Does Your Maintenance Plan Deliver The *System* Performance The Production Plan Requires?

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Integrating maintenance and production departments and their goals has long been the objective of many organisations, in an attempt to create a unified focus towards optimal operation and production. Many maintenance improvement programs suggest they link maintenance to the business plans. This is true in the sense that failure impacts are typically defined in terms of operational performance, but the link is not complete because the resulting level of system performance remains unknown. This paper describes how Reliability Block Diagram logic and Monte Carlo simulation can be used to truly integrate maintenance decisions with system performance to ensure that the maintenance plan will meet the requirements of the business.

Maintenance plans in any organisation are typically derived from manufacturers suggestions. On mature sites these may have been refined based on site specific experience and environment. In some cases the maintenance being conducted may be a completely informal process, where the tasks being conducted are based on site experience that is not formally documented.

Many sites have built and improved on these typical plans by following maintenance strategy development or improvement methodologies such as Reliability Centred Maintenance (RCM) or Preventative Maintenance Optimisation (PMO). The typical result is a revamped (optimised) maintenance plan, which is considered to be the least cost maintenance plan that manages risk, safety and operational consequences.

However once the maintenance plan has been developed (or revised) and implemented, often what is not quantified, is the level of system performance that will be delivered.

A typical maintenance improvement program utilises a structured approach to derive a list of failure modes & causes (how things fail and why), quantify the effect of failure (the impact of the failure), understand how the failure mode occurs over time, and then consider and evaluate potential predictive/preventative maintenance options.

Failure Mode/Cause
↳ **Effect/Impact**
↳ **Failure Behaviour**
↳ **Preventative/Predictive Opportunities**
↳ **Justified?**

Figure 1 – Simplified representation of logic flow completed for each failure mode/cause

This means that essentially each failure mode is considered in isolation, and any resulting maintenance task designed to prevent or predict the failure mode, will be justified based on cost, safety and environmental impact. This can become a relatively simple process of considering the cost and frequency of the failure with the cost and frequency of employing an effective maintenance task.

Some maintenance improvement programs utilise a fairly simplistic calculation whilst others use a more sophisticated analysis that enables the calculation to be reviewed and compared on many levels whilst taking into account many parameters. However, all programs essentially utilise the same logic that justifies maintenance tasks against individual failure modes.

These maintenance tasks are typically grouped into similar frequencies and resource groupings to form the maintenance schedule. System performance is typically not taken into account in such processes and since the maintenance tasks are justified for each individual equipment item, the level of system performance is often not known until failures occur or performance issues arise.

For example, lets take a particular pump that has several dominant failure modes:

- Seized bearing
- Casing leak
- Motor burnout
- Drive coupling failure

Different maintenance tasks are applicable to each failure mode. The tasks are typically assigned at an individual failure mode level, and evaluated by comparing the cost of failure against the cost of performing each task. The individual tasks are then grouped to form the maintenance plan for the pump. Whilst at this stage the maintenance plan would usually be considered optimised, the level of downtime and the likely number of failures of the pump is not estimated. It is only when the series and parallel relationships are addressed, that we see the impact of each of the individual maintenance decisions on the performance of the pump.

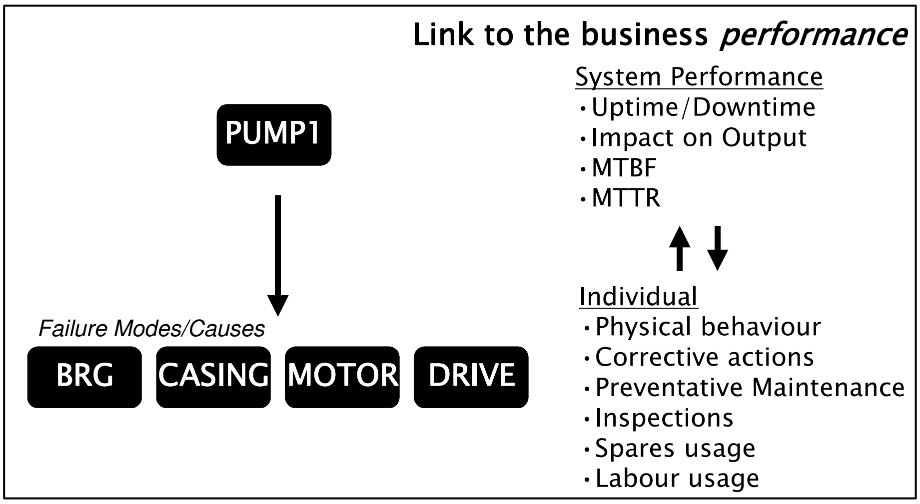

Figure 2 – The analysis usually takes place at the mode/cause level and the performance of the pump is unknown.

