



Useful Key Performance Indicators for Maintenance

Abstract

Useful Key Performance Indicators for Maintenance: A useful Maintenance Key Performance Indicator (KPI) drives reliability growth while guiding your choices for improving maintenance effectiveness and efficiency. A useful maintenance KPI lets you identify the issues causing your maintenance effects and helps you select the right strategy to either support or correct the actions producing the results. It is important that when you select a range of maintenance KPI you pick those that let you improve both equipment reliability and maintenance performance and not simply tell you that you have problems in your business.

Keywords: maintenance performance indicators, defect removal, continual improvement, scientific maintenance method

You measure a thing to learn something about it. To know how heavy an item is you weight it. To know its size and shape you measure its dimensions. From its volume and weight you can calculate its density. Measurements help you better understand a thing, how it works and how you have to work with it. Measuring maintenance is no different in intent. Useful maintenance measures are of two types—those that improve Maintenance effect on business performance and those that drive good reliability-building behaviours.

The key performance indicators (KPIs) that you use ought to help you to understand what Maintenance is doing, what it is achieving for the business and what more it can do to improve operational performance. Maintenance performance can be improved by making it more effective and more efficient. Effective maintenance is doing the right maintenance: that which brings higher equipment reliability and lower operational risks. Efficient maintenance is doing maintenance right so that reliability and risk reduction are achieved with the least resources and time.

Maintenance Supports Business Strategy

The work done by Maintenance needs to support the business aims and operating strategy.

The ideal way to show that is to have maintenance performance clearly linked to the reasons your company is in business. In Figure 1, the pyramid of objectives, and Figure 2, the objectives cascade, you can see how KPIs are matched to business objectives and how maintenance and reliability activities cascade from the hierarchy of business purpose and aims¹.

Developing useful maintenance KPIs starts by creating ‘KPI pathways’ from top to bottom of the organisation so you connect activities across the operation together with a corporate purpose. Note that you build the ‘KPI pathways’ top-down, but the corporate goals are achieved bottom-up. Operational success actually starts on the shopfloor by doing those causes that bring success.

Once you have a clear link between business goals and the maintenance activities needed to achieve them everyone can see the benefits that maintenance brings to the business. With interlinked,

¹ Wardhaugh, Jim. Extract from 2004 Singapore IQPC Reliability and Maintenance Congress presentation ‘Maintenance – the best practices’

cascading objectives connecting the business together from top to bottom you can use KPIs to measure and check if they are being achieved.

