

# **Maintenance Planning and Scheduling for World Class Reliability and Maintenance Performance**

## **3-Day Training Course**

### **Day 3 Maintenance Planning and Maintenance Scheduling Slides with Complete Explanations**

# **The Maintenance Planning and Scheduling for World Class Reliability and Maintenance Performance Training Course Textbook 3**

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## Introduction

Welcome to the final day of the Maintenance Planning and Scheduling for World Class Reliability and Maintenance Performance 3-Day Training Course. I hope that you enjoyed Days 1 and 2 and found the maintenance, reliability, work quality control and work planning concepts they contained useful.

Day 1 covered the vital concepts of industrial asset management and maintenance that a Maintenance Planner needs to be aware of so they can align their duties and output with the aims of the enterprise. If you work in the Maintenance discipline you need to know the strategies that deliver equipment reliability and best production equipment performance. A Maintenance Planner needs to understand those concepts and how their role uses them to produce good maintenance results.

The entire Day 2 and part of Day 3 focus on the methods, routines and techniques of maintenance planning. You cover setting up the necessary work system, processes and practices for doing great maintenance planning. In Day 3 you also cover the equivalent requirements for maintenance work scheduling.

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November 2011

## Day 3

# Maintenance Planning and Scheduling 3 Day Course

## Work Planning continued and Work Scheduling

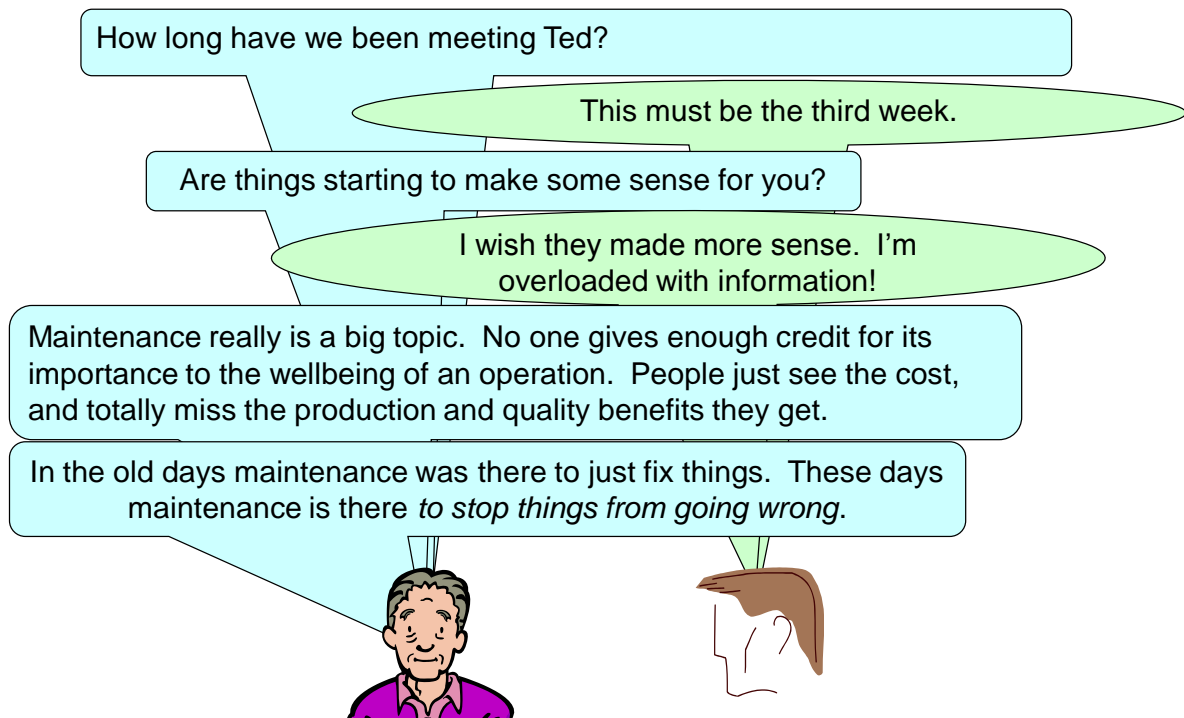
Presented by Mike Sondalini

This is the final day of presentations during which Work Planning is completed and Job Scheduling is explained in detail.

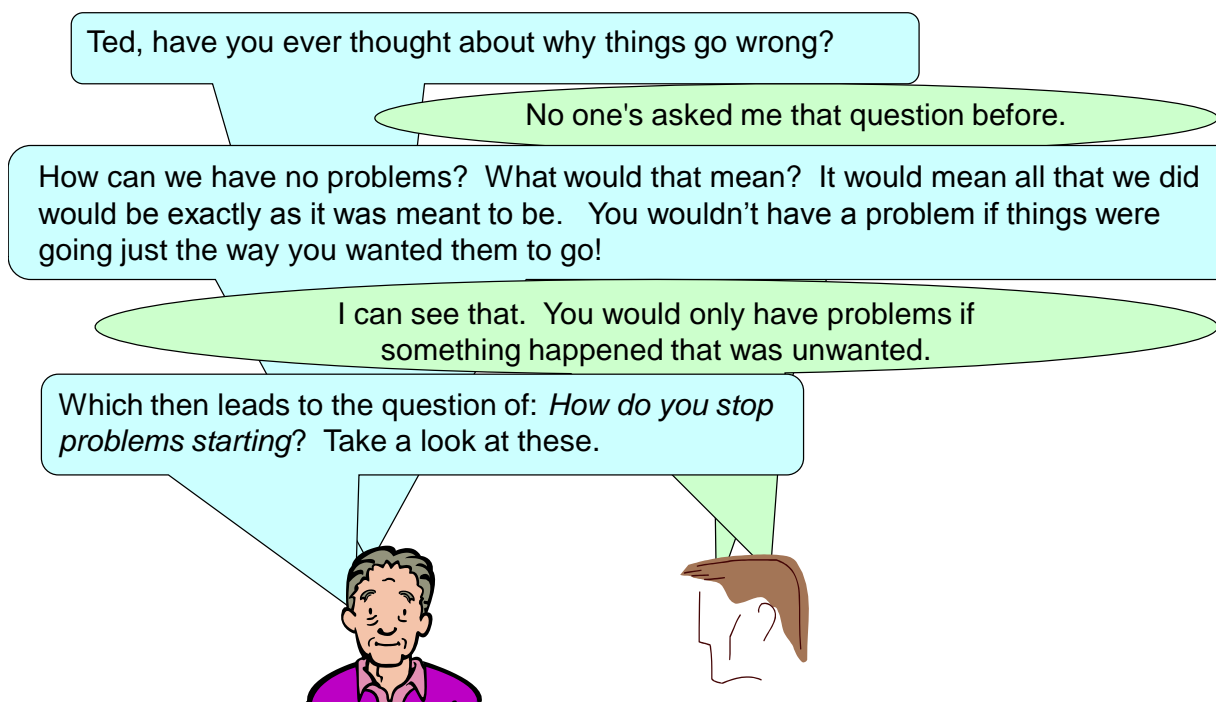
## Day 3 Content

- Defect Creation and Failure Initiation
- 'Cross-Hair Target' Game – understanding process effects
- Work Process Variation Control with 3Ts
- Including Work Quality Standards in Maintenance Jobs
- Maintenance Key Performance Indicators / Benchmarking
- Work Scheduling
- The Work Schedule
- WO Scheduling Process
- Production and Maintenance Partnership
- Role of the Supervisor
- Pre-job Start Preparations
- Backlog Management – the 'big picture'
- Reducing the Risk of Problems on the Job



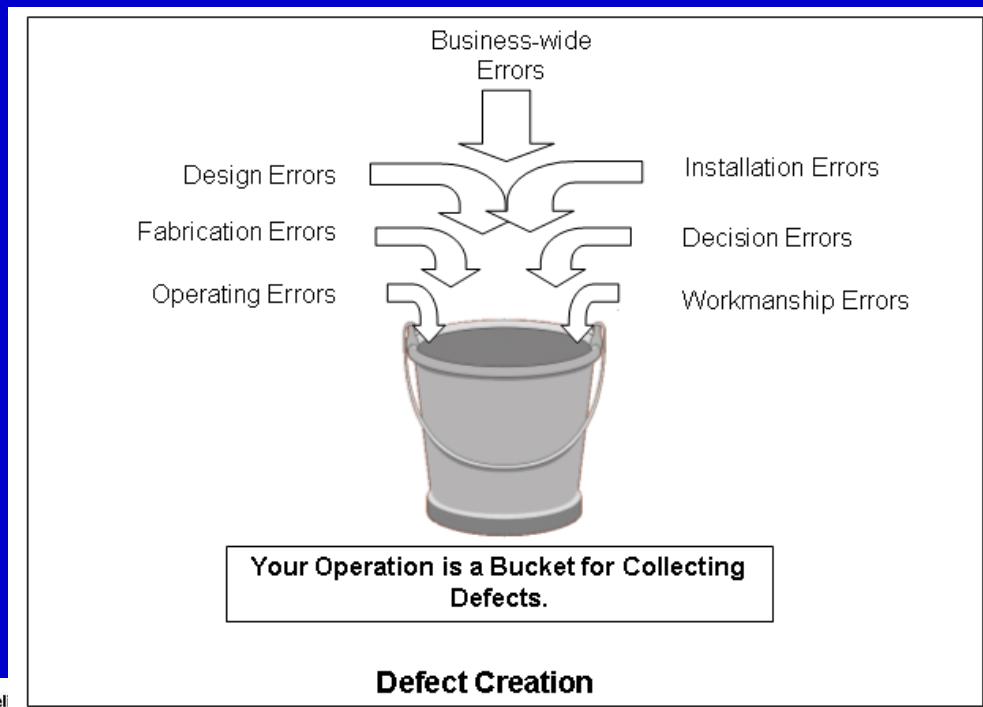


At their next session ...



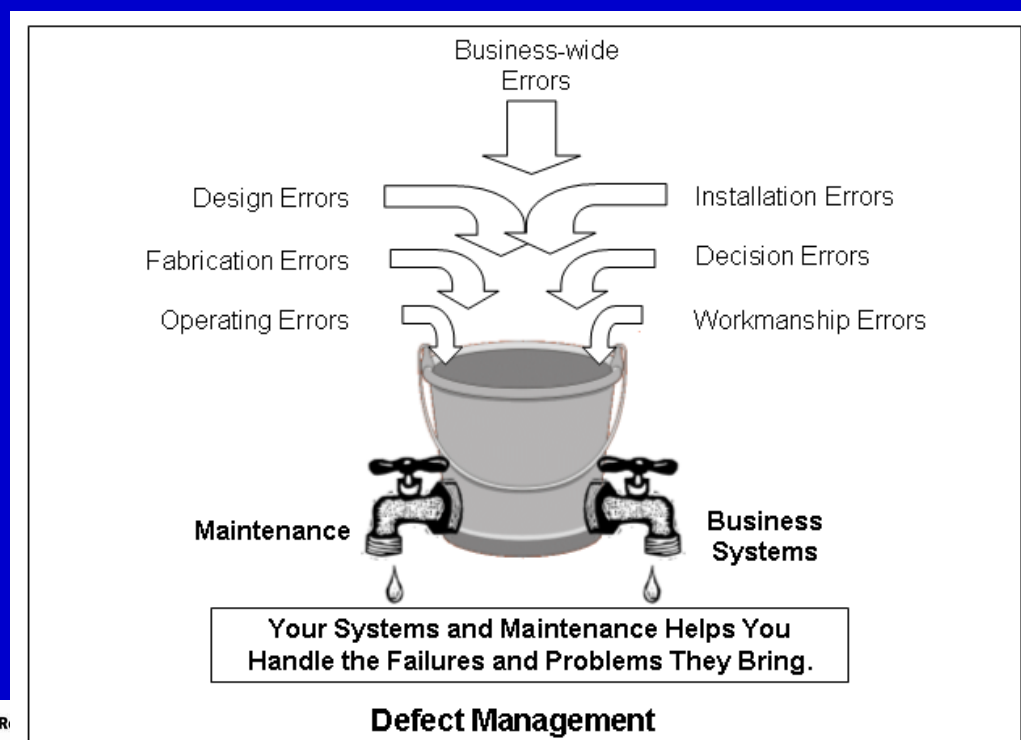
What causes maintenance ...

## Defect Creation and Failure Initiation



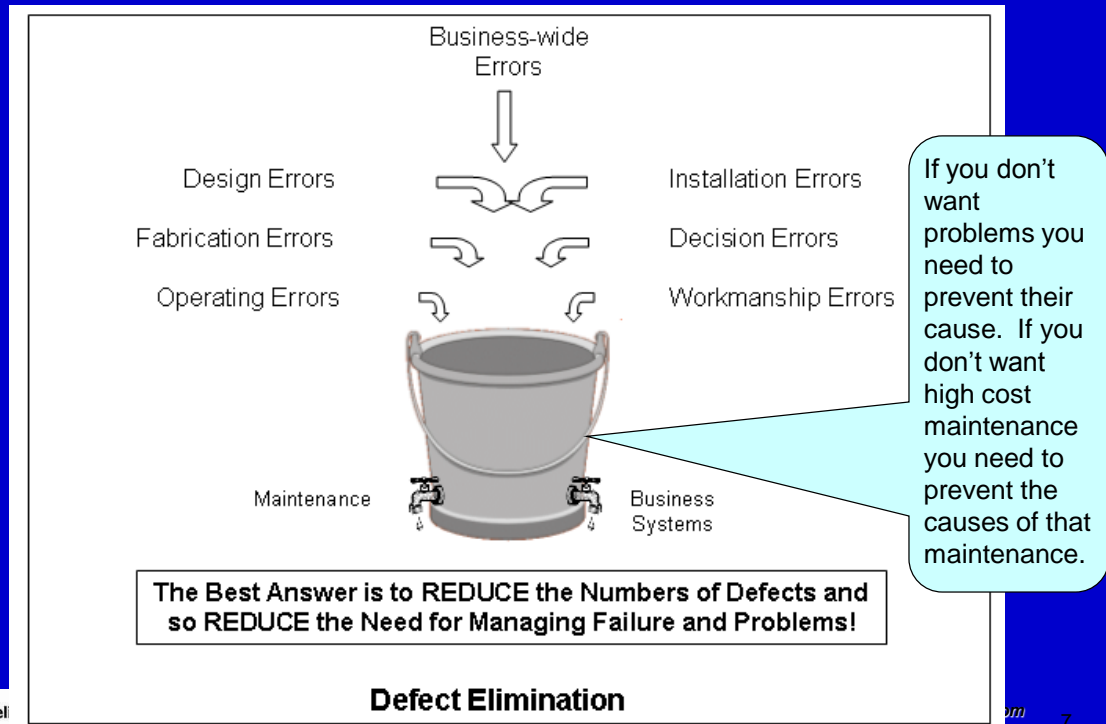
This is a version of the DuPont Defect and Failure Creation Model. It shows that a business collects errors, defects and failures. These then cause further problems to in the organisation. The problems become so numerous that they take resources and time away from the business

## Common Defect Management Strategies



In response to the many problems, a business installs systems to handle them. These become the 'way we do things around here' and are seen as normal behaviour. In reality the business systems are correcting errors, defects and failures that should never have happened.

## Defect Elimination and Failure Prevention



Would it not be better to stop the problems from entering the business in the first place? This is what defect elimination and failure prevention is all about. In the end DuPont developed 105 standards, guidelines and protocol documents of best practices to control the creation of defects.

**Technology & Facilities Safety System documents : 9 off**

**Electrical System documents: 7 off**

**Fire and Explosion prevention documents: 8 off**

**Environmental Risk documents: 8 off**

**Product Stewardship documents: 7 off**

**Distribution Requirements documents: 5 off**

**Occupational Health and Industrial Hygiene documents: 7 off**

### ASSET PRODUCTIVITY

1. **Maintenance and Reliability Systems – 5 off**

2. **Manufacturing Capacity – 5 off**

3. **Energy Optimization – 5 off**

4. **Facilities Infrastructure – 6 off**

5. **Mechanical Integrity - 4 off**

6. **Product Quality and Process Control - 7 off**

### CAPITAL EFFECTIVENESS

1. **Business Planning – 1 off**

2. **Facility Planning – 2 off**

3. **Project Planning – 2 off**

4. **Project Implementation – 3 off**

5. **Start-up and Initial Operations – 1 off**

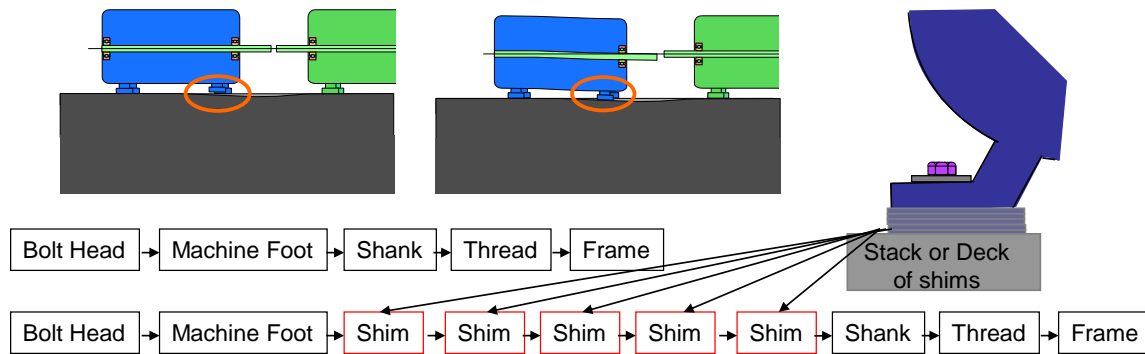
6. **Value Improving Guidelines - 12 off**

7. **Contractor Effectiveness**

8. **Shutdown/Turnaround Practices**

# The Trouble with Accepting a Defect

Soft-foot is an example of a defect regularly brought into companies, that then causes on-going problems



**Using 5 shims has made the connection more unreliable. There are now 5 more things to go wrong. They have added cost, require additional maintenance and introduced certainty of repeated human error throughout future times.**

Defects enter into organisations by the thousands a year; unless the organisation has put up defences. Once the problem is in your operation, you have to deal with it. In the slide, a soft-foot defect has been accepted into the plant. To correct it now requires the use of shims to fill the gap. Though this solves the problem, the shims have caused additional work. They also represent additional risk to the equipment, since if they are lost it is highly likely the foot will be bolted down into the base frame without them, producing in a distorted and deformed machine. The parts in the machine will become deformed, be highly stressed, and fail faster.

By adding shims we may have stopped the deformation, but we have also reduced the reliability of the connection. From what should have been a bolted connection series configuration of 5 or six steps, the addition of the shims has turned it into a series process of 10 or 11 components. If you must use shims never use more than two (2) together (maximum 3) and make certain they are of material that does not compress with age (like plastic) or corrode in the local environment.

Once you have many shim faces you cause a loose bolt. The metal relaxes at each face and the tension in the fastener is lost. The foot becomes loose and the machine starts to vibrate and thereby damage internal components. If you use shims to address soft-foot you also need to regularly go back and tighten those fasteners—at least every month. Companies that use Total Productive Maintenance (TPM) make it the Operator's job to tighten hold-down bolts because they know that the bolts will become loose as the equipment is used. They thereby introduce a second process, on top of the original tensioning process, to protect the operation from the certain occurrence of loose fasteners that will happen in future.