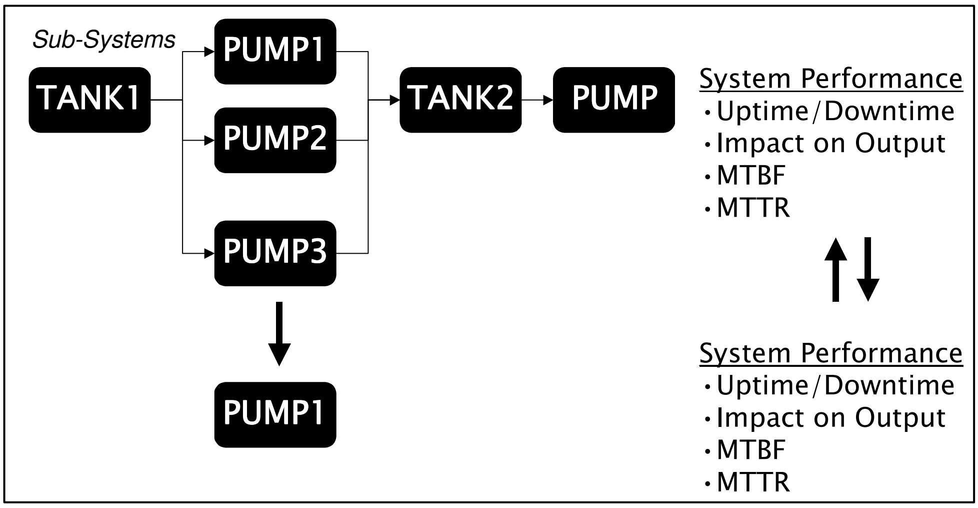

Figure 3 – The total system

Figure 3 shows how the pump is typically an element in a system, where not only is the performance of the pump impacted by our maintenance decisions but also the performance of the total system. If a change is made to an individual maintenance activity, typical maintenance analysis will report the cost impact of the change, and possibly the change in the number of failures experienced due to that particular failure mode. However traditional maintenance improvement processes will not be able to quantify the impact of the change at a system level.

The performance of the total system will be impacted by several factors;

- System Design
  - Inherent reliability
  - Redundancy
  - Alternative operation capability
- Maintenance Plans
  - Tasks
  - Frequencies
  - Online/Offline
- Logistics
  - Resources
  - Spares holdings/delays

What's required by the modern asset manager is a method to translate and report on the system performance that will be delivered by the maintenance plan, system design and logistics. Most operations have a target level of system availability, and it is critical to know the relationship between the maintenance plans being implemented and the ability of the system to achieve the target.

Reliability Block Diagram (RBD) logic and Monte Carlo simulation technology, provide the asset manager with a simple method to generate models that represent the operation of a system or area of plant. Modern software packages such as AvSim Plus include facilities that can represent the likely behaviour of the equipment over time, the maintenance requirements for planned and unplanned activities and the level of resources available. Using a Monte Carlo simulation engine the expected performance at system or plant level can be can be predicted.

This methodology creates a sound link between maintenance and operational performance of a plant that has clearly been missing. The link also reinforces the integration of maintenance and operations since the model contains the operational configuration of the plant along with the maintenance plan and forecast equipment behaviour.

Using success paths to represent system interactions RBD's allow a mathematical determination of system availability.

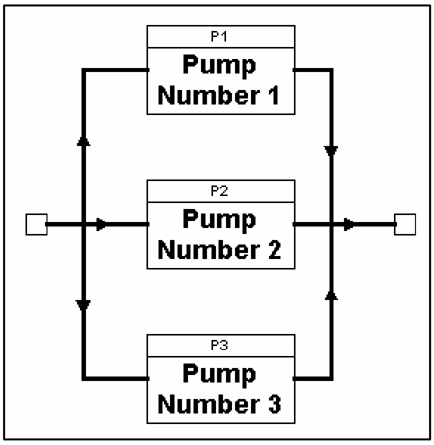

Figure 4 – A traditional RBD

Figure 4 shows a traditional RBD representing a pumping system consisting of three pumps. The parallel arrangement indicates that only 1 pump is required. In system performance calculations the system is considered available if one 1 pump is operating and unavailable only when all three pumps are not operating.

Modern software can now represent a partially failed state by incorporating capacities into RBD logic.