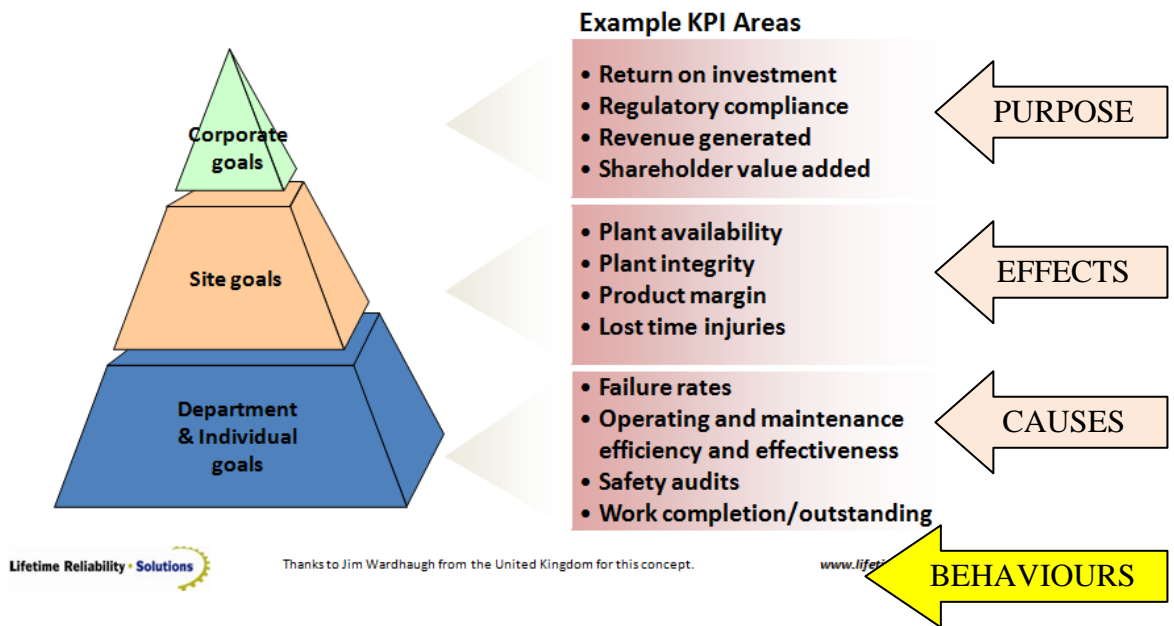


Figure 1 – Control Pyramid of Business Objectives

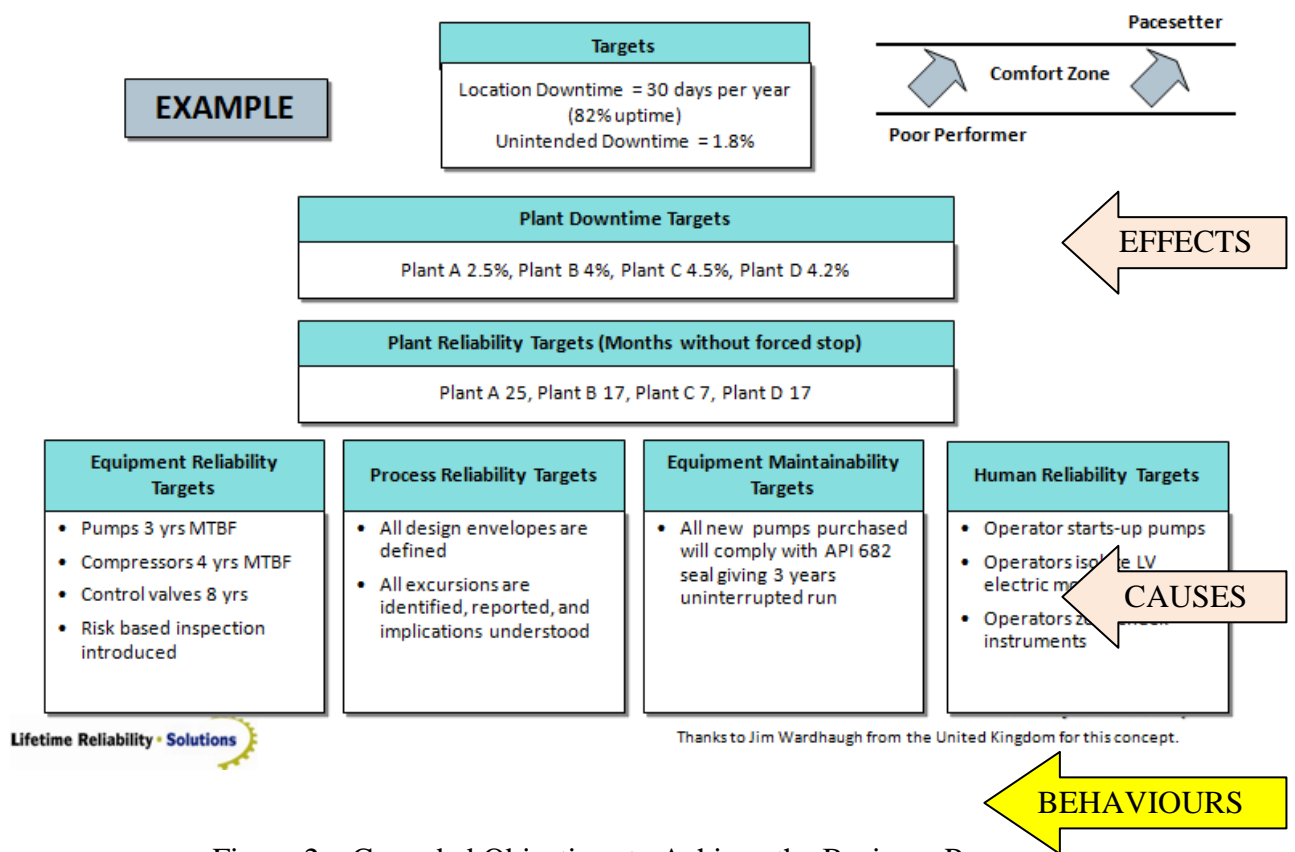


Figure 2 – Cascaded Objectives to Achieve the Business Purpose

Examples of Maintenance KPIs

A warning often heard about KPIs is to select those with outcomes that can be controlled by the group or persons responsible for meeting them. If you are trying to produce results that you cannot

greatly influence there will be much frustration and running-in-circles. You need measures that are relevant to what Maintenance does each day and which Maintenance can mostly control.

It's interesting to see what experienced and successful operators have done when it comes to measuring maintenance performance. Figure 3 lists the KPIs used by DuPont Chemicals to monitor their operating process plants; along with the target benchmarks those plants are required to meet.

Key Performance Indicators

	%Uptime	>90%
	Total Maintenance Cost (TMC) as a % of ERV	2% - 2.5%
* <u>Reliability of Equipment</u>	Reliability Professionals per Mechanic	1 : 12-18
	Mean Time Between Failure	Increasing >10% / year
	% Emergency Work	<10%
	Estimated Replacement Value (ERV) / Mechanic	\$5MM - \$8MM
	Training Days(Development/Refresher) / Mechanic	5 - 10 days / year
* <u>Quality & Speed of Execution/Response</u>	Maintenance Work Force Weeks Backlog	4 weeks
	% Planned Work	>80%
	Mechanics per Planner	20 - 27 : 1
	Schedule Compliance	>90%
* <u>Maintenance Costs</u>	Stores Investment as a % of ERV	<.25%
	% Overtime	10% - 12%
	Maintenance Labor Cost as a % of TMC	20% - 25%
	Contractor Maintenance Labor Cost as a % of TMC	10% - 40%
* <u>Prediction of Failure</u>	% PPM Work	>20%
	% PPM Schedule Compliance	>95%
	% Emergency Work	<10%

Figure 3 – Examples of Site Maintenance KPIs

As an example of not having control over the outcome of a performance measure we can consider the reliability indicator measure of 'Mean Time Between Failure' from Figure 3. MTBF is affected by original equipment manufacturing quality, by capital project design selection, by the quality and accuracy of initial installation, by the