The best answer to the risk of defects entering your business, is to ensure they are stopped before they cross your border. Put into place the necessary methods and precautions that ensure only high quality, high accuracy work is in your machinery from the outset.

# Only 2 Ways to get High Reliability Systems

## • Series Systems



$$R_{\text{system}} = R_1 \times R_2 \times R_3 \dots R_n$$

$$R = 0.95 \times 0.95 = 0.9025$$



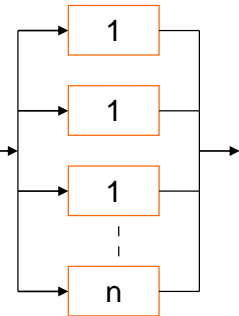
| Number of Components | Series System Reliability |        |        |        |
|----------------------|---------------------------|--------|--------|--------|
| 1                    | 0.95                      | 0.97   | 0.99   | 0.9999 |
| 2                    | 0.9025                    | 0.9409 | 0.9801 | 0.9998 |
| 4                    | 0.8145                    | 0.8853 | 0.9606 | 0.9996 |
| 6                    | 0.7351                    | 0.8330 | 0.9415 | 0.9994 |
| 8                    | 0.6634                    | 0.7837 | 0.9227 | 0.9992 |
| 10                   | 0.5987                    | 0.7374 | 0.9044 | 0.9990 |



## • Parallel Systems

$$R_{\text{system}} = 1 - [(1 - R_1) \times (1 - R_2) \times \dots (1 - R_n)]$$

(only fully active)



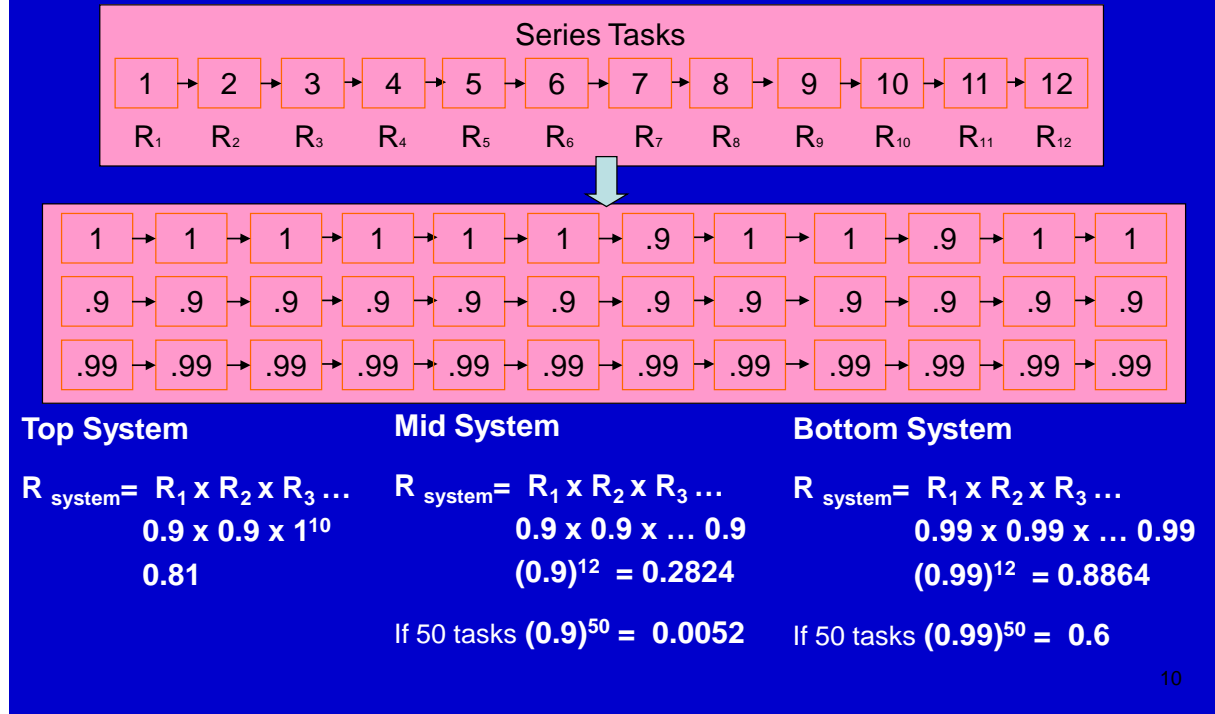
$$R = 1 - [(1 - 0.6) \times (1 - 0.6)] = 0.84$$

| Number of Components | Parallel System Reliability |        |        |        |
|----------------------|-----------------------------|--------|--------|--------|
| 1                    | 0.6                         | 0.8    | 0.9    | 0.99   |
| 2                    | 0.84                        | 0.96   | 0.99   | 0.9999 |
| 4                    | 0.9744                      | 0.9984 | 0.9999 | 1.0000 |
| 6                    | 0.9959                      | 0.9999 | 1.0000 | 1.0000 |

The probability of a series system outcome is the multiplication of the probability that each component will work correctly. This means that as more components are added to the series the system success rate falls, since there are more components to go wrong. While the probability of a successful parallel system outcome is made vastly more certain by having multiple components where if one fails the other components take over the duty.

There are only two ways to get high system reliability: 1) each component in a series arrangement must have greatly higher individual reliability, or 2) put components in parallel.

## Reliability of Series Work Process

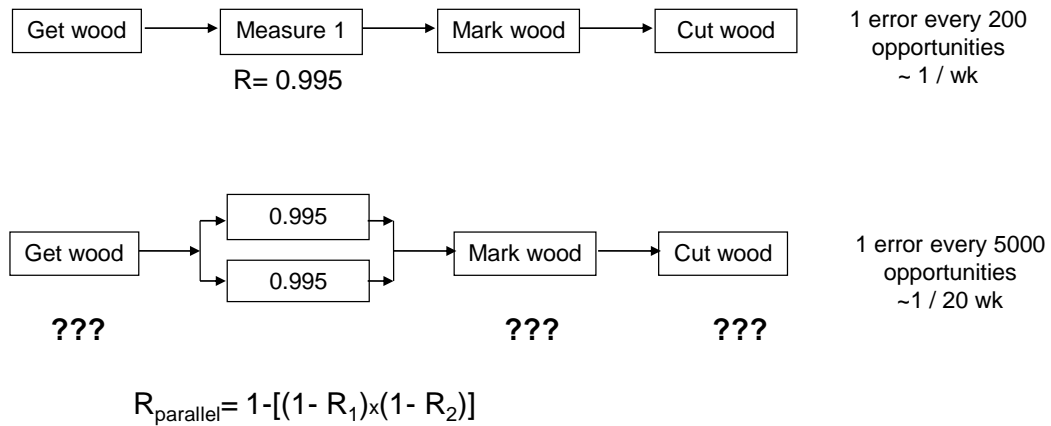


When work is done in series, the poor performance of any task leads to a poor outcome for the whole procedure. In a long series process there is great opportunity for error and defect introduction.

In a 12 task maintenance procedure, if all but two tasks are always done 100% right and the outstanding two are done right only 90% of the time, then the certainty that the whole procedure is right whenever it is done drops to 81 times out of 100 (81%). If instead all 12 tasks are likely to be done right 90% of the time (10% of the time they will be done wrong), the likelihood that the whole procedure will be done right is only 28% of the time. Should the chance of each 12 tasks being done right rise to 99%, then the chance of the whole procedure being done right at any time becomes 88.6%.

The only way to ensure that series work always is done 100% right every time it is performed is to ensure every series task is done 100% right every time. This we know to be impossible because human beings do the work, and human beings make mistakes. We need a better solution than trying to tell people not to make mistakes in their work.

## Carpenter's Creed: *measure twice, cut once*



**This is a 'mistake proofing' method that greatly reduces the chance of an error being made and left behind in a job as a defect that will later cause failure.**

Another example of a parallel process is the Carpenter's Creed - 'Measure twice; cut once'. The advice is to do a double-check before accepting what you think is right. Carpenters know that the double-check will save problems and trouble later. We can turn the adage into the simple parallel process shown in the Figure.

Though each measurement is done one after the other in series, the logic of the proof test is to act as a check on the first measurement. Thus the second measurement is a parallel test activity as shown in the bottom reliability block diagram.

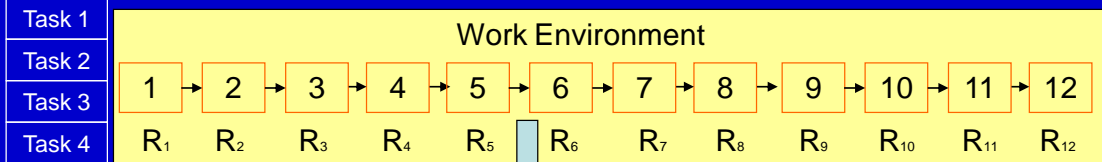
The typical error rate in reading a tape measure is five times in every thousand it will be misread, or 995 times out of 1000 it will be right (a reliability of 0.995). The carpenter will cut the wood in the wrong spot about once every 200 times. It is not hard to imagine a carpenter doing 50 cuts a day. So about once a working week they would cut the wood in the wrong place and have to throw it away. When he also does the proof-test measure the chance of getting the cut right rises to 0.9998, which is an error rate of 2 in every 10,000 times. With 50 cuts a day they will make an error once every 100 working days, or about every 20 working weeks. The simple addition of a check-test produced twenty times fewer measurement mistakes. That is the power of paralleling test activities to tasks to ensure they are right.



# Can we get 10,000% fewer errors? (Two sigma to five sigma)

A Maintenance Job ...

...is a Series Work Process

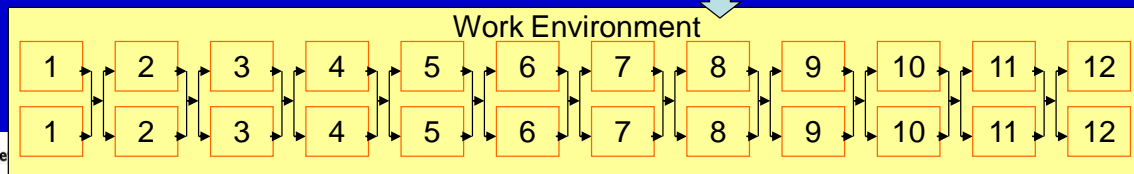


Use 'Human Error Rate Table' in the Workbook to calculate the chance of all 12 tasks being done right?  
 Use the equation ... **Chance of Being Done Right = 1 – Chance of Being Done Wrong.**

What if there were 50 tasks involved in a job?

**How can a Maintenance Planner increase the chance of the job being perfectly?**

**Each task can be made more certain  
 if we can include redundancy and  
 turn it into a parallel arrangement?**



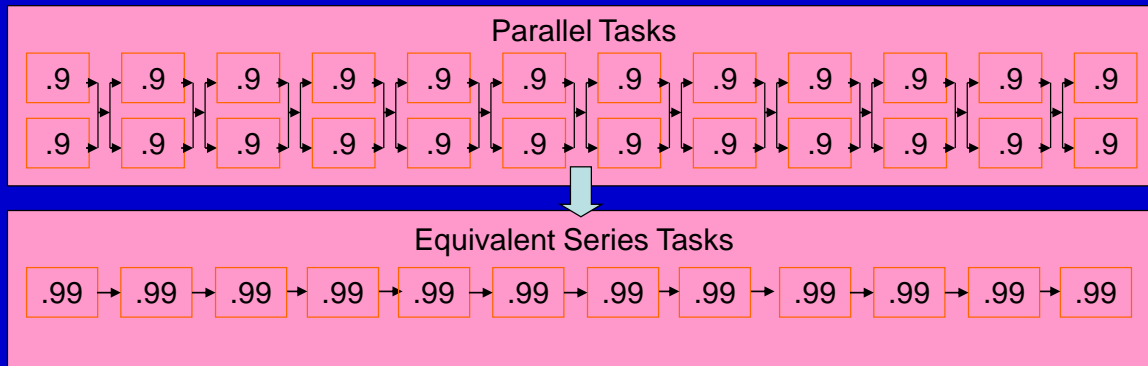
Most organisations without a properly working quality management system have error rates of 15 or more in 100. That means for every 100 opportunities for things to go wrong at least 15 do. They are two-and-a-half (2-1/2) sigma operations. Many companies would have error rates of 30 in 100 and more; a two sigma operation. Such a situation is fantastically expensive for a company because a lot of work will have to be done twice. Very few companies can afford to pay twice as much for a job as they expected to pay.

The Maintenance Planner is in a situation of being able to lift an organisation's maintenance crew performance because they can control the quality of information and the work standards being given to the maintenance crew so that the number of task errors are reduced. The human error table provides Maintenance Planners with useful tools and methods to improve a Maintenance Technician's chance of doing high quality work in every activity they undertake.

The Maintenance Planner can also use the reliability improvement principle of parallel arrangements and introduce a proof test into each task in a procedure to ensure the task is done right. The new 'system' of task and proof test together produce greatly more reliable outcomes. Once all tasks are done right the whole job outcome must be right.



# Parallel Process Boosts Work Reliability



| Parallel Process   | Series Process with Parallel Test  | Without Parallel Test  |
|--|--|--|
| $R_{\text{system}} = 1 - [(1 - R_1) \times (1 - R_2) \times (1 - R_3) \dots]$<br>$1 - [(1 - 0.9) \times (1 - 0.9)]$<br>$1 - [0.1 \times 0.1]$<br>$1 - [0.01] = 0.99$ | $R_{\text{system}} = R_1 \times R_2 \times R_3 \dots$<br>$0.99 \times 0.99 \times \dots 0.99$<br>$(0.99)^{12} = \underline{0.8864}$<br><br>If 50 tasks $(0.99)^{50} = 0.6$ | $R_{\text{system}} = R_1 \times R_2 \times R_3 \dots$<br>$0.9 \times 0.9 \times \dots 0.9$<br>$(0.9)^{12} = \underline{0.2824}$<br><br>If 50 tasks $(0.9)^{50} = 0.0052$ |

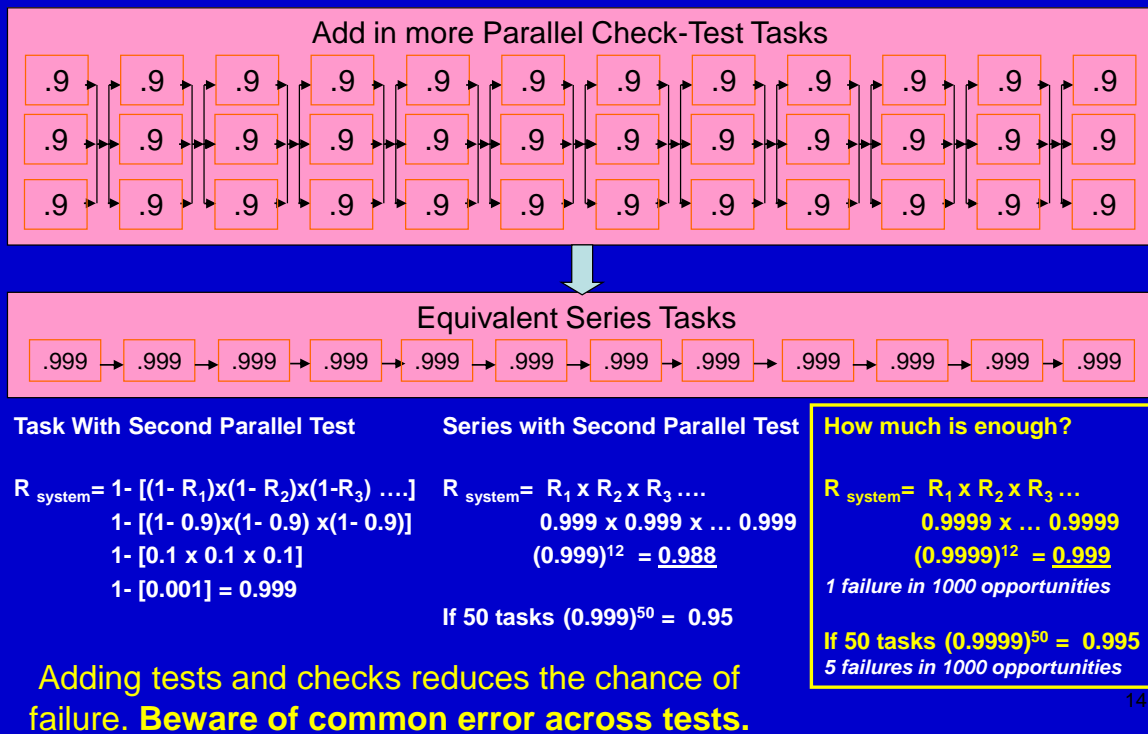
**Clearly, adding a test check into each task makes tremendous improvement in workmanship quality. This process went from a 28% chance of it being done right, to a 89% chance!**

Any time we can turn a series task into a parallel task we increase the chance of it being done right.

In the slide, each task is turned into a parallel task by adding a 3T proof test, which is itself also done right only 90% of the time. Where we would have got the procedure right only 28% of the time if it was a series process. We get it right 88.6% of the time when we have a parallel test, even though both the task and the test are each done right only 90% of the time.

Clearly adding a test check into each task makes tremendous improvement in workmanship quality.

## How Much Must WE Control Chance?



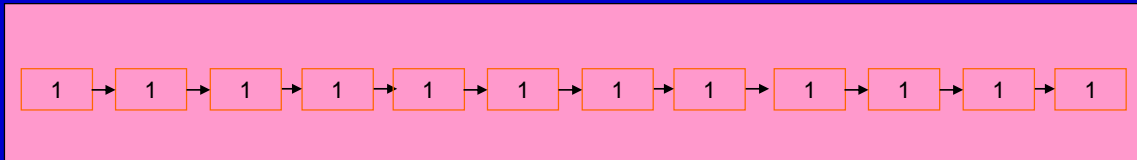
If you want a higher likelihood that the outcome will be right, you must provide additional risk control at every step in the process used to deliver that outcome. Then, as the chance of error in individual tasks is reduced, the likelihood that the whole job will be done right rises.

Beware that if you want high levels of control, each layer of proof test needs to be independent of the others so that any errors in one test is not duplicated in another. For example, if you measure a second time, and the second test is done with the same measuring device used for the first test, you will commit a 'common error'. The measuring device may be wrong and the second test would not detect that error.

Another common cause error example is if a second inspection is used to do a proof-test, but it is done by the other person with the same measuring device. The second person doing the measurement would also suffer the same error with the measuring device. Both people doing the measurement would agree but both would be wrong because the device commonly shared was in error.

