow for reaction time to address the failure

d) Run to Fail, which allows the component to fail before replacements or adjustments are made.

Strategy Sheet: Br - Lifting Finger Stopper Plate

Key	Task(Name)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Replacement															
REP - Br01	Replace - Pneumatic Valve	15	N	Y	1	0	520	COND	COND	COND	RTF	72000	N		
REP - Br02	Replace - Pneumatic Cylinder	20	N	Y	1	0	520	COND	COND	COND	RTF	72000	N		
REP - Br03	Replace - Lifting fingers	30	N	Y	1	0	COND	COND	COND	COND	RTF	192000	N		
REP - Br05	Replace - Finger stopper guide	20	N	Y	1	0	COND	COND	COND	COND	RTF	192000	N		
REP - Br05	Replace - Connectors or terminal blocks	10	N	Y	1	0	COND	COND	COND	COND	RTF	96000	N		
REP - Br06	Replace - Damaged cables or wiring	30	N	Y	1	0	COND	COND	COND	COND	RTF	96000	N		
Adjust															
ADJ - Br01	Adjust - Rise rate of pneumatic cylinder	5	N	Y	1	0	COND	COND	COND	COND	RTF	48000	N		
ADJ - Br02	Adjust - Fall rate of pneumatic cylinder	10	N	Y	1	0	COND	COND	COND	COND	RTF	48000	N		
ADJ - Br03	Adjust - Rise hight of accumulation plate	15	N	Y	1	0	COND	COND	COND	COND	RTF	48000	N		
Inspection - Visual															
VINS - Br01	Visual Inspection - Stopper Plate (Br)	2	Y	N	1	0	1	2	4	8	RTF		N		
	Structure	0													
	- Check structure for any wear / damage														
	Pneumatics	1													
	- Check pneumatic pressure														
	- Check pneumatic system for leaks														
	- Check pneumatic cylinder is secure / correctly connected														
	- Check pneumatic piping for damage / secure routing														
	- Check valve is secure / correctly connected														
	Control	1													
	- Check cables and wiring for damage														
	- Check terminals / connectors for damage														
Inspection - Stop															
IINS - Br02	Intrusive Inspection - Stopper Plate (Br)	5	N	Y	1	0	8	13	18	26	RTF		N		
	Pneumatics	3													
	- Check pneumatic pressure														
	- Check pneumatic system for leaks														
	- Check pneumatic cylinder for wear / damage / smooth movement														
	- Check pneumatic cylinder is secure / correctly connected														
	- Check pneumatic piping for damage / secure routing														
	- Check valve exhaust ports for blockages / silencer														
	- Check valve is secure / correctly connected														
	Structure	1													
	- Check structure for any wear / damage / deformation / cracks														
	- Check bolts and fixings for tightness														
	Control	1													

Image 4 - Showing an example of a strategy sheet for a pneumatic stopper on a materials handling system.

As part of the creation of the maintenance strategies you can also develop safe working practice method statements and generic risk assessments for all of the maintenance tasks that you have identified. These method statements and risk assessments are an ideal way of helping to develop a training plan for new employees.

By developing these individual strategies, we found it relatively easy to adopt a cohesive maintenance strategy across the entire baggage system.

There are a couple of things to remember when developing this strategy:

- All of the condition-based inspections, such as Vibration, Thermography and Ultrasound, are supportive of a sound maintenance strategy, and should not be performed in isolation. For example when the equipment exhibits high vibration, you need to have a clearly defined activity, such as replace the bearing etc.
- If you determine that there is a particular failure that you want to design out, then this action becomes a small project to eliminate the failure, and once it has been eliminated then the strategy is updated to reflect the new maintenance regime being applied.

Phase 3 – Extract the Maintenance Plan

Phases 1 and 2 can be progressed in tandem, however they need to be complete before continuing with Phase 3 of the work. At this point we know all of the equipment we aim to maintain, how critical it is to your business, what strategies we will be using and what maintenance we will be performing.

We now need to extract this as a maintenance plan for each piece of equipment and insert it into our Computerised Maintenance Management System (CMMS).

This is where things started getting a little tricky! While for many situations this is a manageable task, in the baggage system discussed above, we had around four time-based activities per piece of equipment, therefore amounting to 112,000 planned maintenance activities to enter onto the CMMS. These tasks ranged from weekly visual inspections through to oil replacements every three years on the motor reducers. Downloading this many planned maintenance tasks is clearly a significant task, not to mention the work involved in planning and managing a weekly paper trail of around 31,000 work orders. Clearly we needed a way of grouping these activities into more manageable groups, while still keeping the maintenance information at equipment level. To achieve this we created a software program to reduce the work involved. This then fed the CMMS system we were using which managed this level of complexity in the form of maintenance routes.

In order to develop a manageable maintenance plan, you will need to identify and group these PM tasks together, based on frequency, strategy, skill and on a physical line of equipment to restrict the impact on the system during a stop inspection (an inspection requiring the equipment to be turned off). Our experience has also shown us that these maintenance routes need to be limited to one person for a maximum of 4 hours per route, otherwise the impact on the system will be too great and the likelihood of completion during a shift will be low. In the baggage system, this resulted in around 1200 planned maintenance routes, which was far easier to manage than individual job cards on every piece of equipment, and could be managed by one planner.

At this point there are a few key items to consider:

- The maintenance plan needs to be flexible:
    - It should allow you to review and enhance the strategy, adding/modifying/deleting tasks or check list items.
    - It should allow you to change the frequency if you find that the current frequency does not adequately protect the system or the P-F curve has been incorrectly estimated
- It should allow you to review criticality (impacting on the frequency and strategy applied)
    - We all know that business environments change over time. This could be as a result of external forces (changes in customer demand) or internal forces (changes in product profitability). Every time these change, the maintenance plan needs to be updated to reflect the current business environment.
    - As equipment ages, the maintenance demand may increase as a result of changes in the individual component reliability or component obsolescence.

Once all of the maintenance routes are entered into the CMMS, you will need to ensure that the risks associated with performing the maintenance are correctly addressed. The generic risk assessments developed during Phase 1 of this process need to be refined given the actual environment in which individual pieces of equipment are installed. This ensures that all risks are identified and people are trained accordingly.

Conclusion

The development of this process allowed us to produce a cohesive maintenance strategy and a comprehensive maintenance plan for a very large system, but the process also holds well for smaller systems. More than enabling the creation of the strategy and plan, it also helped to:

- determine the manpower needed to support and maintain the system
- anticipate the spares consumption for the site for the first 10 years of operation
- create the training material used to train the engineers on the maintenance of the equipment

Overall the process helped to minimise the operating cost of the maintenance operation from the outset, where we found the maintenance personnel level required was 15% lower compared to similar asset numbers elsewhere in the airport. In addition, since everything was well documented, we were able to perform a review of the applied strategies and the maintenance routes, and refine them as a result of the lessons learned over the first 18 months of operation. We believe that without this process and the tools we developed to support the overall delivery of the maintenance plan, the initial maintenance plans would still be in development, rather than having gone through the first major review and refinement.

Footnote
Strategic Maintenance Ltd provide training on developing maintenance plans, please see our web site for details.