severity of operating duty, by the quality of operator practices, by the maintenance activities performed or not performed when due, by the quality of parts storage and by maintenance workmanship. A KPI that shows MTBF is not greatly under Maintenance control because of the extent of life cycle influences that Maintenance has no way of affecting. For a company to greatly improve the MTBF of its equipment the whole life-cycle needs to be addressed and not only its maintenance performance. If Maintenance is charged with improving MTBF you would have to develop a company-wide training scheme to teach people at each phase of the life cycle what to do to improve reliability, and follow that with a business-wide project to change business processes to those that produce higher reliability. (That is what DuPont did.)

Many companies only measure maintenance performance with historic indicators. A maintenance performance KPI that appears in a monthly report delivered mid-month is already six weeks out of date for the first week. Historic information is interesting, but as shown in Figure 4, feedback control means a lot of time passes before effects are observed and you can act in response. Useful and relevant maintenance performance indicators are those that drive the actions and behaviours needed to meet the goals you set at the lowest level in Figure 2, the Objectives Cascade. If we can

do the cause of high reliability well it automatically follows that we will get a good operating effect that feeds into the corporate goals.

The measures listed in Figure 3 are historic outcomes and indicate the effects of past actions taken. In terms of Figure 1 they are site-level performance measures. They are fine for checking a site's overall maintenance performance but they are struck too high up the Objectives Pyramid to tell you if you are doing the right maintenance rightly until a lot of time passes and the effects confirm or condemn the actions taken. You also need KPIs set below the site measure level to confirm the right causes are being done to produce equipment reliability and operating risk reduction.