## But Paralleling Test Tasks adds Cost... *So what can you do?*

**BEST ANSWER IS TO 'ERROR PROOF', SO IF IT IS WRONG IT DOES NO HARM**



**ERROR PROOFED Series**

$$R_{\text{system}} = R_1 \times R_2 \times R_3 \dots$$

$$1 \times 1 \times \dots 1$$

$$(1)^{12} = \underline{1}$$

If 50 tasks  $(1)^{50} = 1$

**A PERFECT RESULT EVERY TIME!**

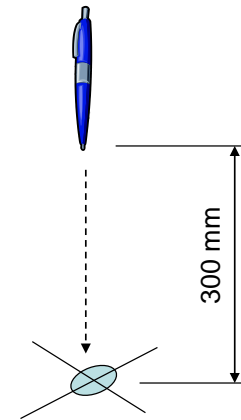
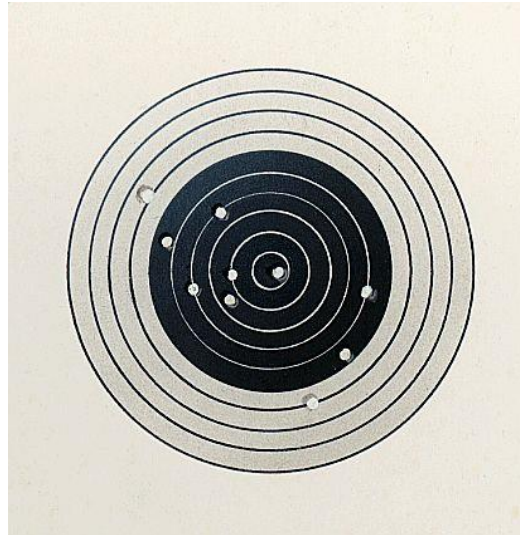
15

Human error cannot be prevented. It is in our human nature to make mistakes. They will always happen because our brains and bodies have limits<sup>1</sup>. But it does not mean that a mistake must lead to a failure. There is a better way to control failure than paralleling test activities. That is to ensure failure cannot happen by using error-proofing. Error-proofing means to change the design of a thing so that mistakes have no effect on the outcome. We get 100% reliability in an error-proofed process. In all situations and circumstances no human error leads to failure. Error-proofing does not mean mistakes are not allowed, they are inevitable; rather, when mistakes are made they will not fail the job. Examples of the practice of error-proofing equipment include changing designs of parts so they can assemble only one way, and providing parts with tell-tale indication of correct positioning. In information collection, transcription problems can be greatly reduced simply by changing the layout of forms to promote clear writing and easy reading. The slide shows a job designed so that each task is error-proofed.

In machines designed where maintenance and operating tasks are completely error-proofed, there are no failures from human error. The work and parts are designed in ways that allow human error to occur, but the errors cannot progress to equipment or job failure. We cannot stop human error. But we can create machines and work processes that do not allow human error to cause failure. The right outcomes result first-time-every-time, done faster and for less cost.

<sup>1</sup> Gladwell, Malcolm., 'Blink, the power of thinking without thinking', Back Bay Books, 2005

## Activity 9 – The Cross-Hair Game: Observing Business Process Outcomes



Cross-hairs and  
10 mm diameter  
circle

How do you hit the bulls-eye every time?

You develop a process to deliver repeatable outcomes. The process is built so that its inputs always result in a known output. If the process does not deliver the same result every time, it is a very poor process. The 'cross-hair' gets people to use a process and identify how to improve it. Finally they are challenged to make the process error proof so it can never be done wrong.

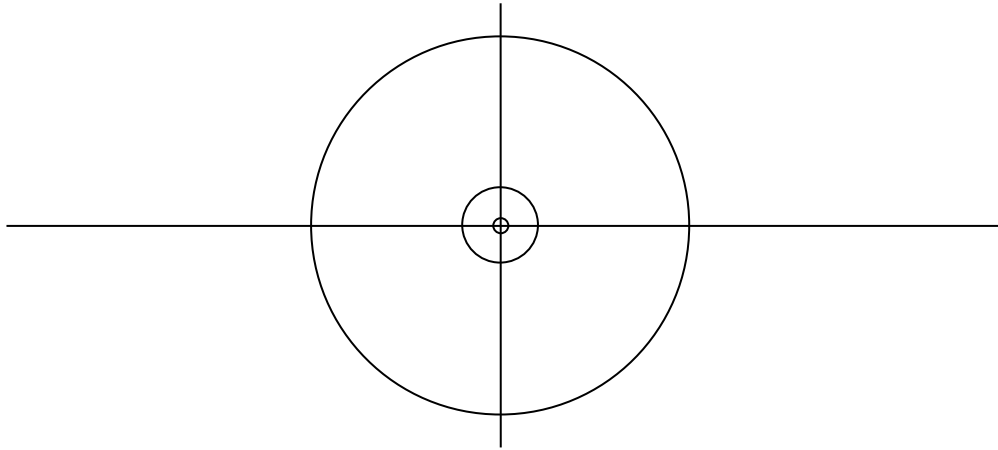
The Attendees drop a pen from 300mm height into the 10mm diameter circle. The circle is the tolerance, and anywhere within the circle is acceptable. 10 attempts are made to get the pen into the circle. After which the group discusses why they cannot get repeatable results.

The next task for the group is to develop a new process that will always have the pen land on the cross-hair point and to test the process actually works. The group discusses their learning and problems. One issue that the group needs to consider is how much human interaction is present in the process, because the risk of human error increases as the number of human activities present increase.

Lastly the group is asked to invent a process that is error-proof, with no possibility of human error. There is at least one known error-proof solution.

## Activity 9 – The Cross Hair Game

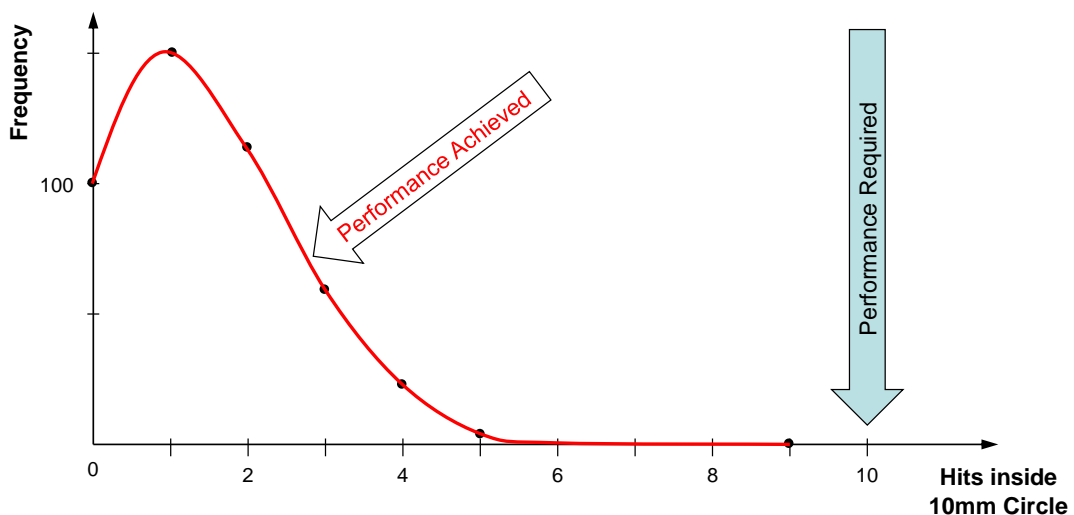
1. Drop a pen 10 times from 300mm above the top cross-hairs (height of the long side of an A4 sheet of paper) into the 10mm circle and count how many times you land within it.
2. Design a process that will always land the pen within the 2mm circle no matter who does it.



There have been a number of process changes proposed by past players. These include a long, tapered funnel to guide the pen onto the target; a tube in which the pen slides; a vee-shaped slide to direct the pen into the circle; a guide rod with the pen fixed in a slider that moves up and down the rod, and a robot with a steady manipulator to drop the pen.

There is one error-proof answer known to the Author. It requires that you use the paper in a different way and make the paper into a funnel with the 2mm circle at the bottom. No matter where the pen is dropped it always goes in the circle. This error-proofed solution turns a very difficult problem into one that is always perfectly done. Human error has no effect on the outcome.

## ‘Cross Hair’ Manufacturing Process Results



The distribution of results from the ‘cross-hair game’ process after playing it some 500 times are shown on the slide. Of the around 500 people who played the game one person landed their pen in the circle 9 times out of ten. Some people are exceptional at what they do. The rest of us are not. But companies cannot only employ exceptionally talented people; there are very few of them about.

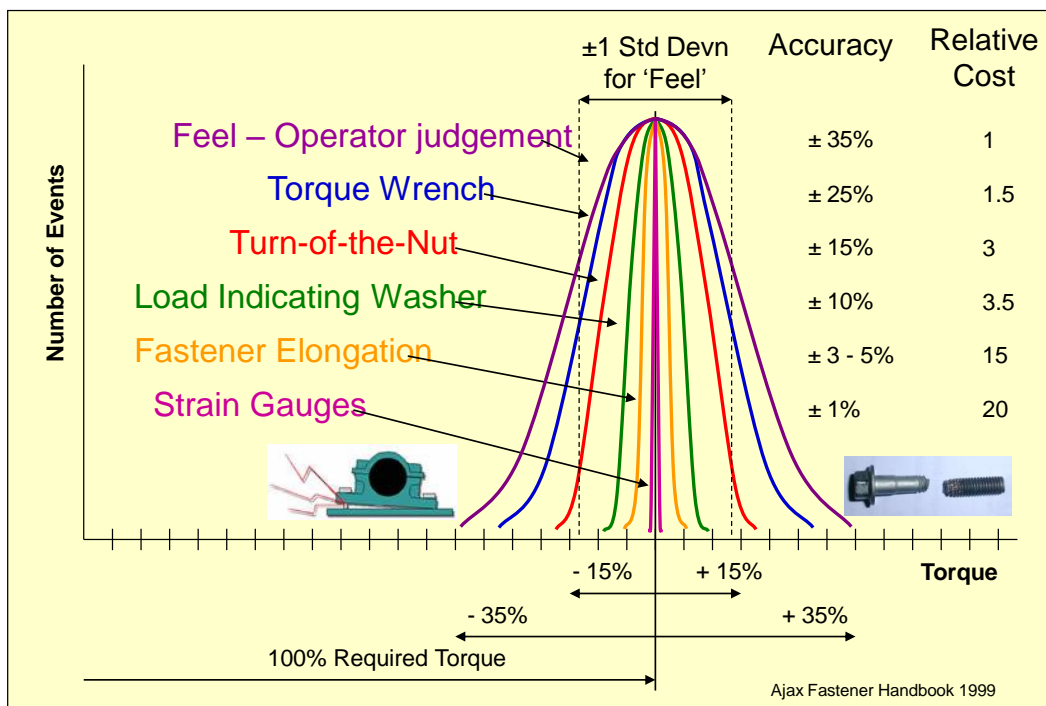
The process of dropping a pen by hand to make the marks inside the 10mm circle from 300mm height used can never deliver the required results except by great luck. If a company is to stay in business you need a process where the right outcomes are totally certain every time.

The results from the process in use prove that the output requirement cannot be met by this process—it is not capable of meeting the specification. Many company problems are the result of using a process that cannot reliably produce the needed result every time.

An answer jokingly suggested from time to time is to open the circle up to 50mm diameter and then everything will be on target. The suggestion totally defeats the purpose of having a process that delivers accurate results. Unfortunately, many businesses unwittingly select it as the solution to their problems. They chose to ‘widen the target’ and accept any result, good, mediocre or disastrous, rather than set high quality standards and improve their processes to match them. A business that does not pursue excellence in their activities will not last<sup>2</sup>.

## Where does Failure Start in a Process?

*The problems start with ‘chance’ variation...*



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An example of a classic misunderstanding of variability that makes equipment breakdown is the tightening of fasteners. This misunderstanding is the root cause of many flange leaks, fastener looseness and machine vibration problems. The slide shows the variation in the typical methods use to tighten fasteners<sup>3</sup>. The method that produces the greatest variation, ranging ± 35%, is ‘Feel- Operator Judgement’, where muscle tension is used to gauge fastener tension. Even using a torque wrench has a variation of ± 25%, unless special practices are followed that can reduce it to ± 15%.

It is impossible to guarantee accuracy when tightening fasteners by muscular feel. Using a process that ranges ± 35% to get within ± 10% of a required value is like playing the cross-hair game – it requires a great deal of luck. Those companies that approve the use of operator judgement when tensioning fasteners must also accept that there will many cases of loose fasteners and broken fasteners. It cannot be

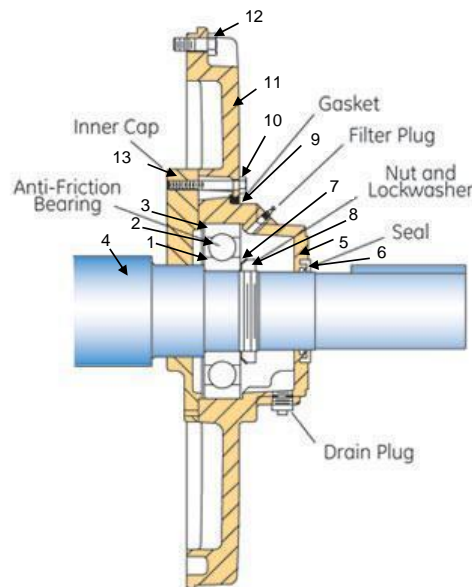
<sup>2</sup> Denove, Chris., Power, James D. IV., ‘Satisfaction – How Every Great Company Listens to the Voice of the Customer’, Penguin, 2006

<sup>3</sup> ‘Fastener Handbook – Bolt Products’, Page 48, Ajax Fasteners, Victoria, Australia, 1999 edition

otherwise because processes that use torque to tension fasteners have a high amount of inherent variation. It would be a very foolish manager or engineer who demanded that their people stop fastened joint failures, but only allowed them to use operator feel, or tension wrenches, to control the accuracy of their work. Such a manager or engineer would come to believe that they have poorly skilled and error-prone people working for them, when in reality it is the process which they specified and approved that is causing the failures. They have totally misunderstood that it is the process being used that is not accurate enough to ensure correct fastener tension, not the people.

Joint failure, loose fasteners and broken fasteners are inherent in the muscular-feel process. Torque is a poor means for ensuring proper fastener tension. To stop fasteners failing needs a process that delivers a required shank extension. It is the fastening process that must be changed to one that guarantees the necessary fastener stretch. Only after that management decision is made and followed through by purchasing the necessary technology, quality controlling the new method to limit variation, and training the workforce in the correct practice until competent, that the intended outcome can always be expected. The use of operator feel when tensioning fasteners is a management decision that automatically leads to breakdowns. Any operation using people's muscles to control fastener tension has failure built into its design – it is the nature of the process. This is why W. Edwards Deming said his famous warning to managers, “Your business is perfectly designed to give you the results that you get.” Poor equipment reliability is the result of choosing to use business and engineering processes that have inherently wide variation. These processes are statistically incapable of delivering the required performance with certainty, and so equipment failure is a normal outcome of their use and must be regularly expected. Failure is designed into the process and it is mostly luck that keeps these companies in business.

## Machines are Arrangements of Parts



Electric motor drive end bearing

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This sketch of the drive end bearing of an electric motor shows how the arrangement is assembled. Fourteen parts are needed to allow the drive end bearing to operate (No 14 is the lubricant).

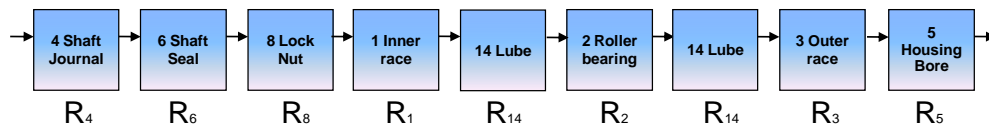


For the motor to do its work reliably in the years ahead the shaft must rotate within the bearing, the bearing inner ring must be correctly mounted on the shaft journal and the outer ring properly located within the housing. The shaft seal must keep grease inside the bearing chamber and contamination out. The lock nut must be firmly tightened and remain so throughout the motor's operating life.. The end cap holding the bearing assembly and bearing housing must be properly connected and centralized on the motor body frame. Contained within the entire motor are many more parts, all of which must work correctly for the motor to rotate and drive the attached machinery. If any of the above requirements that let the motor turn are not continuously met the motor will eventually fail and breakdown.

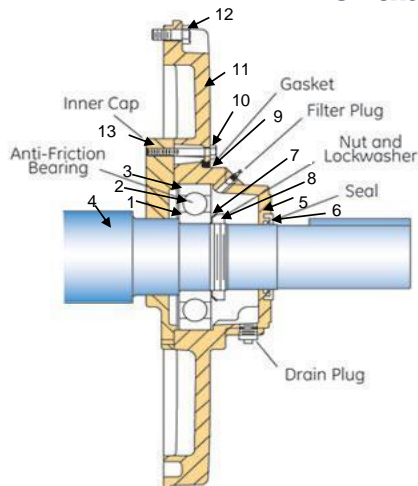
The motor is also supplied with power from the electrical supply system. Furthermore, it sits on a base and foundations and is held in place with fasteners bolted to the foundation. All the individual parts of the motor, along with its supporting structure and its power supply form a complete system that allows the motor to rotate. If any one of the parts anywhere in the system fails the motor will stop.

All electronic, electrical and mechanical machinery and equipment is made of individual parts that work together a system. The system fails as soon as one of its working parts fails. Once a part fails the item it belongs too stops and that then causes the system to fail. This is why it is critical that our strategy for trouble-free operation be focused on ensuring individual parts inside your physical assets are kept in good health their entire operating life—machines stop only after the parts fail.

## The Parts in our Machines Form a Series



### Reliability: the chance of Success



1. For the motor to be highly reliable every bearing must be even more reliable.
2. For the bearing to be highly reliable each of its parts must be even more reliable.
3. For every part to be reliable its design and operating health must be risk-free.



NOTE:  $R_n$  = Component reliability

Electric motor drive end bearing

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The string of boxes at the top of the slide is a reliability block diagram for a portion of the drive end bearing in the motor. The collection is a series arrangements of parts sequentially following one after the other. This is how the bearing is designed, as a string of parts that must work together so that the bearing can perform its duty.

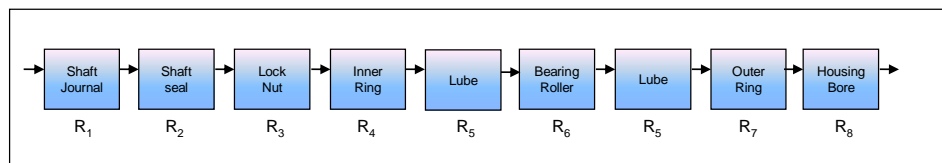
This approach, where parts are combined in series, is the same for all machinery and equipment—they are made of many parts assembled in a series arrangement that must work as a complete system for the item to fulfill its service.