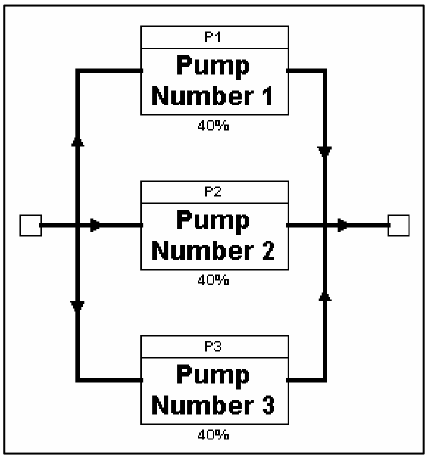

Figure 5 – A RBD with component capacities shown.

Capacities included in the system performance calculation provide a more representative analysis of system performance, particularly where partial down states need to be accommodated. In the above example when one pump fails the system can only perform at 80% capacity. When two pumps fail the system can only perform at 40% capacity. These partial failure states factor into the system performance calculation that is reported as total system capacity.

Example

In order to conduct a system performance prediction the failure logic has to be described using Reliability Block Diagrams. The capacity each item of equipment also has to be defined.

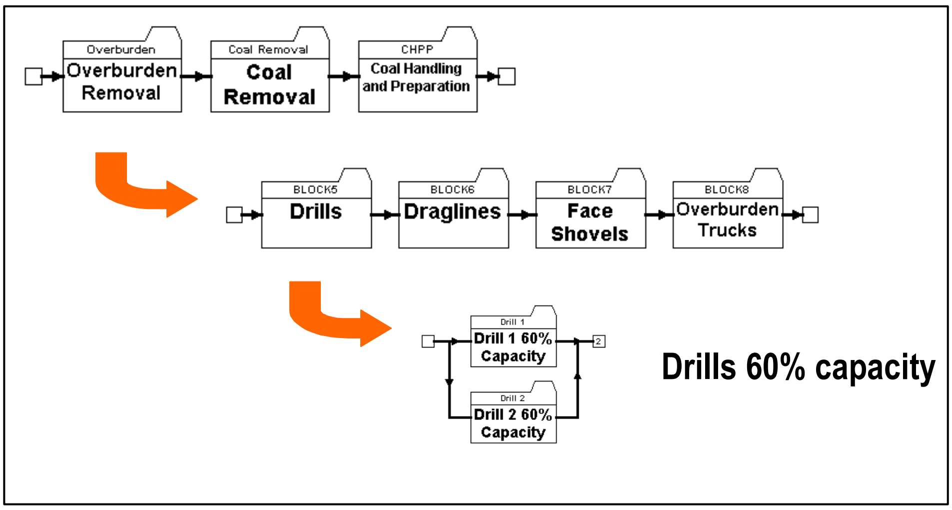

Figure 6 – Example construction of system failure logic.

In this example a coal mine is being modelled. Under the Overburden Removal area are four major equipment groups. There are two drills utilised by the mine each of which can provide 60% of the required throughput.

Once the RBD has been constructed the data for each individual failure modes can be entered. This data is typically already known particularly when the maintenance plans have been optimised, since all the failure mode data would have been considered in the optimisation process.

At this stage the evaluation of system performance can be generated. For the above example the mean capacity of the drill major equipment group was 99.4%. The reported 99.4% capacity is based on the performance of each drill. The performance of each drill is based on the failure modes and all their associated behaviour and parameters, such as failure information, corrective maintenance details, spare parts, resources and potential maintenance tasks.

For the above example, the impact of utilising a spare drill that can provide 40% of the required throughput was evaluated. The RBD was changed to reflect this.

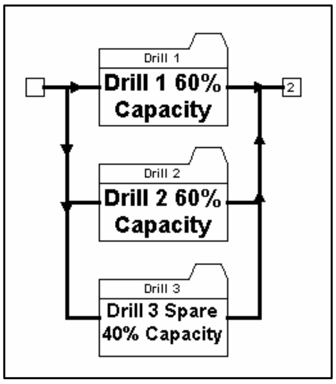

Figure 7 – Revised RBD showing 2 drills at 60% and a spare drill that can provide 40%.

The evaluation was run again and the results that the drill major equipment group is now capable of delivering 100% of the required throughput. The total mine capacity also increased by 0.5%.

This systems analysis provides a unique and revolutionary method to link maintenance plans to system performance. Once a maintenance plan has been optimised the question of whether the system will meet the production performance targets is typically unknown. Systems analysis as described above enables the maintenance plan to be evaluated against system performance targets, and alternative plans and system configuration to be compared.