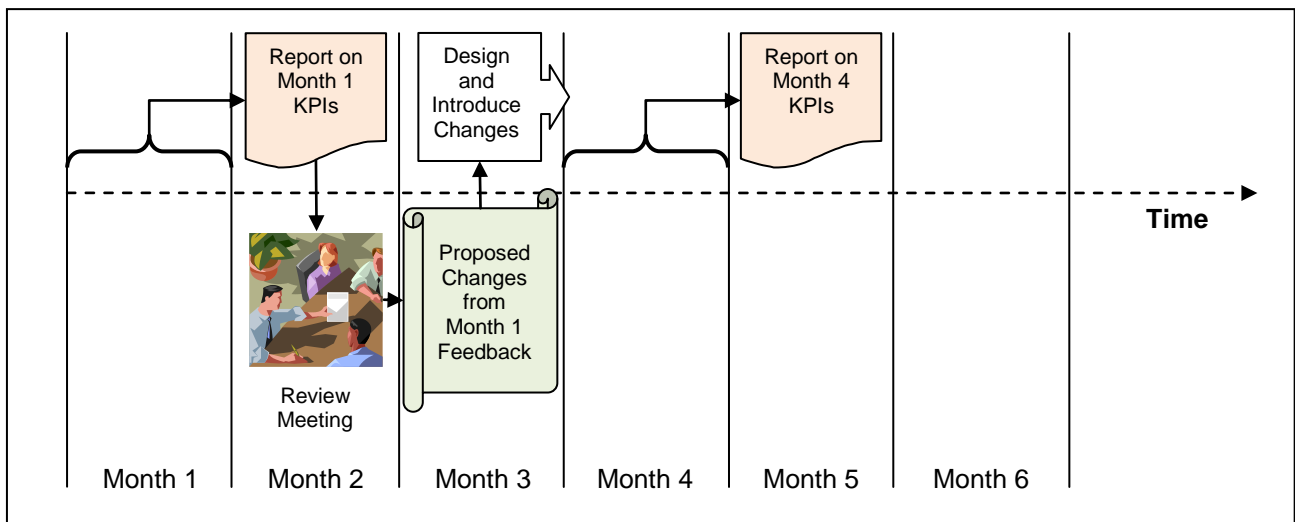


Figure 4 – Historic KPIs Provide Tardy Feedback and Promote Slow Response

The types of maintenance KPIs to develop which are useful to the business are those that:

- Identify what are causing your equipment failures (measure the influence of life cycle factors)
- Direct what Maintenance is doing with its time and resources (measure effectiveness and efficiency of the Maintenance Group)
- Identify if Maintenance is removing the causes of failure (measure the reliability improvement and operating risk reduction results of the maintenance effort)
- Drive the business benefits delivered by Maintenance (measure the business value contribution of Maintenance)

Measure Where Equipment Problems Comes From

A useful maintenance KPI to collect and present is why failures are arising. Today's failures have root causes in the past and across several departments. Collecting the causes of repairs (i.e. corrective and breakdown work) under separate life cycle categories lets you identify where to focus your reliability improvement efforts. This is a business quality system and life cycle management indicator that drives defect removal and the adoption of better asset life cycle practices.

The categories initially start with broad coverage such as manufacturing defects, production process causes, materials selection causes, equipment installation factors, human error causes, vendor-produced causes, procurement errors, storage failure, poor quality workmanship, etc. Your aim is to find-out why you are doing repairs and what can be done to remove the causes of those repairs.

This KPI requires assessing each corrective and breakdown work order and allocating it to a suitable life cycle category. Typically a well experienced maintenance engineer or maintenance

planner would investigate the failure and identify the categories (there maybe more than one category) that influenced the failures. A pie chart or bar chart of work orders per category each month would be a good way to show this KPI.

As time goes by and data accumulates you develop additional categories within the major categories to further target the actual factors contributing to the repairs and failures. This KPI justifies efforts to eliminate root causes of failure.