In combination the parts form a chain, with each link of the chain being made of one of the parts. Once a single part fails the chain will break. In fact if any

## Calculating Equipment Reliability

Reliability is the **chance** that an item will last long enough to do its duty



$$R_{\text{series}} = R_1 \times R_2 \times R_3 \times \dots \times R_n$$

$$R_{\text{series}} = 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.99 = (0.99)^8 = 0.92 \text{ (or 92\%)}$$

$$R_{\text{series}} = 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0.5 \times 0.99 \times 0.5 \times 0.99 \times 0.99 = 0.23 \text{ (or 23\%)}$$

$$R_{\text{series}} = 0.99 \times 0.99 \times 0.99 \times 0.99 \times 0 \times 0.99 \times 0 \times 0.99 \times 0.99 = 0$$

*“Any poor,  
all poor”*  
*“Any fails,  
all fails”*

21

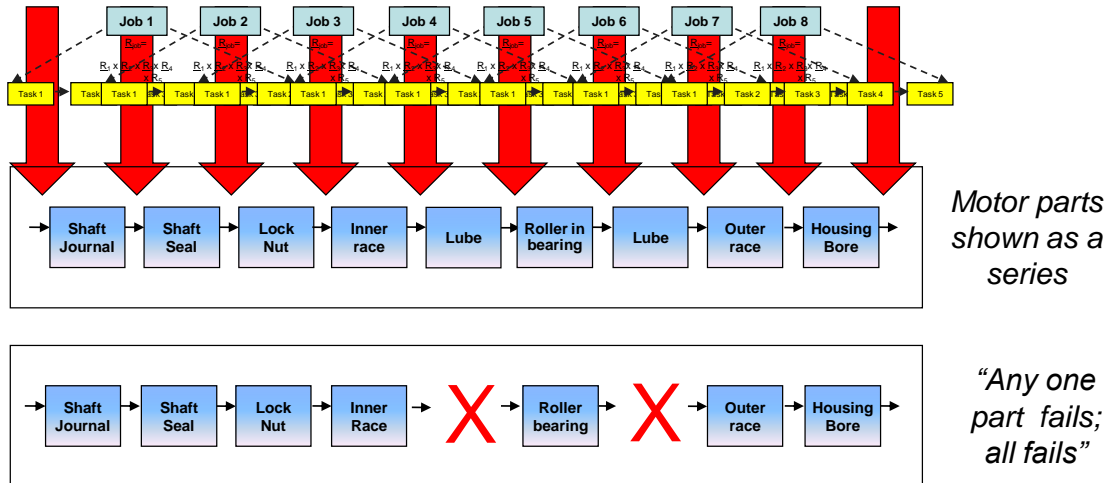
The parts' series arrangement in the bearing design is now modelled with reliability values for each part. Because the reliability of the system is the multiplication of the probability of each part's working properly (i.e. its chance of success), the equation makes clear that any time a part is in poor condition, or it fails, then the whole system is equally impacted.

Any poor condition part causes a poor condition system. Any broken part results in a broken down system.

The longer the series of parts becomes the lower the system reliability, as each part added provides an opportunity for more failures. For long series the chance of system failure becomes high.

The reliability values used in the equations are not real values. They were chosen only to show you how the equations worked. In reality the reliability of each item would be greater than what was used in the calculation. It would be a very poor bearing that had reliabilities as low as the 1 in 100 chance for each component failure used in the calculation.

## Machines Suffer High Risk of Failure from Human Contact

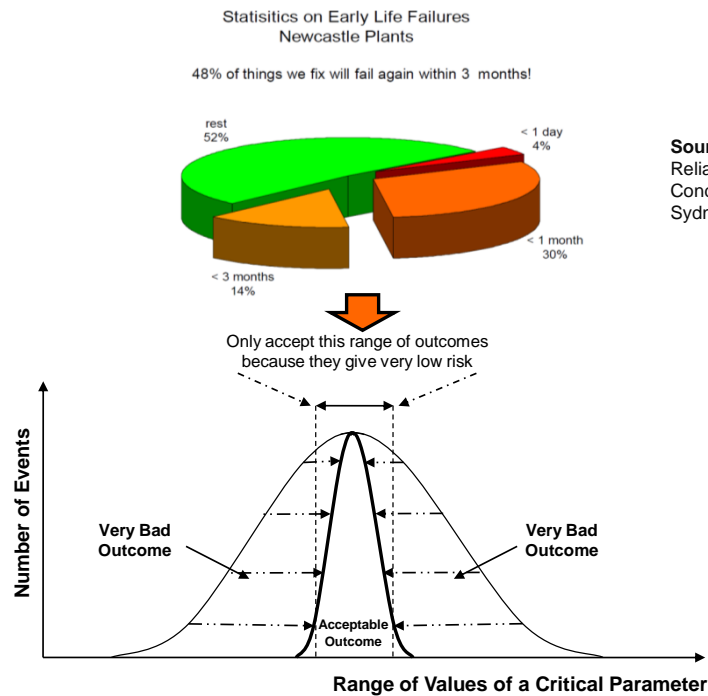


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People to use plant and equipment and people maintain plant and equipment. Human beings are mistake prone due to brain and body limitations. When you put error prone human beings with machinery whose individual parts requires amazing precision to keep the machine in operation, you naturally result with unreliable plant and equipment. Unless you proactively prevent reliability problems you are bound to get them when you mix machines and people together.

The truth is that if you have the choice do not put people anywhere your machines—they should not operate them and they should not maintain them. People destroy perfectly good equipment. This is why Rio Tinto, the global miner, is moving towards a fully automated mines where people are replaced with instruments and computer controls. In the mines where this technology is used the maintenance cost from failures caused by drivers completely stops. The mobile equipment fleet lasts longer between outages since loads and working forces are regulated and adjusted by the computer controls to stay within the design limits that parts can take.

# We need to remove all unwanted Variability



**Source:** Wayne Bissett, OneSteel Reliability Manager, Planning and Condition Management Presentation, Sydney, Australia, 2008

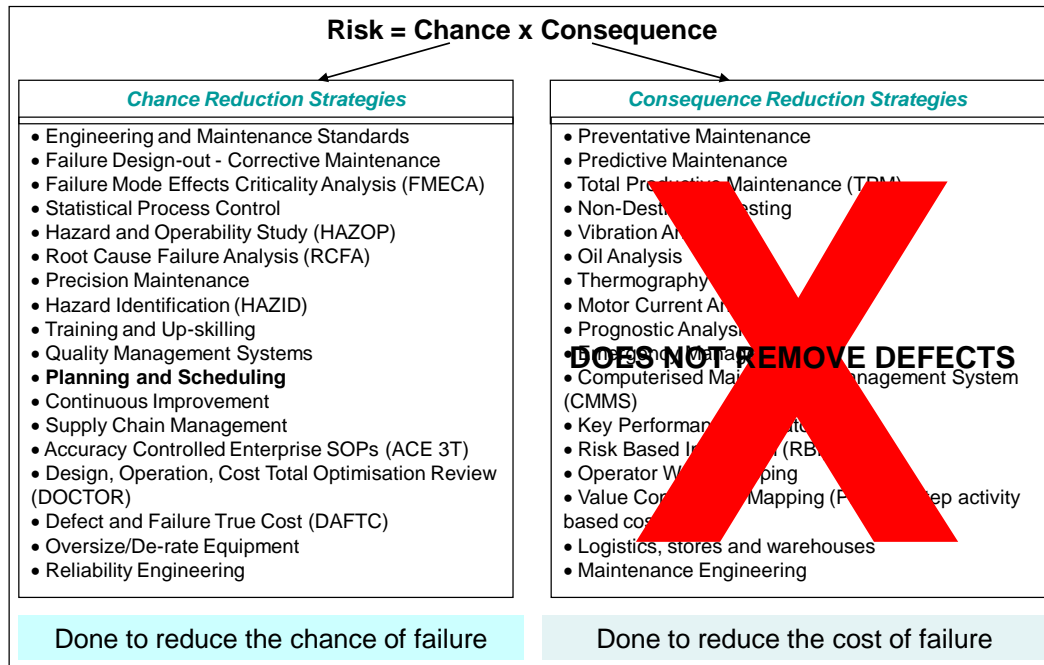
**In the end... reliability is a quality control issue.**

To stop repeat failures and repetitive breakdowns we need to create the precise conditions for endless longevity of the parts in our equipment. We need to operate all equipment with precision skills so that the parts in them are minimally deformed so that they live in a low-stress, healthy environment. Once you create the right conditions for machinery health and low stress the causes of failure are minimized and your reliability dramatically rises.

It becomes necessary to identify the exact conditions that each part in a piece of equipment must achieve if you want extraordinary reliability. These conditions are the quality parameters you set that, when achieved, automatically give you high reliability. Reliability eventually becomes a matter of how precise and accurate you can keep control of the stress and local environment of each working part.

In the end, reliability is a quality control issue, because the quality that you deliver to your plant and equipment is the reliability you will also get back.

# To Have Reliability Growth You Must Reduce the Chance of Failure



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We have seen that risk = consequence of failure x chance of failure. The chance of failure = opportunity to fail x the likelihood of failure at that opportunity. The full risk equation is then:

**risk = consequence x [opportunity to fail x the likelihood of failure at that opportunity]**, which in terms of reliability becomes:

**risk = consequence x [opportunity to fail x (1-reliability)]**

Since reliability is the chance of success it follows that anything you can do to improve the odds of success in your favor is worth doing. The table above is separated into activities that improve chance and those that reduce consequence.

If you want high equipment reliability then concentrate your efforts on improving your chance of success by doing those concepts in the left hand column.

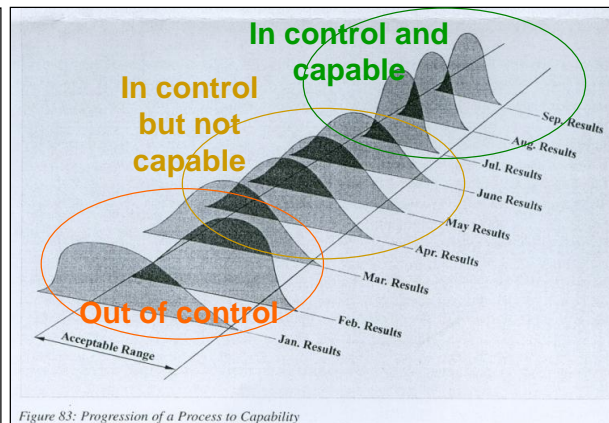
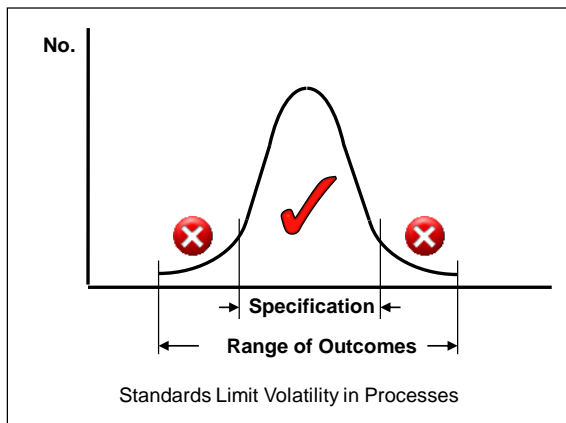
# Use Basic Statistical Control ('Three Sigma' method)

You only need to understand the concepts of an in-control process.

## Process Disruptions Causes Variation in Outcome

Measure your processes to know if they are in control and are capable.

*This requires use of basic statistical quality control methods.*



**Your processes (plant *and* human) need to be in control *and* capable.**

Lifetime

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This is the 'real' game that you need to play in every production operation. The game is known as statistical process control and it is represented by the right hand side series of curves. See how the closest three curves are each of different shape. The outcome distributions that the curves represent are dissimilar every month; there is also much waste and loss each month from unusable product. The process that these distributions reflect is out of control because nothing can be predicted from month to month. This is bad state to be in for a business.

In the next set of three months the process has come into control—it is repeatable month after month. Something was done that aligned the distributions and stabilized the process. We have confidence about what the future holds. We now only need to solve how to prevent the scrap which is still being made.

The last three months are the best—all in control and all capable of staying within the limits of acceptance. The process now makes 100% usable output with much of it of very high quality (i.e. well inside the acceptable range).

This is the 'game of production'—to make 100% quality output all the time. The winners are those companies that play the game best for the least costs.

What is the first thing that you must decide if you want to measure whether a business process is in control and capable? You first need to decide the limits of acceptance. Until you know what is acceptable from the process you cannot judge if the process is in control or capable. The limits of acceptance are also called quality standards. Again quality (i.e. the standards you work too) becomes the driving factor in production and operation—the acceptable quality you set for every task directly impacts the performance of the process and your capability to know how well the process is working.

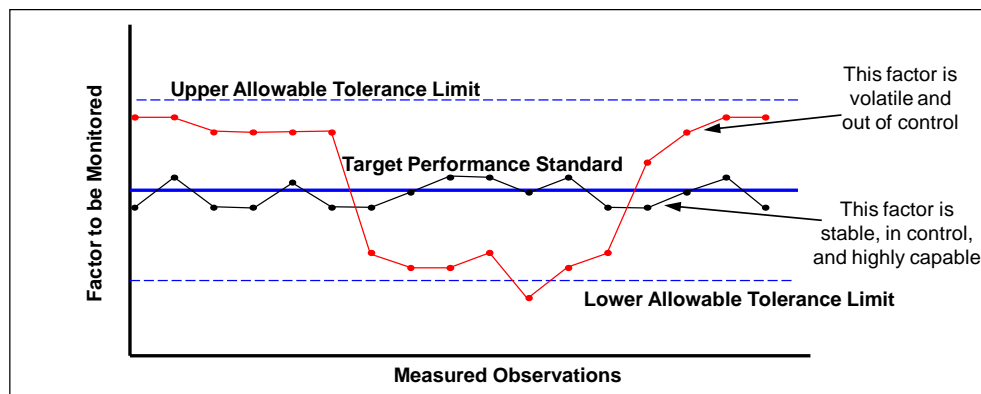
When we operate plant and equipment we want to make consistent quality product at the required production rate. If we can do that we are 'in-control' of the situation. Problems start when that cannot be done.

In order to control a process we must know the boundaries of acceptance for the process outcome, and we must be able to measure what the process produces. Then we can identify if the process is producing acceptable results.

The reality is that the universe we live in is probabilistic. The only constraint is the physics of the situation (at 0C water can be ice, liquid or vapour – which one a particular molecule will be is probabilistic). This means a variety of outcomes are possible from any situation, unless influence is brought to bear in deciding what situation is wanted.

Variability in human managed processes is controlled by defining which of the possible outcomes from each step in a process are the desirable ones. By selecting what is desirable and specifying it, the relevant processes are directed through a series of steps that, if done correctly, will produce a known outcome. Hence we get what we want by making sure the inputs into a process are correct and that the process behaves correctly.

## Control Charts Spot Variation After Its Happened



Control charts give feedback

Measuring a process is important. Once you have factual values that reflect the process performance, you can chart it and see its behaviour over time. Then you can make experimental adjustments to learn how to better control the process.

The purpose of controlling variability is to provide certainty of performance; to be sure you get the right results. Once variability in a process is identified, decisions can be made whether to accept fluctuating outcomes, or to address the underlying problems causing the fluctuations. If improvement is wanted the causes of problems must be found and solved. By removing performance fluctuations the process stabilizes and volatility reduces as the spread of results tighten around a consistent target. A process that produces consistent results with little fluctuation is highly predictable and results can be guaranteed.

The Figure in the slide is an example of a typical control chart showing the performance standard required and the acceptable tolerance limits either side of it. The chart is a visual management tool used to monitor process performance by recording measurements from the actual operation and plotting the distribution of them on the chart. The process is in control and capable when the results are randomly distributed closely about the target standard. When the results show a trend of three or more points, or



persistently track toward the limits, or gyrate widely about the target, or are outside the tolerance limits, you have an unstable process. A control chart provides accurate information to make the decision to alter, change or stop the process or operation. There are several control chart types and simple statistical techniques that can be used to monitor process and variable performance.

The unfortunate problem with control charts is they are an 'after the fact' measuring device and indicate the results following an activity, sometimes hours later.

## We all need clear Targets that we can SEE.



*How do You know You have got full marks?*

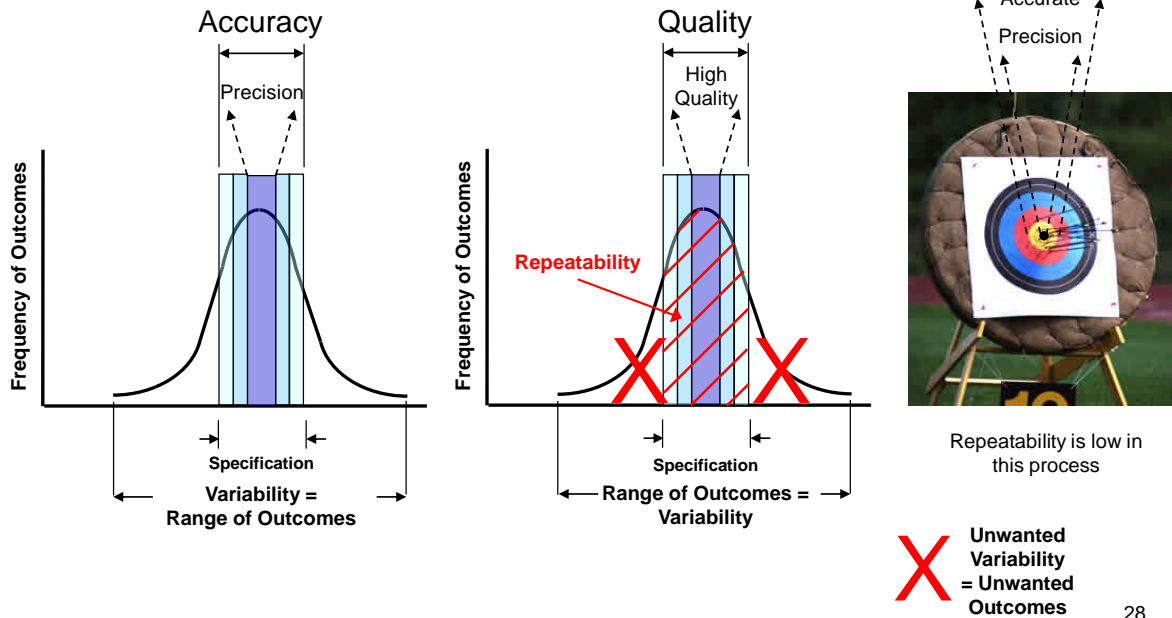
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If we played games where we only used feedback control to make decisions we would never win. By the time we collected the data, understood it and made a choice the moment to strike would be long past. In games we also use feed forward control—feedback control is useful when we read the scores tomorrow in the newsprint and realize that if we lost we need to develop better processes.

All the games shown in the slide give you immediate indication of what you are doing and how good are the processes and methods that you use. Equally as important you see your performance through your eyes. You observe the immediate result as it happens and with that knowledge you feed forward changes and adjustments to improve your chances of success next time. In our games we use visual management to permit our brains to make adjustments that improve our odds in future. You need to do that in your work processes and work tasks as well.

# What do we mean by....

## Quality, Precision, Repeatability, Variability



It is worth understanding quality, precision, repeatability and variability. Quality you would have read about in the last few pages—it is the maximum acceptable limits you want to achieve. Precision means to be highly accurate. Variability is the distribution of the results. For a capable process 100% of its variability is within the acceptable limits.

What we want to prevent is variability that is outside of acceptable quality. Once an item is not acceptable it must be reworked for an extra cost, downgraded to a lesser quality at great expense, or it must be thrown away as waste with its full value up to that point in the process. If you make too many unacceptable items, or do too much work that is sub quality, you spend a lot of money that you cannot recoup and the company goes broke.

How many defects, errors and failures can your operation afford each day? Do your people have the time to go back and do a job twice or three times because it was done wrong the first time? Are people happy to regularly accept wasted production and lost time due to mistakes and poor quality? If not, then do your internal work procedures support doing the job right the first time?

The elimination of error is vital in business operation. Problems drastically reduce profits. Errors produce bad, unwanted outcomes. They are wasteful. They take resources and money away from where they were intended to be used. They use valuable time to correct what should have been done right in the first place. Worst of all is that they did not need to happen. Business systems need to prevent errors, and if not they must quickly detect and stop them from going further. The longer an error is undetected during production the more work is performed on the product, and the more money and time is wasted when it is finally scrapped.



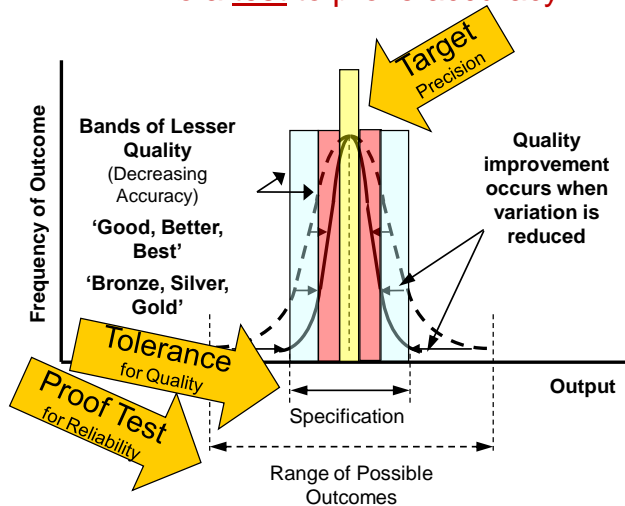
# Reliability Creating 3T Error Proof Procedures

## Build Mistake Proofing into SOPs

- Set a target for each task.
- Specify the acceptable tolerance.
- Do a test to prove accuracy.

**3Ts of Failure Prevention -**

**. Target**  
**. Tolerance**  
**. Test**



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The best failure prevention strategy is to proactively stop problems from entering the business. This requires that pre-emptive practices and methods are built into all business processes and systems as the normal way of doing work. Fortunately your business systems are in the written standard operating procedures and we can prevent errors by writing suitable preventive practices and measures in the operating procedures and teaching them to your people.

## Controlling Accuracy – Removing Error

If it is important to be correct it will be necessary to introduce procedures to guide people to constantly attain the necessary standards of performance that deliver the desired results. Test laboratories, such as materials testing, pathology testing, etc, have long recognised that if they want consistent, reproducible, correct results they need to work to proven and endorsed procedures. The test procedures provide clear guidance, set the required standard and stop variations in work performance. These standard operating procedures perform the role of helping employees efficiently (i.e. with the least use of resources) and effectively (i.e. in the least time required) deliver a specific result with certainty. The standard operating procedure, if followed faithfully, will produce the required outcome distribution. But if there is no procedure to follow it is uncertain what the actual result will represent and the testing maybe invalid.

Standard operating procedures are much more valuable than normally understood by many managers. Not often appreciated is their ability to greatly improve the likelihood of top quality performance from employees. They are a quality control device which has the power to deliver **a specific level of excellence**. They should be used to step-by-step take people through both simple and complex tasks so that they are done correctly every time. For the best results include the 3Ts – Target specification, Tolerance and a Test for proof – in the procedure to ensure people get feedback on how they are performing the tasks as they do them.

Having targets in your procedures to aim for will remove many current business problems. The target acts to centralise and control the spread of the distribution. Target-based procedures recover great

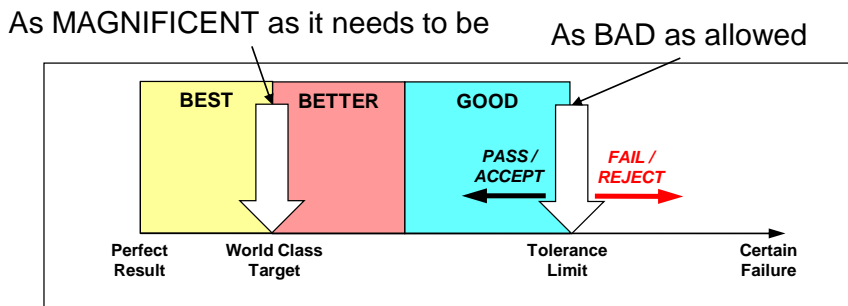
amounts of time and money. Adding targets, tolerances and tests in standard operating procedures will detect problems and prevent them from progressing further. They maximise productivity from current operating methods and turn-in a bigger profit.

A classic example of what great value an accuracy-focused SOP can bring is in this story of a repair on a piece of production equipment. A shaft bearing of a fan regularly broke down. Instead of giving many years of reliable, failure-free service, the rear roller bearing on this fan never lasted more than about two months after a repair. Each time the bearing failed the production downtime caused by the breakdown was an expensive and great inconvenience. To take it out of the realm of a breakdown the bearing was replaced every six weeks as planned maintenance.

The bearing was also put on regular observation using bearing vibration condition monitoring. After several replacements enough vibration data was collected to diagnose the problem as a pinched outer bearing race. The bearing housing had been machined oval in shape when manufactured and it had squeezed the new bearing out-of-round, every time it was bolted up.

You could say that vibration analysis was applied wonderfully well, since it identified the cause of the recurring problem. But the real truth was the repair procedure failed badly. If there had been a task in the procedure to check and measure the bolted bearing housing roundness and compare the dimensions to allowable target measurements, it would have been instantly noticed at the first rebuild as having an oval-shaped hole. There was no need for the bearing to fail after the first time! A badly written standard operating procedure had let bad things happen! A failure prevention focused SOP, with target, tolerance and test for proof, (the 3Ts) would have found the problem on the first repair and it would have been fixed permanently.

## How 3T's guide workmanship quality



Each person do  
 Good / Better /  
 Best for a clock<sub>30</sub>

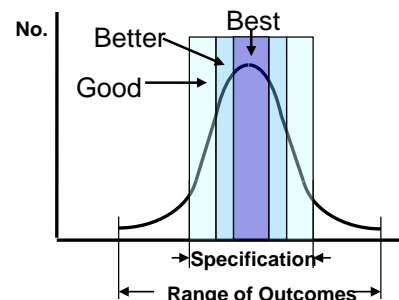
By using the 3Ts you create statistical process control in human dependent activities. The target is set as the very best results that you want. The Tolerance is set as the very worst results that you will accept.

The proof test confirms if the result is within tolerance and is acceptable. Target provide precision, Tolerance set the quality standard, and Test delivers highly reliable work.

The 3Ts create a mental bulls-eye challenging us to hit it right on centre. They are like an archery target, full marks are got for hitting dead centre. but you still get good marks for being close. The inner target tells you how good you need to be to produce outstanding performance—a magnificent result. The other limit tells you how good you need to be to be passable. Human nature will do the rest.

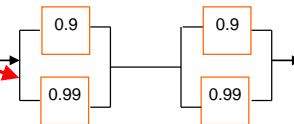
## Standardize Human Dependent Processes with Mistake Proofed SOPs to Prevent Variation

- Specify the 3Ts (Target, Tolerance, Test) for precision, accuracy and error proofing
- Range tolerance 'good, better, best'
- Make 'best' the world-class performance
- Make a SOP with a table of **successive** activities in each row
- Provide columns for 'good, better, best' tolerance range
- Give all tasks a proof test
- Advise what to do when out of tolerance
- Get a signature when 3T is done to tolerance



**Warning – This is a series system!**

**\* It is this test that makes an activity error proof!**



**3T SOPs give feedforward control**

Procedures in companies that are controlled by accuracy and precision (Accuracy Controlled Enterprises) use the 3T methodology. To make a game out of work incorporate 'good, better, best' banding in the tolerance. People will naturally want to do well, and if you set clear and demanding targets, they will self-direct their efforts to try and meet them.

ACE procedures also become excellent training documents because perfect performance, and how to do it, is written down in the text, along with the necessary standard to achieve and the means to test progress toward it.

# Why put Quality Control in Procedures?

**Maintenance Work Instruction**

|             |         |
|-------------|---------|
| Task List # | Various |
|-------------|---------|

Visual Inspection of Pump

Pump Inspected: \_\_\_\_\_

Visual Inspection Only

- 1) Check pump base - corrosion / security.
- 2) Check pump guards - cracked / secured / adequate.
- 3) Check associated pipework for support / leaks.
- 4) Check associated valves have handles and are in safe condition.
- 5) Check suction expansion joint for external wear and cracking.
- 6) Check condition of motor and associated cables.
- 7) Check condition of stop / start station.

**Raise Subsequent Notification Maintenance Request for any repairs required.**

Inspected by: \_\_\_\_\_

Date: \_\_\_\_/\_\_\_\_/\_\_\_\_

**THIS IS A 'ROVING INSPECTION' WITH ERROR RATE OF 1 IN 10!**

**NOTE:**

None of these task will prevent the pump and piping from failing. These tasks find future repairs... and you want a healthy, reliable pump set...

**...prevention is easier than cure**

This inspection work order is real. The company that used it had been in business for 40 years and they had always had pump failures for 40 years. Their owners are now looking closely at whether the business should be shut down. Can you work out why their inspection efforts lead to nothing? How do you know what is a right results when you read this work order? Maintenance technicians call this type of work order a 'tick-and-flick'. They have a game amongst themselves as to how many of these inspections you can do in a day. They treat it like the total joke that it is. The next activity will help you to understand why they never had a chance to become a top class operation.

## Activity 10 – Turn the Inspection Procedure into a Standardised Accuracy Controlled Procedure

- In the workbook complete the pump set inspection procedure with quality standards to meet and checks to prove they have been met or bettered.

## Activity 10 – Create Inspection & Test Plan for Maintenance Tasks

Provide an Inspection and Test Plan for this maintenance job.

Once there are quality standards you can begin to measure if your processes are in control and capable. But without acceptable limits you have no measure of success and failure. Without quality you default to a process that has no in-built control except what people feel like doing at the time. They are never challenged to do better. That is a sure recipe for business failure. The activity requires people to add the 3Ts into the previous inspection. Tell people doing the job what a good result looks like.

## Inspection and Test Plan for Pump Set Condition

**THIS IS A 'CHECKLIST CONTAINING DEFINED CRITERIA' WITH ERROR RATE OF 3 IN 1000!**

| No | Task                            | Activity Inspection and Test<br>Include Photos, Values, Charts  | Applicable Standard   | Inspection   | Record of Result  |
|----|---------------------------------|---|---|--|---|
| 1. | Check pump base:                |   |   |  |   |
|    | Corrosion                       | No corrosion on completely painted steel frame<br>No corrosion on stainless steel frame   | Pitting corrosion no more than 1mm deep and no more than 5mm long for length dimension and no more than one pit per 25mm square | Visual inspection and ruler measurement                            |   |
|    | Security                        |   |   |  |   |
| 2. | Check pump guards:              | Guard prevents direct human contact with rotating equipment parts.<br><i>(Could include photos of good guards and photos of bad guards)</i> | Prevent human body parts contacting rotating components   | Visually inspect complete guard structure and securing connections | What if the guard is there to prevent people touching hot machinery and not rotating machinery? <i>(You would need to make its purpose clear to the inspector.)</i> |
|    | Cracked                         | Visually inspect Guard for cracks<br><i>(Could include photos of where guards can crack)</i>  | No cracks at welds and fastening points   |  |   |
|    | Secured                         | Physically push guard hard to simulate a person falling against it to prove it is firmly fastened in-place                                  | No movement of guard off its mounts and no flexing of guard so that it allows body parts to reach rotating machinery            |  |   |
|    | Adequate                        | Visually inspect the guard prevents access to all rotating parts  |   |  |   |
| 3. | Check associated pipe work for: |   |   |  |   |
|    | Support                         |   |   |  |   |

|    |                                       |  |  |  |  |
|----|---------------------------------------|--|--|--|--|
|    | Leaks                                 |  |  |  |  |
| 4. | Check associated valves have:         |  |  |  |  |
|    | Handles                               |  |  |  |  |
|    | Safe Condition                        |  |  |  |  |
| 5. | Check suction expansion joint for:    |  |  |  |  |
|    | External Wear                         |  |  |  |  |
|    | Cracking                              |  |  |  |  |
| 6. | Check condition of:                   |  |  |  |  |
|    | Motor                                 |  |  |  |  |
|    | Associated Cables                     |  |  |  |  |
| 7. | Check condition of stop/start station |  |  |  |  |



# The Accuracy Controlled Enterprise uses 3Ts in Their Procedures

“An ACE organisation applies 3T accuracy controlled procedures at every level of operation.”

| Task Step No. | Task Step Owner | Task Step Name    | Full Description of Task                         | Test for Proof | Tolerance Range  | Record Actual Result | Action if Out of Tolerance | Sign-off After Complete |
|---------------|-----------------|-------------------|--|----------------|--|----------------------|----------------------------|-------------------------|
| 1             |                 | (Max 3 – 4 words) | (Include all tables, diagrams and pictures here) |                | Describe the test and below specify the target as 'BEST' and range of acceptable results that are 'Good enough'. |                      |                            |                         |
|               |                 |                   |  |                | Good Better <b>Best</b>  |                      |                            |                         |

## One Layout for an Accuracy Controlled 3T Procedure

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The way we write our procedures needs to change to the layout shown in the slide. This layout makes it clear to users exactly what they must achieve in every task. Each task has a boundary and test to confirm compliance. The only ‘rule’ is that no new task is started until the previous task is proven to be done right.

With the ACE 3T layout you still use your current procedures’ text. The one new requirement is to incorporate the 3Ts to provide the statistical control needed to ensure task accuracy. You’ll want to make the Target clear to people. You want to be sure they understand the Tolerance limits and what is and is not good enough. They need a place to record the Test result and visually check it is within tolerance. And just as important is to tell them what to do if the result is out of tolerance.

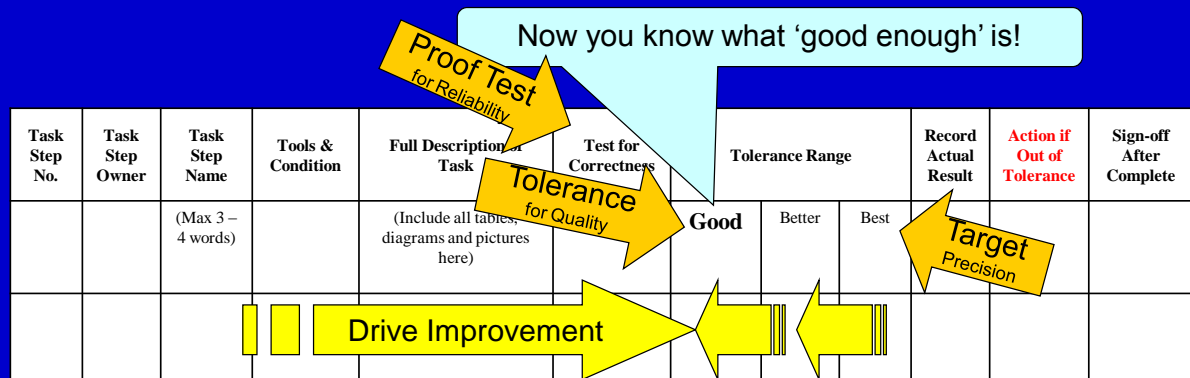
The people doing the procedure are busy, they have time constraints, the workplace maybe difficult to work in, they maybe in bad weather, they may not be well—they are in situations where the chance of human error is greatly increased. They can unwittingly do the wrong thing from being under stress and pressure. So in your ACE procedure make life easy for them by telling them what they must do when the quality is not up to standard.

The person writing the procedure is the only person in the whole maintenance process (maybe in the entire life of the asset, which can be 50 to 60 years) that has the time to think clearly about the quality of work required to get trouble-free service life from the equipment. If the procedure is written well, full of good advice and quality controls, then that is how the technicians will use the procedure for the life of the asset.

It really is a great investment of time to get your ACE 3T procedures right, because they will create reliability in your company forevermore.



# Continuous Improvement with Accuracy Controlled Procedures



Accuracy Controlled 3T Procedure Layout

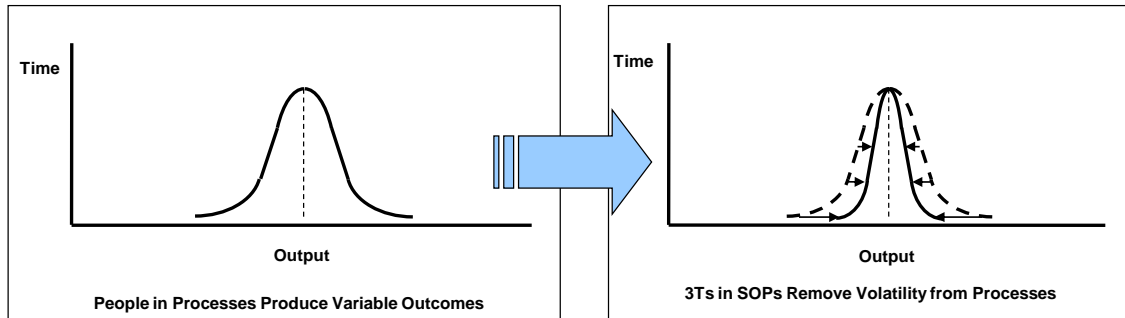
**Continuous improvement:** Make 'better' 'good', make 'best' 'better' and set a new standard for 'best'. In this way, you will drive quality improvement and innovation in your company. 'Good enough never is!'

There is another truly fantastic advantage in addition to reliability improvement that an ACE 3T procedure also brings you. It forces continuous improvement.

When the distribution of maintenance work quality continually falls within tolerance it is time to make the tolerance tighter and the target smaller. Human nature will do the rest. Your people will be challenged to perform better, and they will. As a consequence your reliability again improves and costs come further down.

# The Purpose of Accuracy Controlled Enterprise (ACE) Standard Operating Procedures

***“Instead of doing the task and measuring at completion to see if it is accurate, the 3Ts require measuring during the task so nothing proceeds until it is accurate.”***



The 3T method - Target, Tolerance, Test - introduces quality control into human-dependent processes. It keeps a procedure in-control and capable. It greatly increases repeatability and reliability of work results.

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What ACE 3T is really all about is as the slide indicates—process quality control. The process addressed in the course happens to be a maintenance work process, but the principle of Target-Tolerance-Test works with any process. It makes people in the process aware of what right is, of what it looks like, of how to check for it. It gives people control over their own work quality. They will not let you down—with ACE 3T you will get great work done quickly, right first time.

ACE 3Ts with tolerance banding procedures are the best way known to proactively introduce statistical quality control so that work only proceeds when the inputs are proved correct and the process is in control and is capable of producing correct outputs.

We build understanding and predictability for users of ACE procedures by including the 3Ts into every task.

There you go Ted, now you know how to help the guys get the job right every time!

It's so obvious now. The 3Ts really are a very powerful idea.

And they don't need to stop at the shopfloor. They will work for every job in an organization, at every level.

It's been a good hour today Joe, I really feel as if I've learnt something important.

With the lesson, goes the homework. Spend some time over lunch putting together a list of the steps you would use to do the planning of a maintenance job. Instead of meeting me tomorrow, spend the hour converting them into an ACE 3T procedure and show it to me when we meet next.

Okay, I like that. I can see that writing this procedure will bring a lot of clarity to the job, and give me the best chance to do it really well.



## They wrap-up the session ...

Not long before we finish our regular morning meetings Ted. Today we complete your introduction to maintenance planning with the KPI's we use. Tomorrow we start explaining scheduling. It won't be long and you will have seen all that I can tell you. Your last two months will be hands-on, on-the-job training. Its the best way to learn.

Joe, thanks for what you are doing for me. I could never have learnt so much without your help.

It's a pleasure. It gives me great satisfaction to pass you what I know. My only request is that you keep adding to, and improving, the planning procedure every time you find a better way to do the job. It'll make me happy when I'm retired to know that the company is getting better and better through the work you do.