Measure What Maintenance is doing with Its Time and Resources

The sorts of KPIs in this category are those that identify where Maintenance allocates their time, people and money each month. Unfortunately Maintenance is often the ‘tail of the dog’—it is an afterthought. If Maintenance has no focus on delivering business objectives Maintenance ends up doing anything and everything to keep the operation running. Over the centuries we have come to understand that successful maintenance is not about fixing things; it is about not having to fix things. When done well Maintenance delivers reliability and lower risks that liberate fortunes of expenditure year-after-year.

The secret is not to focus on doing maintenance; rather focus on creating reliability and removing operating risk. Maintenance has the duty to stop problems starting and where there are problems they are responsible to remove them so that reliability and risk reduction are produced. You only need to measure how much effort is being made in your company today to improve it and make it a better place tomorrow to predict its future. If you KPI Maintenance on the factors listed below and they are not a significant use of its time and resources then it is easy to predict the future of your operation—it will be the same as it is today and highly likely to get worse.

- Maintenance work orders spent on improving equipment
- Maintenance time and effort spent removing breakdown causes
- Maintenance time and effort spent improving maintenance procedures
- Maintenance time and effort spent improving maintainer skills/knowledge
- Maintenance time and effort spent reducing operating problems
- Time spent removing wasted effort and cost from maintenance processes
- Efforts spent improving stores management processes and stored parts reliability
- Maintenance work orders spent improving safety

Efficient maintenance is only partly about having the smallest maintenance crew. It is mostly about having the least equipment failures because the equipment is properly maintained. Efficient maintenance means doing high quality work right-first-time. The size of the crew is only a reflection of the effectiveness of your work processes and the amount of business process waste you will tolerate. In a reactive maintenance business maintainers average about two hours of ‘tool time’ work a day per eight hour shift. In a highly planned and organised maintenance operation they average four hours ‘tool time’ per eight hour shift. In a world-class, reliability-driven business the maintainers spend most of their time designing and doing production productivity improvements on equipment and removing maintenance costs. When people have more engineering knowledge, use precision skills, create standardised work management processes and build supportive quality management systems you can run your business in very profitable ways.

Measure if Maintenance is targeting the Causes of Operating Problems

Equipment fails because a part’s atomic structural integrity collapses from overstress or degradation. There are six major causes of mechanical equipment failure—lubricant contamination, out-of-

balance, misalignment, working component distortion, incorrect fastening and induced vibration. For electrical equipment the six major causes are—contamination, induced vibration, over temperature, moisture, distortion and power supply stability. I call these ‘The Big 6’ maintenance problems and they should be purged from your plant by Maintenance.

Proactive maintenance behaviour prevents the ‘Big 6’ from happening whereas reactive maintenance fixes them after they happen. You want Maintenance to go and find the ‘Big 6’ problems in both mechanical and electrical equipment and get rid of them before they cause failure. This requirement is far beyond just using condition monitoring to observe equipment health. Condition monitoring accepts failure as a possible outcome, but the strategy of ‘Big 6’ prevention is all about never allowing the defects that produce those failures to arise.

You need KPIs that measure if Maintenance is focused on eliminating the ‘Big 6’ and how successful their efforts are. You don’t want your operation living with risk of failures but instead you want to be proactively creating certain reliability. To make this happen in your operation you need to use maintenance KPIs in a different way—the scientific method.

Scientific Maintenance

The scientific method says that you first suggest the effect that will result from doing things in a particular way. You then test your theory and if the experiment’s result was not as you postulated, your suggestion was wrong and you look for a better approach. The way to apply the scientific method in Maintenance to improve reliability is to propose such things as, “If we filtered our gearbox and hydraulic system oils to remove wear particles we should triple and even quadruple the MTBF.” Another postulate is, “If we reduce atomic level stress in roller bearings by removing machine frame and bearing housing distortion we should get multiple increases in their MTBF.” A third, “If we remove pipe stress from our flanges we will stop all flange leaks.”

With proposals like these we can design experiments with specific causes to test. We know exactly what was done to produce the results. The KPIs to use as measures are also clear. The wear particle removal experiment would have gearbox failures trended against numbers of gearboxes filtered each month. The expectation would be that as more gearboxes are regularly filtered the breakdown count falls significantly. The atomic stress reduction experiment is measured by electrical power consumption before and after rectification as well as bearing MTBF. An alternate measure would be to trend vibration of corrected bearings over the following months. A successful experiment would show that as the numbers of work orders raised and completed to rectify machine and bearing housing distortion (by using high precision methods) rises the bearing failure rate falls.