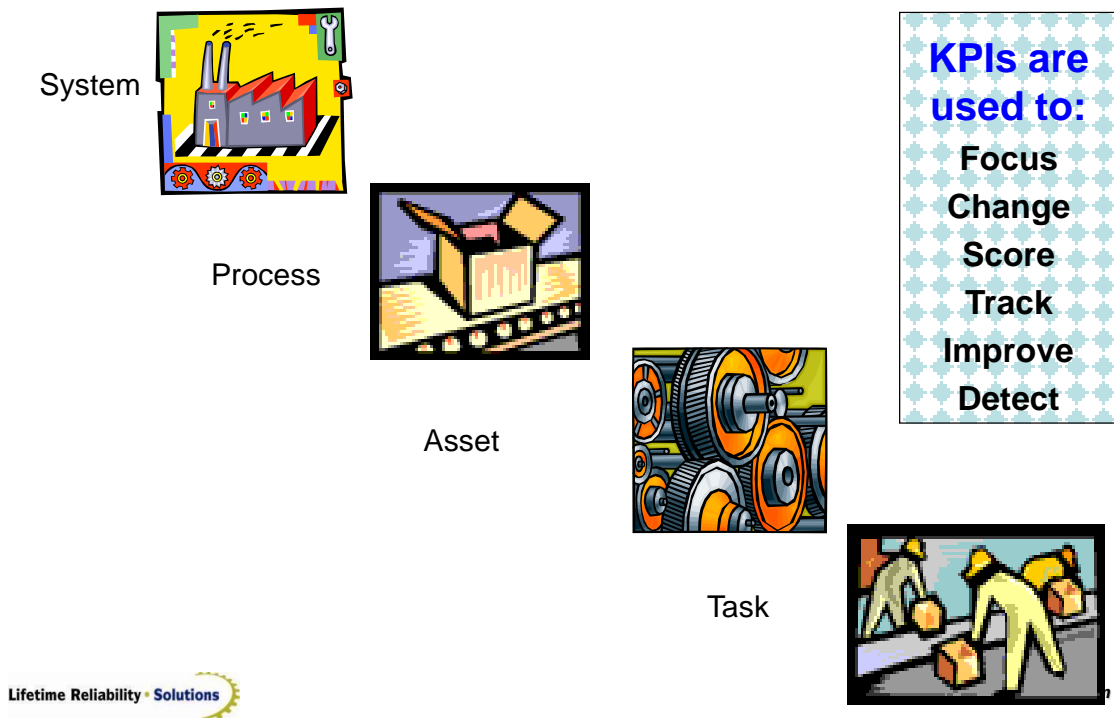
You can count on that. I can see the ACE 3T approach helps me to always do top quality work and deliver my best.

Good. Now let me explain what Key Performance Indicators are, and how we Maintenance Planners use them.



## A new lesson starts ...

# 4 Levels of Key Performance Indicators



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A Key Performance Indicator (KPI) is a number that provides a measure of a situation. Typically a KPI applies to a particular level of an organisation. Any time that you want to measure changes in a process, be it a business process or an industrial process or another type of process, it is appropriate to track it with a key performance indicator, or even a number of KPI's.

The use of a KPI allows the outcome of a process to be monitored and trended. The actual process performance can be compared against its ideal performance, or required performance. This permits identification of any discrepancy between what is wanted and what is actually happening. Once recognised, a negative discrepancy can be investigated and rectified if necessary. A positive discrepancy can also be analysed to learn what are causing the good result and whether the better performance can be retained and made standard practice throughout the organisation.

There is no limit on the range, scale, timing and use of KPI's. They can be used to measure the results of a single step in a process, right through to evaluating the complete process itself. As the industrialist previously mentioned found to his great success, the use of KPI's can be extended to controlling complex, multi-national operations regardless of place or time.

When an outcome is monitored and trended with a KPI, the resulting figure tells you the process performance effectiveness. The KPI should be an accurate, honest reflection of the process efficacy in delivering the outcome. With a reliable KPI measure of performance the effect of a change made to a process, or a new strategy implemented, is then reflected in the KPI results produced. The KPI will echo if the change improved the result, did not affect the result or made the result worse.

Once the effects of a change can be monitored reliably, repeatable and accurately by KPI it is reasonable to use the KPI as a tool to improve ongoing process performance. Simply introduce the test change into the process and monitor its effect with the KPI. Keep those changes that work and discard those changes that do not produce suitable results.

A KPI can offer many perspectives on an event. It can permit intense focus and scrutiny, it can detect changed conditions, it can score performance, it can indicate a change from plan, it can detect potential problems and it can drive improvement.

### **Focus**

A KPI can be used to closely monitor the results of actions.

When it is not certain that a result is due to a specific set of plans and actions it is useful to introduce KPI's to detect and track what is happening. KPI measures that are thought to be appropriate can be trended over a period of time, and in different situations, to see if they in-fact highlight the relevant factors that are truly important to the successful outcomes from the actions.

### **Change**

A KPI can track the effect of making a change.

If a change is made to a process how is one to know it has been a useful change. This is when an appropriate KPI, or a series of KPI's, can be used to prove that a change has been beneficial. If in fact the change has made matters worse, then the KPI's will prove it and things can either be changed back to what they were or further changes are introduced and tested.

### **Score**

A KPI can act as a means to measure progress toward achievement.

Often the organisation's aim is simply to gradually improve what is being done. In such cases the current performance becomes the base line for improvement and all future performances aim at being better than the last result.

### **Track**

A KPI is also ideal to use when set targets are to be met.

When a target is set it becomes critical to track the efforts used to meet the target. Suitable KPI's are put into place to monitor the effects of the organisation's processes on meeting the targets.

### **Detect**

A KPI can proactively warn of future performance.

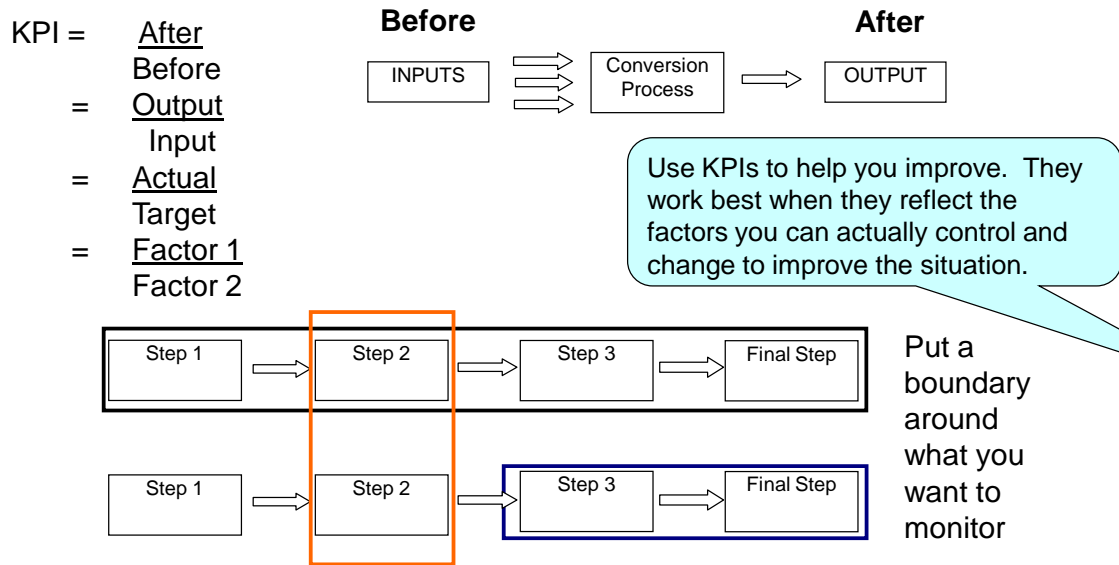
In every organisation there are people who are aware of the 'danger signs' that forewarn of future problems. These indicators can be made into KPI's and purposefully tracked and monitored to prevent and reduce the risk of future failures.

### **Improve**

A KPI can drive continuous improvement.

Where organisations have several similar operations it is valuable to introduce identical KPI's into each workplace. This allows comparisons between groups. One group will always outperform the rest. Once that group is identified, investigate why it outperforms the rest and introduce its methods into the other operations. In this way the KPI system is used to continually improve the organisation as a whole.

# Measuring and Trending Processes



## Combining KPIs e.g. OEE = Availability x Performance Rate x Quality Rate



OEE = Overall Equipment Effectiveness

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A business or industrial process can be represented on paper as a series of progressive steps linked one to the other in a pattern. An example is a process logic flow chart for a manufacturing plant, or a flow diagram for the processing of accident insurance claims in an insurance company.

Once the process is drawn on paper a boundary can be put around the steps that are to be monitored. KPI's are then selected that reflect what materials, documents or other inputs cross into the boundary region versus the materials, documents or outputs that come out of the boundary region.

If there are no formal diagrams of your organisation's process flows they will need to be created. It simple requires that people who know the various parts of the operation well sit down with pen and paper and flow chart the process. As the process is developed on paper include the various inputs and outputs from each phase to the next. Once completed by hand the flow diagrams can be drawn up and made an official company document to be kept up-to-date.

The process boundary approach typically results in multiple KPI's. The majority of business, organizational and industrial processes requires several key factors to be addressed at the same time. It is unlikely that one KPI alone will be sufficiently sound and robust to alone reflect all the factors affecting the process. By using multiple KPI's it is possible to measure the performance of individual factors and identify their individual effects on the performance of the entire operation.

Once the boundaries are set the various inputs and outputs into and out of the boundary available to be used in KPI's are also specified and defined by default.

Often the multiple KPI's can be combined into one 'global' KPI that more simply represents the entire group's performance. An example of a 'global' KPI often used to measure manufacturing equipment performance is 'Overall Equipment Effectiveness' (OEE).

OEE combines KPI's that measure production quality, production throughput and time available for production. The one measure blends the effects of the three individual factors into one number that

reflects how the entire operation performed. The full KPI for OEE is shown below as an example of a single number that reflects multiple factors in an operation or process.

### **OEE = Availability x Performance Rate x Quality Rate**

**Availability** - Percent of scheduled production (a measure of reliability) or calendar hours 24/7/365 (a measure of equipment utilization), that equipment is available for production.

$$\text{Availability} = \frac{\text{Hours equipment was available to be used in the time period}}{\text{Total hours for the time period}}$$

Measures the equipment uptime (actual production time) divided by the time that the equipment could be used (usually total hours of 24-7-365) as a percent. It is also another measure for equipment utilisation. Along with determining this KPI it would also be necessary to record the causes of the losses and their frequency of occurrence. Each of the causes can then be analysed and plans put into place to address how they can be totally eliminated.

**Performance Rate** - Percent of parts produced per time frame, of the maximum Original Equipment Manufacturer (OEM) rated production rate. If the OEM specification is not available, use the best known consecutive production rate over a four-hour period.

$$\text{Performance Rate} = \frac{\text{Actual production output in the time period}}{\text{OEM rated production output for the time period}}$$

Measures the percentage of available time that the equipment is producing product at its theoretical speed for each individual product. It measures speed losses regardless of cause (E.g. inefficient batching, machine jams). Along with determining this KPI it would also be necessary to record the causes of the losses and their frequency of occurrence. Those causes can then be analysed and plans put into place to address how they can be eliminated.

**Quality Rate** - Percent of in-specification parts out of total parts produced per the time frame.

$$\text{Quality Rate} = \frac{\text{Number of parts in specification for the time period}}{\text{Total number of parts produced in the time period}}$$

Measures the percent of the total output that is good. Along with determining this KPI it would also be necessary to record the causes of the waste and the frequency of occurrence. Each of the causes can then be analysed and plans put into place to address how they can be totally eliminated. It is necessary to address all product quality losses, including those due to production, handling, engineering design, etc that produced rework and scrap, otherwise no improvements will be permanent.

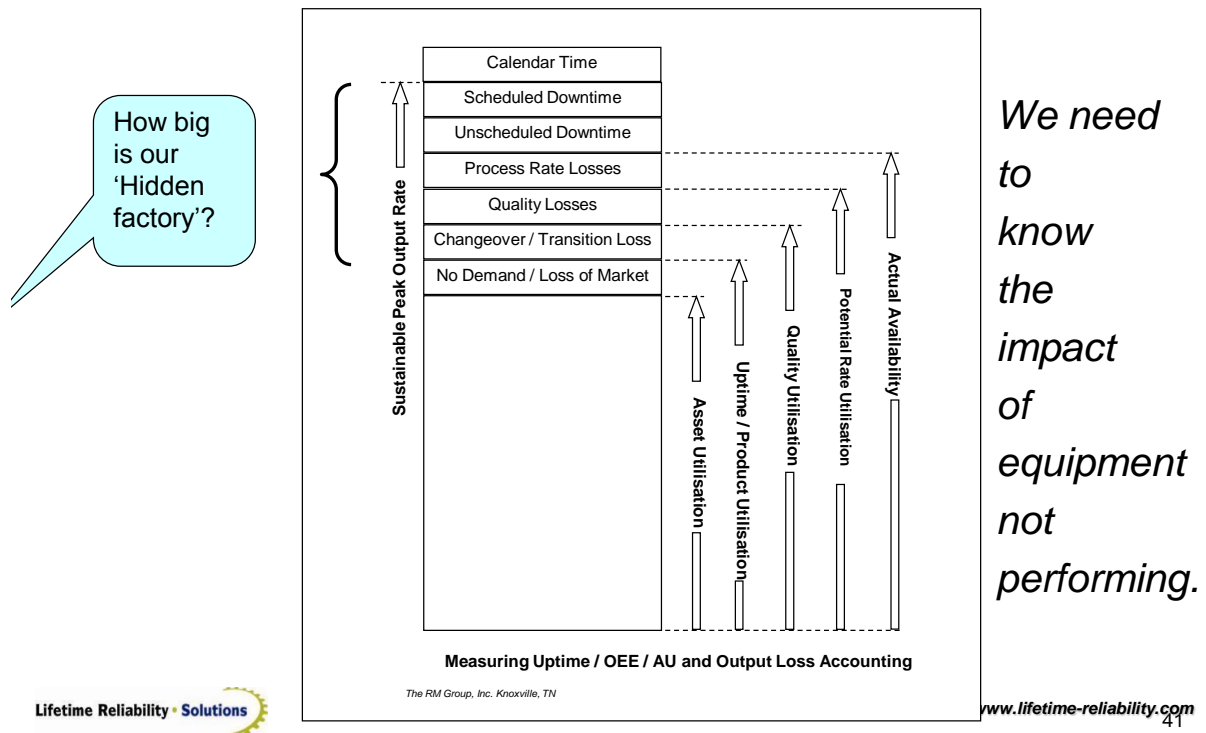
**OEE Example:** Availability (0.5) x Performance Rate (0.8) x Quality Rate (0.9) = 36% (which is a terrible result when compared to the world-class benchmark of 90%)

A KPI like Overall Equipment Effectiveness becomes a benchmark target that is used to:

- focus on improving the performance of machinery, plant and equipment already owned.
- find the areas for greatest improvement to provide the greatest return on asset.
- show how improvements in the process, such as changeovers, quality, machine reliability improvements, working through breaks, etc, will affect your bottom line.



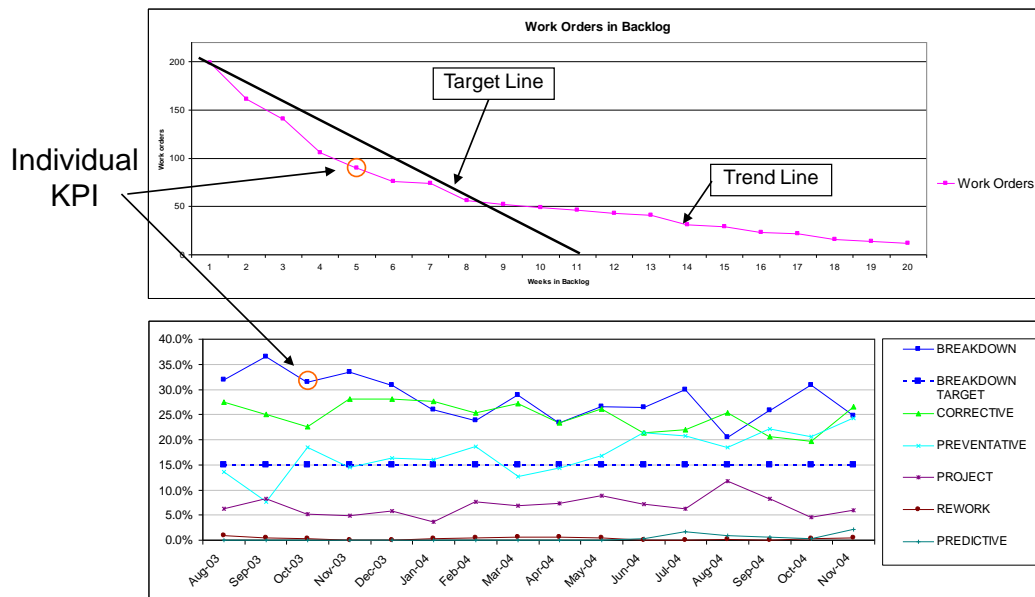
# Measuring Plant & Equipment Performance



In relation to plant and equipment there are certain performance indicators that are more meaningful than others – the key performance indicators (KPI). The slide shows various measures based on how the time is spent by the plant. The most important measure is Asset Utilisation (AU) because this tells the overall performance of the plant verses its maximum sustainable capacity. The lower the AU the less productive the operation. By measuring AU and investigating and fixing the causes of poor AU performance the operation can be gradually improved.

This then is the purpose of KPIs, to show discrepancy between required values and actual values. When the discrepancy is negative, action is taken to address the causes.

# Trend to Monitor KPIs



Trending KPIs turns measurement into monitoring



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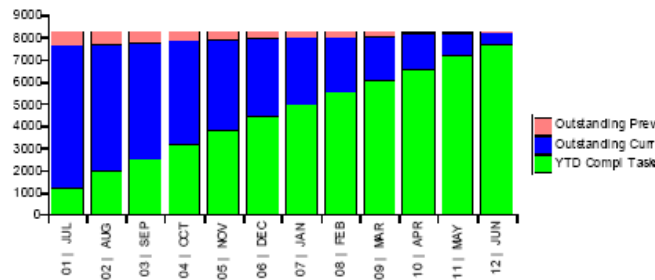
A KPI can be as simple as a single number, through to multiple lines on a graph or strings of results in a table. KPI reports can be a single page, through to a substantial multi-page document in length.

Human beings receive most sensory data through their eyes. The brain can handle only 5 or 6 pieces of information at one time. Our brains are excellent at detecting changes and variation. These natural traits make graphic formats using colour, contrast and clarity preferred to using numerical lists. Where possible it is best to present KPI results in a graph.

As well as showing the current KPI being reported the presentation must also show either historical trends or the benchmark target to be attained. It is only by comparing the reported value against a known performance that a true comparison of achievement can be made.

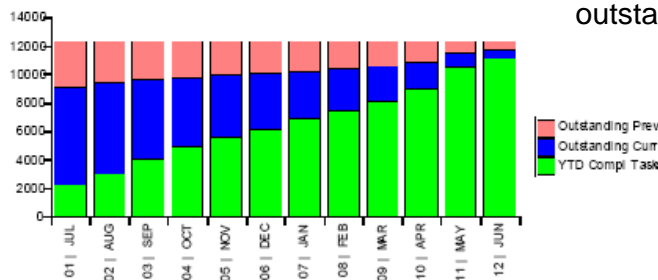
# Showing Progress

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

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To encourage people to meet their obligations it maybe necessary to employ some psychology and make the KPIs public for all to see. By using a stacked bar chart a group's performing in meeting their targets becomes clear to everyone. With this visual management device the message is obvious when progress is measured against the necessary target. If targets are not met, people see there is a problem, and start to query the cause.

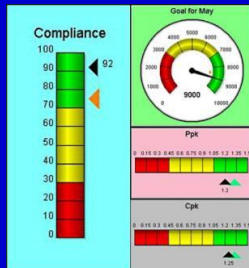
In this bar chart, of an electrical maintenance groups preventive maintenance inspections, we can see how they are progressing in meeting the annual inspection targets. The groups has 12 months to complete all inspections. Each month the KPI graph tells us how they perform. Green means inspections completed, red means inspections overdue and blue are inspections to be done not yet overdue. The use of this KPI proved to be highly successful in getting the inspections completed. Previously barely 80% of inspections were done in the year. Since maintenance is a risk control activity, any inspections not completed means greater risk of undetected problems. But with this graph 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. That is the power of a good KPI.

# Use Visual Management to Show Status



Red ... Green ... Yellow

75% of what we learn comes through our eyes



Confirming a result is suitable by use of sight is known as the 'visual control' method.



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Confirming a result is suitable by use of sight is known as the 'visual control' method. Visual control measures give immediate feedback on whether we are getting the right result. At the traffic lights we know if we are going to make the lights in time or not. The pilot landing a plane can line-up with the centre line and lights to know the plane is in the middle of the runway. The kick for goal either went between the posts or it missed, there is no question about it. By converting into visual control measures it becomes possible for anyone and everyone to know if a thing is being done right. It means a manager or supervisor can immediately see for themselves how well the work is being done. It lets people check themselves with certainty that requirements are being met. Visual controls clearly indicate whether they made the target or not.

The center board on the bottom row is from a warehouse. The team installed the board with traffic light coloured holders for picking slips. Green means there is time to do this job; amber means the job is at risk of running late; red means the job is overdue. Can you guess what immediate message is signaled to the people that go to the board to get their next job?

The visual indication is clear to everyone—your next job is the picking slip in the red holder if one is there. No one has to say anything to anyone because the visual signal is so clear for all to see.

# Visual Management in All Occasions



Make things visual for operators and maintainers if you want them to understand what is happening



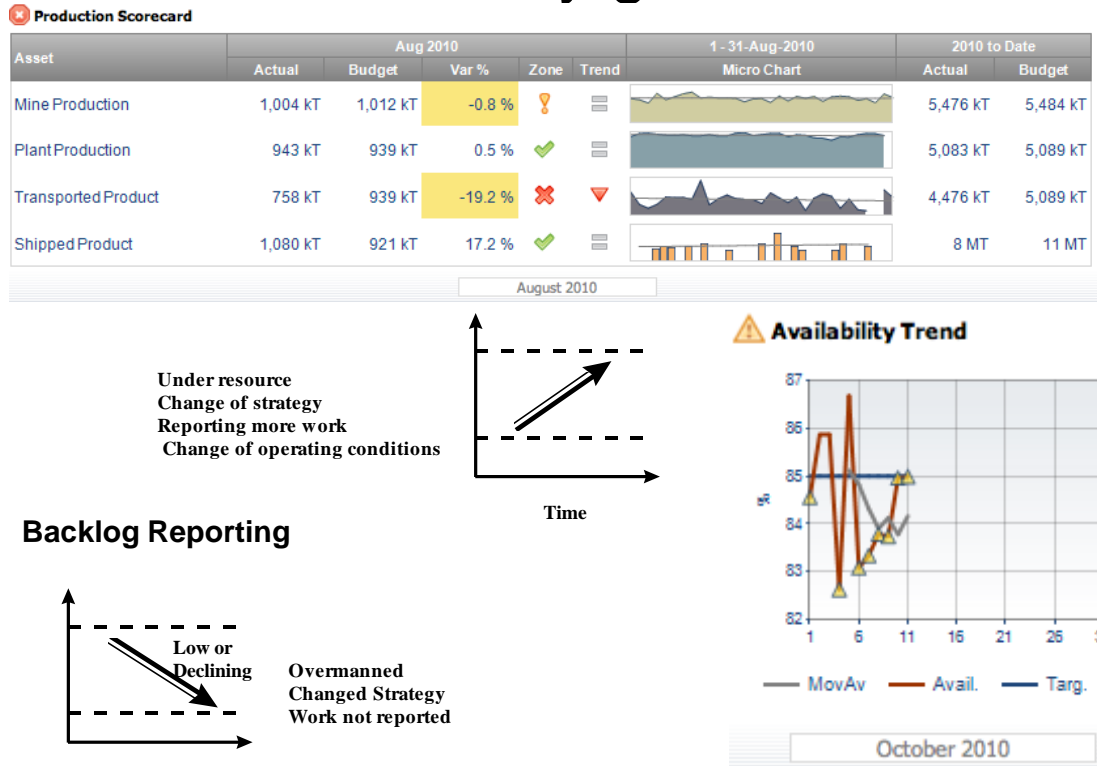
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Visual management is used to communicate progress and needs to be out in the workplace for all to see. To help keep in contact with other shifts, other departments and interested people, a communication board is often established at a suitable location. The problem with such boards is that they are a chore to keep current. As soon as the content is out of date and not maintained it becomes clear that the process of upkeep has failed. The everyone gets disheartened.

If you use communication boards as visual indicators they must be kept up-to-date . Someone must be made responsible for their accuracy and relevance. Otherwise do not bother with them and find another way to keep informed.

# Historic KPIs only give Feedback



Electronic notice boards can be used to display KPIs in real time from the workplace as can computer screens like in the performance charts shown above. Signalling performance and results is immediate and information is quickly passed throughout the entire company.

The messages contained with the KPIs are also of value. For example, the availability trend is all over the place. Though a steady line at 85% is the aim, the results show a process that is out of control and unpredictable. The company is struggling to consistently achieve its target. To be honest, an availability of 85% is that of a reactive organization.

The directions of trends also contain information about the underlying situation that produces the indicator. When trends are not stable then the process is not stable as well. There will be natural process variation that produces a wavering line, but fluctuations outside of historic trends signals a problem to be investigated and addressed.

# Planning and Maintenance Key Performance Indicators (KPI)

- Maintenance Effectiveness Indicators
  - Predictive
  - Historic
- Equipment Performance Indicators
- Production Indicators
- Planning Indicators
- Job Quality Indicators
- Supplier Performance
- Inventory/Store Management
- Safety
- Top-performance Industry Benchmarks



KPIs can be used in all situations and for many purposes. A list of some of the uses of KPIs is provided in the slide.

Key Performance Indicators trend performance. Performance is the result of actions taken. And actions are the result of decisions made. You use KPI's to either help people make decisions or to check on the effect of the decisions people have previously made.

A KPI will tell you if the decisions taken and the subsequent actions have produced a change. Hopefully the change has been beneficial.

KPI's can be used to aid in improving the decision making of all your people. Once a KPI is presented it should be made available to all persons who can gain benefit from knowing the result. People will self-correct and adjust their practices based upon the KPI. It may require some time for some people to change their work methods and practices based on seeing a KPI. It is necessary to continue pointing out that no beneficial change has yet occurred and that is unacceptable for the future wellbeing of the person, workgroup, department or organisation.

If the result is not an improvement then your people will take that to heart and begin looking for ways to better the result next time. This will require encouragement and the opportunity to discuss ideas that will bring about improvements. Make time to let everyone affected by the need for change to be involved in deciding how to make the change. If they are not involved they will unconsciously block the effort of others. This approach will get commitment and acceptance from all. It will also be the quickest way to find a good, lasting solution to the issues.

If the result is on or above expectation then your people will see it as an endorsement of their efforts and want to continue, and even improve, what they do. Reward people for the progress they have made.

Once a KPI is in use there will be people responsible for its attainment. A KPI reflects performance. Some people will be affronted by fear of under-achievement while others will see the KPI as a



challenge to strive for. The proper use of KPI's is not to cause pain to people but to help them to find ways to improve the process they are in charge of so that it produces the required results.

KPI's bring a means to measure the effects of actions performed in a process. If the actions do not deliver the required results then they are scrutinized and reviewed to determine what part of their performance was not effective. Once issues are identified an action plan with time limits and individual responsibilities is put into place to rectify the situation.

Without KPI's monitoring a process, the process is not under control. A process can be horribly inefficient and ineffective, terribly costly to the organisation, but continue being performed because there are no measures in place to judge the worth of its results.

KPI's provide a check on progress, they provide direction and they provide data to make sound decisions. KPI's purposefully feedback and feed-forward critical information in a timely manner to address bad effects of changes in a process.

## Maintenance Performance Prediction Indicators

**We can foretell the future by the focus of our efforts today**

- Maintenance work orders spent on improving equipment
- Maintenance time spent removing breakdown causes
- Maintenance time spent improving maintenance procedures
- Maintenance time spent improving maintainer skills/knowledge
- Maintenance effort spent reducing operating problems
- Time spent removing waste effort from maintenance processes
- Efforts spent improving stores management and layout
- Maintenance work orders spent improving safety
- ??
- ??



It is easy to predict the future of your operation.  
You only need to measure how much effort is  
being made by the people in it today to improve it  
and make it a better place tomorrow

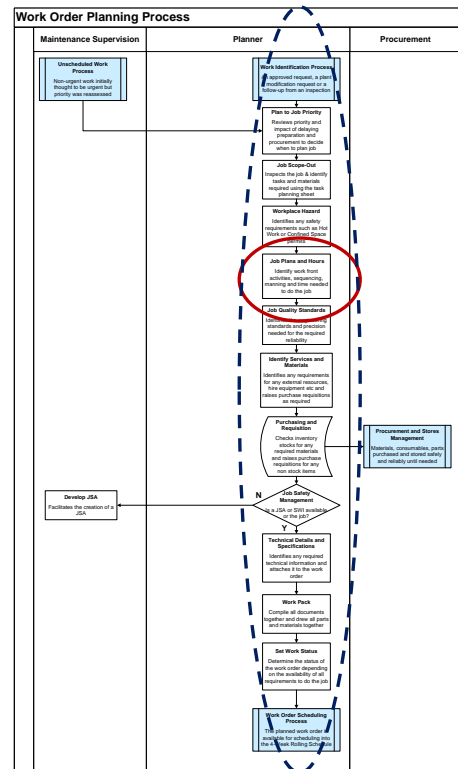
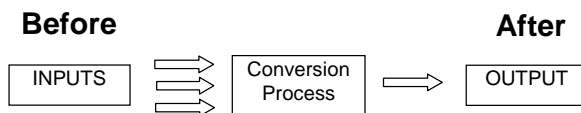


It is not difficult to develop KPIs that indicate if we are focusing our time and efforts on improving the operation. We have a resource available to use and we are in a position to schedule the work it will be doing. This means that as a Planner you can direct how much effort is put into implementing improvement strategies to make the plant and equipment more reliable.

The KPIs noted above are predictive indicators that tell you what will happen in future. If nothing is being done to improve a workplace or a process then you will get the same results as always.

# Developing Planning Process KPIs

- Develop a data collection sheet to identify if the planning process is working and to spot opportunities for improvement



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The flow chart is of a maintenance planning process. Once you have a process flow diagram you can develop KPIs for it because you have inputs and outputs. You could KPI the effect of the whole process and you can KPI the individual steps in the process.

You will select appropriate variables or parameter to measure that have sense and meaning in monitoring and improving the process. Do not over do it with too many KPIs or with KPIs that do not tell the true story of what is really happening in the process.

# DuPont KPI Expectations

## 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 &amp; 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                  | <0.25%                 |
|  | % 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%                   |

*Measure yourself against these!*



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This list of KPIs is what DuPont used to rate the maintenance performance at their 170 + facilities around the world.

## Benchmarking against the Industry Best

### Equipment MTBF years

| Equipment   | Poor | Top Quartile |
|-------------|------|--------------|
| Pumps       | 1    | 6            |
| Compressors | 1    | 5            |
| Motors      | 3    | 20           |

This sort of KPI is used for benchmarking. You survey your operation and then compare it against the rest of your industry to indicate what needs to be improved.

| Performance              | Poor  | Top Quartile |
|--------------------------|-------|--------------|
| Urgent job requests %    | 70    | 5            |
| Jobs per manday (M, I/E) | 1 , 4 | 3 , 8        |
| Testing jobs overdue %   | 20    | 2            |

### Comparison Plant Performance

| Performance               | Poor    | Top quartile |
|---------------------------|---------|--------------|
| Downtime %                | 12      | 1.5          |
| Time between trips (FCC)  | 2 weeks | 2 years      |
| Turnaround duration (CDU) | 6 weeks | 2 weeks      |
| Turnaround interval (CDU) | 2 years | 5 years      |

### People Performance

| Performance                    | Poor | Pacesetter  |
|--------------------------------|------|-------------|
| Hands on tools time % possible | 20   | 50          |
| Accidents per employee         | Some | Almost none |
| Employees per manager          | 4    | 12          |



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Benchmarking with other industry players aims to provide direction in your maintenance efforts. You gauge yourself across a range of important factors to identify weaknesses and strengths. The evident weaknesses are investigated and a plan developed to improve them.

It is also possible to use the benchmarking process in another way that does not need you to go to the rest of industry. You still conduct a benchmarking survey on your operation using all the relevant factors that apply to an industry benchmarking process. These then become the baseline on which a decision is made to improve them all, or selective factors. Again plans are developed and put into place to improve performance. The benchmarking exercise is then repeated in the future and compared back to the baseline to quantify the extent of the improvements.

## Activity 11 – Setting, Measuring and Trending Performance Indicators

This Activity requires identifying KPI equations and where to find the data to measure the KPIs

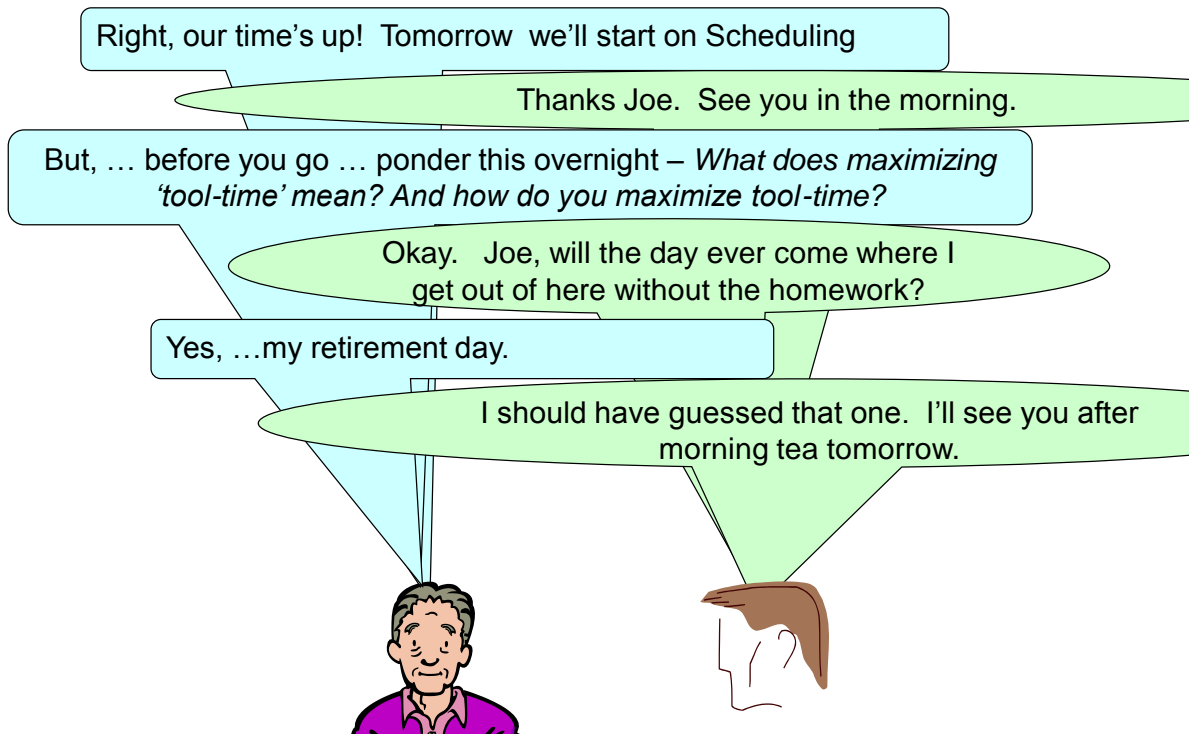
### Activity 11 – Set, Measure & Trend Key Performance Indicators

Determine the Equation and where to find the data to complete the following Maintenance KPIs

This activity requires use of the Workbook. The purpose of the activity is to show how maintenance KPI's are developed and where the data for them can be found within an organisation's management systems. You need to determine the Equation and where to find the data to complete the following Maintenance KPIs

| KPI  | Equation   | Data Location                                |
|--|--|--|
| Uptime (per time period)   | <u>Scheduled Production Time – Lost Production Time</u><br>Scheduled Production Time | Production Plan,<br>Production Daily Records |
| A suitable measure for Tool Time per Trade Type                          |  |  |
| Total Maintenance Cost (TMC) as a % of Equipment Replacement value (ERV) |  |  |
| Mean Time Between Failure (MTBF)   |  |  |
| % Planned Work   |  |  |
| % Emergency Work   |  |  |
| % PPM Work   |  |  |
| Maintenance Labour Cost as a % of TMC                                    |  |  |
| Contractor Maintenance Labour Cost as a % of TMC                         |  |  |

|                            |  |  |
|----------------------------|--|--|
| % PPM Schedule Compliance  |  |  |
| Mean Time to Repair (MTTR) |  |  |



They end for the day ...

Good morning Joe. I think I got those 'tool-time' questions worked out.

Tell me more Ted.

'Tool-time' means the maintenance guys are physically working on equipment. They add-value to the operation when they use their skills to keep equipment operating. Maximum 'tool-time' would be if they spend all their time working on machinery.

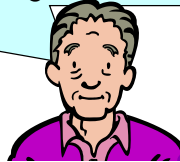
Sounds okay to me so far.

If I wanted to maximise 'tool-time' I would remove all the waste time from their day.

That is very good thinking Ted.

What bothers me is that the guys also add-value when they aren't working on machinery. They can improve equipment performance by preparing themselves to do better or quicker work, but that is not valued.

It is valued, but we see it as improved efficiency. The better prepared they are, the more 'tool-time' they'll have in their day. Scheduling helps maximise 'tool-time' because the operations guys plan in advance to give us access to the plant.



## Work Scheduling

### Objective of Scheduling

"Use resources efficiently and effectively to produce value for the customer in shortest possible time with maximum margin for the Company."

### *Scheduling Maintenance means ...*

1. Make sure maintenance is done so failure is prevented
2. Least production disruption
3. Right resources and people to the job on-time



Once a job has been requested it is planned. Once it is a planned job it is then scheduled. Scheduling maintenance work involves deciding with Production when a job will be done. The decision to stop production can only be taken by Operations personnel. Maintenance has the duty to advise Operations

of the operating risks that exist due to plant and equipment condition, but Operations must decide when to hand the plant over for the maintenance.

Whenever safe to do so, maintenance is done with the plant in operation. Only bring plant down if there really is no other safe option. In fact, if at all possible, redesign your plant and its operation in ways that allow it to be maintained while in use. By improving plant and equipment maintainability you will save downtime and get more production out.