These are hypotheses that we can scientifically test and measure in our operation to see if they are true or not. We apply what we think are the causes of higher reliability and then measure their effects with monthly KPIs. Now our maintenance activities become proactive and each monthly report confirms the success (or not) of our reliability improvement efforts. We can immediately make useful and sensible adjustments to our ‘experiment’. If there are lower maintenance and operating costs in subsequent months we know exactly what caused them and we can repeat them with certainty again and again.

Figure 5 highlights how the scientific approach lets Maintenance quickly take control of reliability improvement and operating risk reduction and deliver good results. But more importantly, we may have a money-making business case that if experimentation proves successful will let Maintenance generate a lot of money for the company by stopping failures. We will create a proactive atmosphere in management and on the shopfloor with people eagerly seeking successful

maintenance outcomes. These are the type of activities to use Maintenance for if you want to make a lot of money fast from your maintenance efforts.

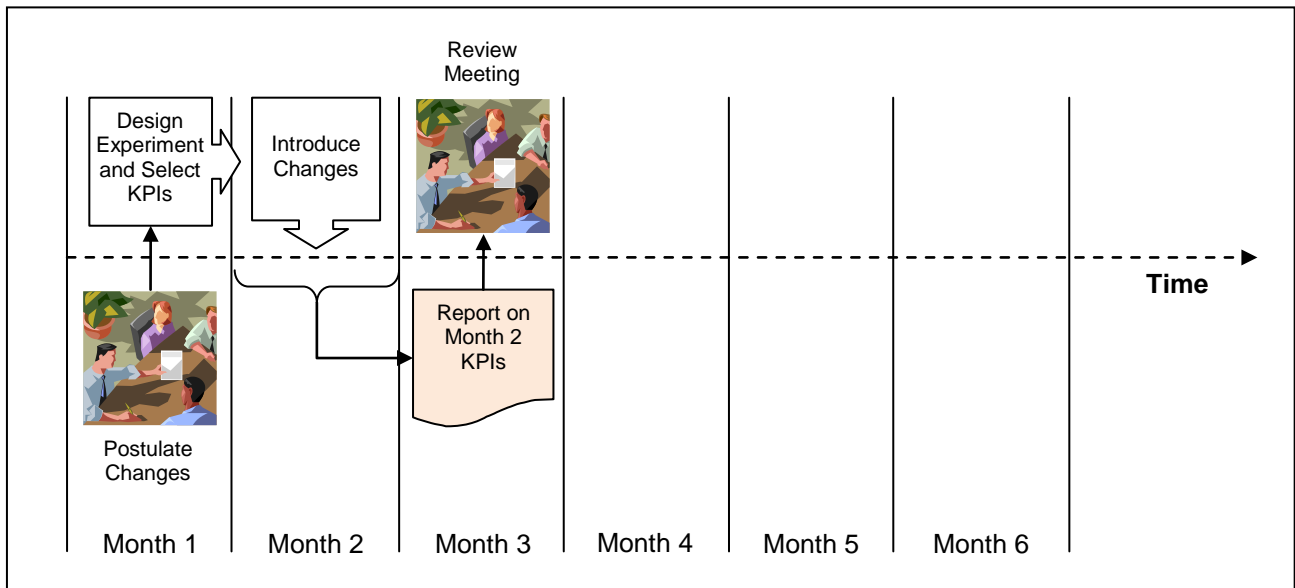


Figure 5 – Scientific Method Promotes Proactive Behaviour and Rapid Improvement

Measure What Business Benefits Maintenance is Achieving

Maintenance makes serious money for a company by delivering operating equipment reliability and operating equipment risk reduction. You see the effects of both good and bad maintenance in the cost of your products. Bad maintenance policies and practices add operating cost whereas excellent maintenance policies and practices lower costs.

A useful site level maintenance KPI to measure is the proportion of operating costs attributable to Maintenance per unit of production. The Maintenance Group then has bottom level KPIs identifying where the cost contributions come from that make-up the maintenance proportion of the unit cost of production. This KPI directly links Maintenance to operating profit. You would be aiming to get a steady downward trend in maintenance cost per unit of production as evidence of continual improvement. The unit cost of production values may need to be identified by using Activity Based Costing, since financial accounting is often not detailed enough to differentiate the individual cost components of your products.

Use Visual Management Principles to Display KPIs for Action

Where possible show KPIs visually rather than in lists or tables. This encourages people to meet their obligations by employing psychology to drive good behaviours—we all want to be seen as competent and professional in what we do. An example is the stacked bar chart in Figure 6 where the group’s performance in meeting their targets is clear to everyone². This visual management device shows current progress in meeting a necessary target. If targets are not met people see that there is a problem and start to query and resolve the cause(s).

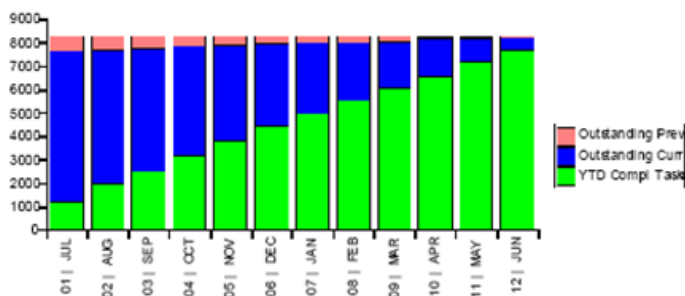
The example bar charts are of an electrical maintenance group’s preventive maintenance inspection requirement and we can see how they are progressing monthly in meeting the annual inspection targets. The group has 12 months to complete all inspections. Each month the KPI graph tells us how they perform. Green means inspections complete, red means inspections overdue and blue are

²Smith, R., ‘Monitoring and Reporting for Success’, ICOMS 2007, Energy Australia

inspections remaining to be done not yet overdue. The use of this KPI proved to be highly successful in getting the inspections completed. Previously their assets suffered high rates of breakdown. Investigations identified that barely 80% of condition inspections were being done in a year. Since maintenance is a risk control activity any inspections not completed meant undetected problems that would inevitably lead to failures. When the graphs were made public the persons in charge of resources began to plan and schedule work to meet target dates. Within the first year the overdue inspections fell dramatically and breakdown rates plummeted. Changing behaviour to the right practices is a powerful use of a KPI.

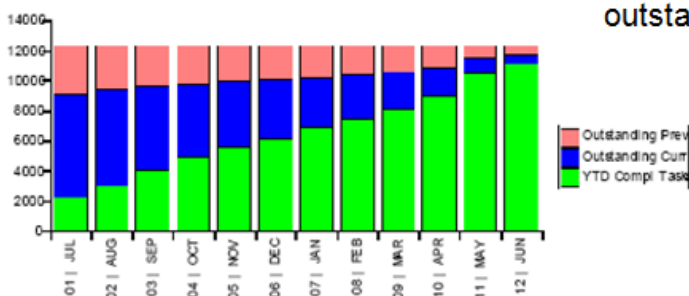
Showing Progress

Zone Substations
Inspections – 2004-05



Zone Substations group Inspections – Fig iii

Distribution Substations
Inspections – 2004-05



Distribution Substations group Inspections – Fig iv

Stacked Bar Chart with Red, Blue, Green quickly shows both progress and work outstanding still to complete

Figure 6 – Make KPIs Visual so Performance is Clear for All to See

Conclusion

KPIs are useful if they drive the right behaviours that produce good corporate outcomes. It's easy to choose KPIs that present information but are not directly actionable. When KPIs are set too high up the corporate objectives structure you make changes by guesswork and live in hope that a desired result will happen. Such KPIs are not suitable for Maintenance because successful maintenance is proactive and needs KPIs that produce proactive performance. By applying the scientific maintenance method to prove if a maintenance action will produce a desired reliability outcome you create useful KPIs to drive proactive maintenance performance that will permanently fuse into your business.

My best regards to you,

Mike Sondalini
www.lifetime-reliability.com