Scheduling is a surging beast that requires constant observation to bring it back on track whenever it starts to wander from the agreed plan. If you want to get greater than 90% compliance to schedule the daily plan must be set and unchangeable by the afternoon before. The coming week's plan should be 80% scheduled and fixed by the Friday before.

## Work Scheduling is about ...

- Work and Time Management
- Being Visual – painting the picture clearly
- Team / Relationship Building
- Production Requirements and Limits
- The Production Plan being the Maintenance Plan
- Preparing Maintenance People to do the Job Well
- Manpower and Resources Scheduling
- Preparations before the Job Starts
- Addressing Onsite Issues & Changes in the Plan
- Monitoring Job Performance and Schedule
- Backlog Management



Scheduling aims to make efficient use of resources and time. It does not directly contribute to high equipment reliability, except in providing sufficient time for the work to be done to a good quality. From the 'human error rate' table, it is clear that workplace stress increases the chance of human error. To maximise the chance of high quality work during maintenance the repairers need a fair time allowance to do their work well. If the work is rushed, it will show-up later as unnecessary failures and production stoppages.

Scheduling is so much more than developing a timeline to get work done. Scheduling includes organising the job so that all what is needed to do the work is at hand right at the workplace. When a maintenance job is well scheduled there is no need for the Technician to leave the job to find what they need—everything is already there with them or everything is brought to them just before they need it.

The list above records the tell signs of scheduling. All of the points in the list need to be done when scheduling maintenance work. If any are not done then the jobs will now flow well and there will be much unnecessary disruption and jobs will take longer than necessary.





## Back to Basics Scheduling

### What do you want from a schedule?

- An overall plan
- A critical Path
- A resource impact report (Dynamic)
- Effort planned and earned
- Work by group, Supervisors , Contract groups etc...
- Budget forecast and actuals
- Risk forecasting
- S-Curve, Histogram and Executive summary reports
- “What if” modelling
- Easy to read easy to follow
- Makes sense to the people on the ground
- A good schedule should satisfy management with succinct and accurate reporting and at the same time meet the needs of the Supervisors in the field by producing (daily) easy to follow updated and accurate Gantt charts

John Bowie – Palm Crest Consultants Pty Ltd

[www.palmcrest.com.au](http://www.palmcrest.com.au)

As the slide from John Bowie indicates, there are particular aspects of work control that you want your schedule to provide you. Not only is it a ‘map’ of how work is to be completed on time, it is a way to coordinate groups and resources. It is a way to monitor achievement of goals and aims for each group and it provides a means to inform people of progress towards completing the schedule.

Once a schedule is develop it becomes possible to analyse the risk at each step in the schedule and to develop mitigations for the unacceptable possibilities that if they arose would delay the job completion.

The schedule will be used by those people organizing, doing, supervising and managing the work. The one document will need to cater for each persons’ needs. Its layout must be easy to understand while containing content and the necessary information that each level of the maintenance group requires.

# Scheduling in a Snap Shot

***A schedule is the physical evidence of planning***



## Visible Signs of Scheduling

- Rolling list of all work (*The Backlog*).
- Rolling 4–6 week schedule of likely jobs
- A detailed weekly schedule of **fully planned** jobs with all tasks and resources to make the due date.
- An agreed **daily 'to-do' list** of work
- A series of **measures** to indicate progress and achievement of the plan.
- Work group awareness and involvement in meeting the targets.
- Co-ordination meetings.



Lifetime Reliability • Solutions

## What's Important To Know To Meet the Schedule?

- You have time to do it.
- You have machinery and equipment to do it.
- You have people with the skills to do it.
- You have space to do it.
- You have materials to do it.
- You have all the information you need to do it.
- You can get resources to where they have to go.

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A believable schedule is the physical evidence of good organisation and preparation. Until you know to within 10% of the actual length of time a job will take, you need to continue refining it. A two hour job (120 minutes) should finish within 12 minutes of plan. Two shift job (2 x 8 hr, or 960 minutes) needs to finish within an hour and a half of plan.

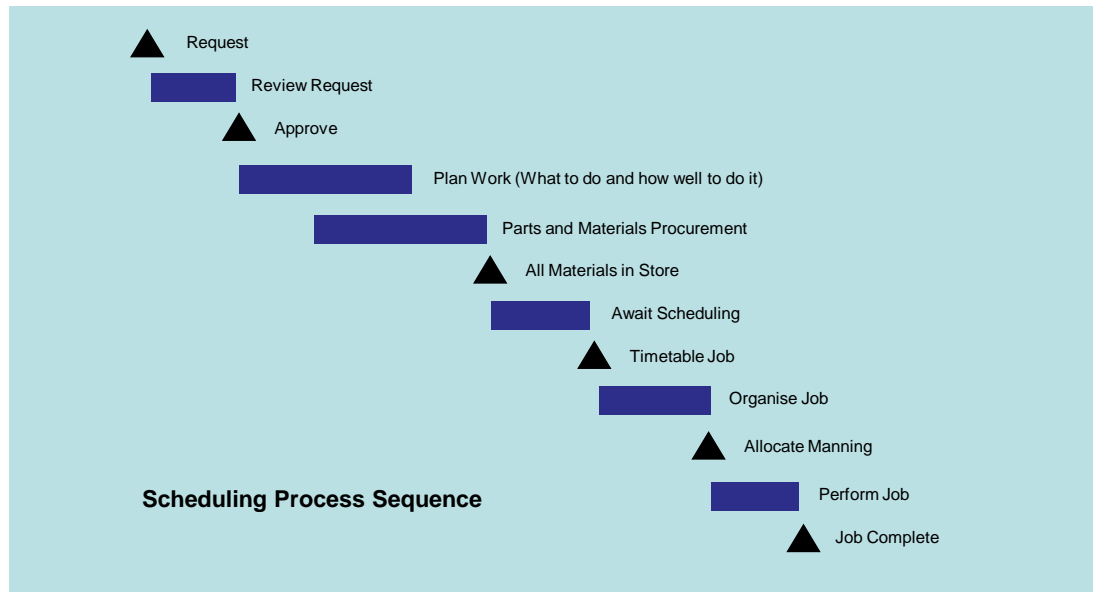
This accuracy is required if you want to maximise the number of work orders completed by each maintainer. Each person needs a full day of work and the time estimate on a work order is used to determine how many work orders to give a person or team. If the actual times for jobs are greatly in error you cannot allocate work to people that is believably done in the day. As a consequence, people will have no confidence in the scheduling system.

Job time estimates can be determined from historical records of hours for doing the same job by using the equation  $[\text{Least Time} + (4 \times \text{Average Time}) + \text{Longest Time}] \div 6$ . Times can also be estimated based on task allowance and by interviewing experienced people.

The problem with using the above equation is that it gives you a single answer to the minute that is impossible to meet. In reality there is a range of time during which a job can finish. The final completion time depends on who does the work, how well it was prepared, what complications arose during the work, how we addressed the complications to get back on time.

To minimize the uncertainty and time range during which a job can end requires breaking the work done into more and more tasks (called the work breakdown structure) to the point when the times allocated for each task or activity are truly believable and accurate. Once the task times are summed together we arrive at a reliable time for the job based on accurate times for the sub tasks. At this level of work analysis we can address all the issues in the right hand side panel of the slide. For each breakdown work structure task we know the time, resources, parts, skills and information needed to do the activities well. Then we provide them exactly as we identified that they were needed.

# Scheduling is a Process



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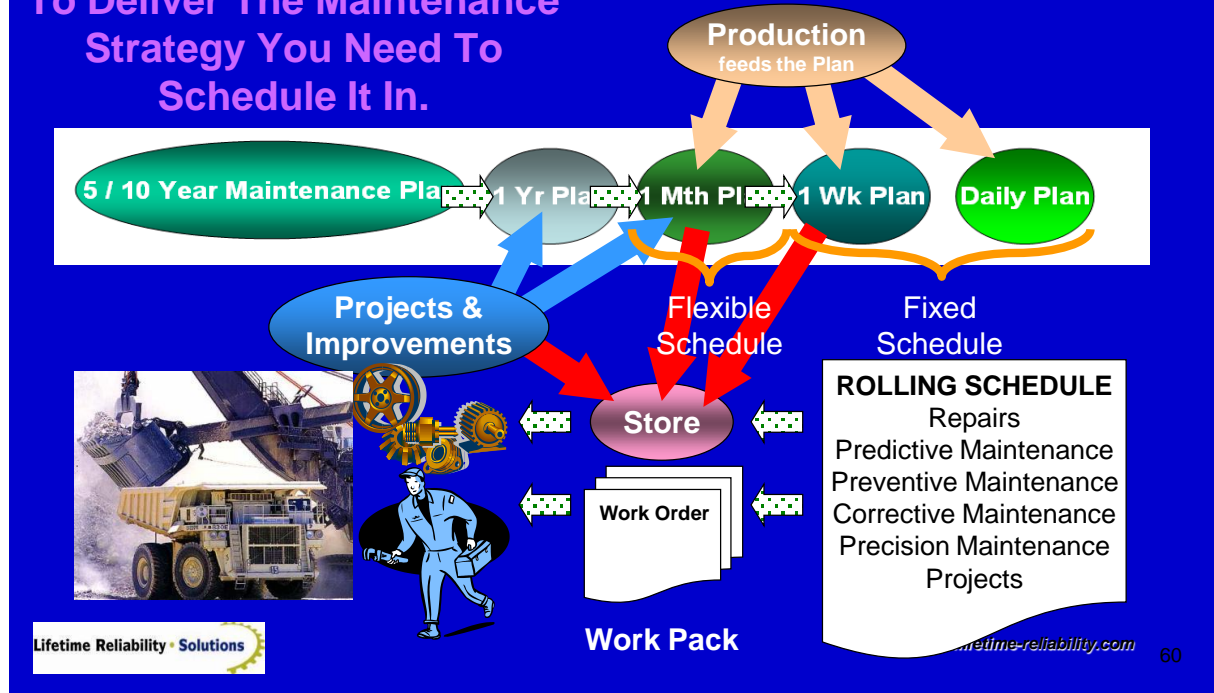
Maintenance Scheduling is a process. Starting with the work pack and parts procurement completed by the Maintenance Planner function, the Scheduling function is responsible to take the job to the point that it can be done by the technicians.

The Scheduler function organizes any subcontractors required, lifting equipment, access equipment, safety equipment, and as far as organizing that the parts and materials are brought to the workface on the day the job is to be done.

You need to put the Scheduling activities into a flowchart showing the individual steps and responsibilities to be undertaken from work pack to workface. Each step requires a detailed description of the activities performed within the step so people understand the inputs – the process – the outputs to be achieved by the work done in the step.

# Scheduling Makes Available Time, Place and Resources to Do the Work

To Deliver The Maintenance Strategy You Need To Schedule It In.



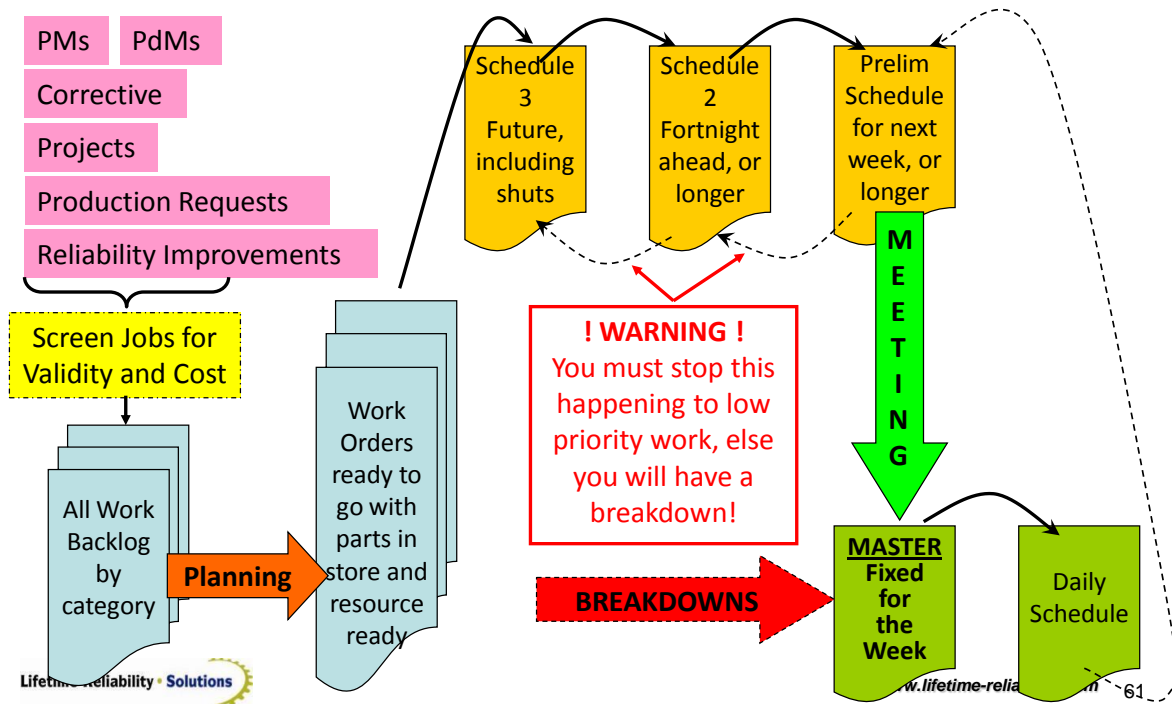
Scheduling is the process of turning the maintenance strategy, the production requirements and the improvement plans of the business, into a list of work to be performed by certain dates and times using the necessary resources.

The further out in time the work is to be done the more flexible is the schedule. In order to meet better than 95% schedule compliance each week it becomes necessary to not let the schedule change that week. New work cannot be added into a fixed schedule week. The new work must be done the following week or it is done by the 'emergency' crew. Unscheduled work must not be added into an already full workload.

One way to handle unknown urgent work that needs to be done soon is to only lock-in the fixed schedule work for the immediate seven days ahead. This requires creating a rolling daily schedule that released each afternoon for the next seven days. That means if today is Monday, then the flowing Monday's scheduled work is set and locked-in-place, but the Tuesday work is adjustable. This is a helpful way to get high scheduled work order compliance yet keep the flexibility to adjust future plans for new urgent work.

Usually companies fix a working week at a time so that on Friday afternoon the next full week is set in the schedule. Some companies fix a working fortnight ahead with the intention making people, plan and organize better.

# Develop a Scheduling Process



The scheduling is subdivided into future periods. The scheduling is subdivided into future periods. These periods are based on equipment priority, work priority and availability of parts and resources. Work on critical equipment is done soonest . Work is prioritised based on risk to the operation if the work is NOT done.

Work on lower importance equipment is done when it can be fitted into the schedule or as opportunity maintenance. The exception is when valid work of low priority is continually rescheduled and never done.

Since maintenance is a risk reduction process, any maintenance not done increases the risk of failure. You need to increase the priority of low importance work based on its DAFT Cost consequence should the item fail. If a breakdown is not acceptable, the work must be done.

During the fixed week only breakdowns get greater priority. Work not completed is rescheduled at the next scheduling meeting.

# What's on the Weekly Master Schedule?

|   | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | AA | AB | AC | AD | AE | AF | AG | AH | AI | AJ | AK | AL | AM | AN | AO | AP | AQ | AR | AS | AT | AU | AV | AW | AX | AZ | BA | BB |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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***Track each job by the hour and identify problems early...***



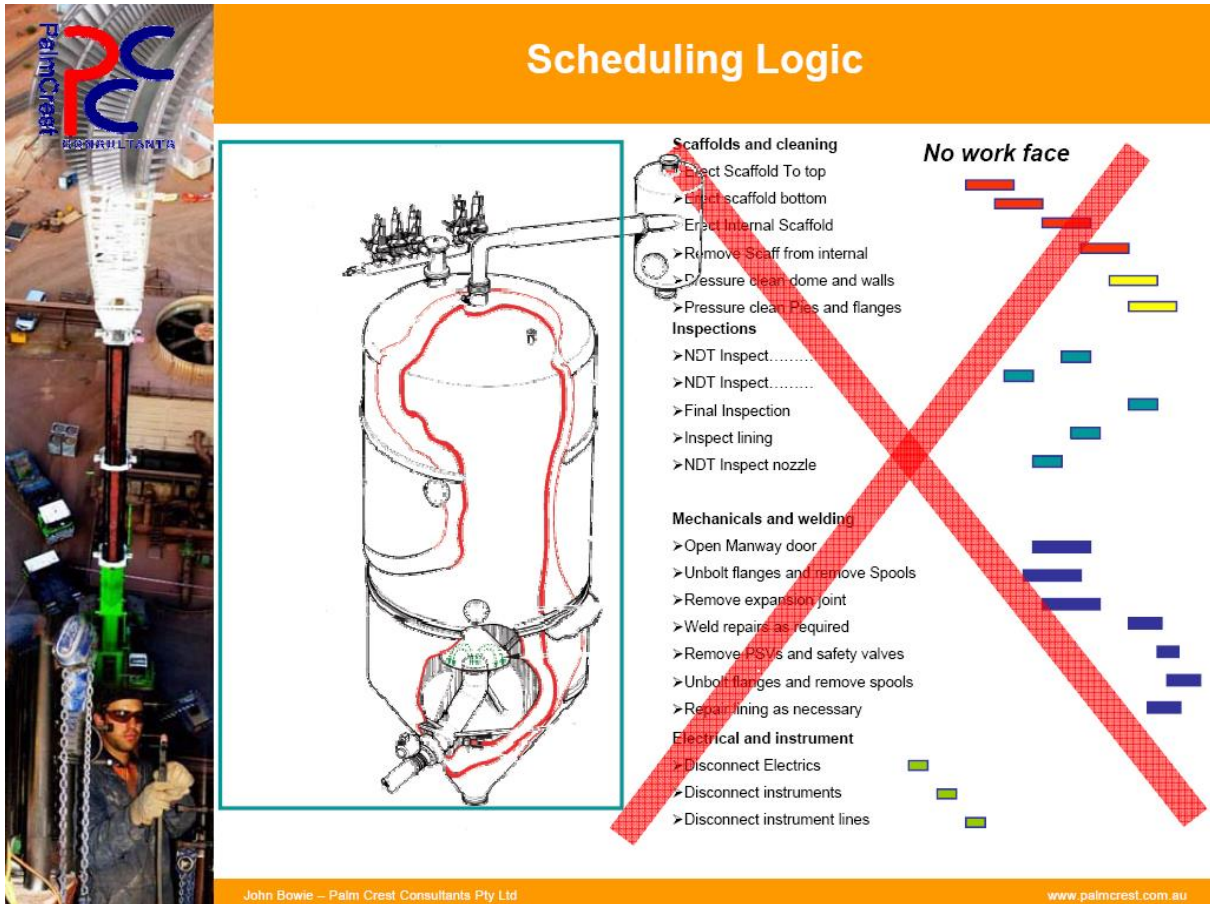
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The Weekly Master Schedule is a tracking chart of each job on each day and is used to ensure work is progressing to the agreed schedule. Every person in the crew is given work. Those that are also covering for breakdown emergencies are less lightly loaded or given work that can be put down and picked up again later for completion. The '3Rs' in each job represent Remove-Restore-Replace and lets the Supervisor quickly check a job to see how it is progressing against the job schedule.

Each day of the fixed week master schedule is also scheduled. Though the schedule is changed daily each afternoon in preparation for tomorrow's work, it is still well worth specifying each week day work orders in advance, as most will not change and people can see what is going to happen in the coming days and think about how they will do that work.



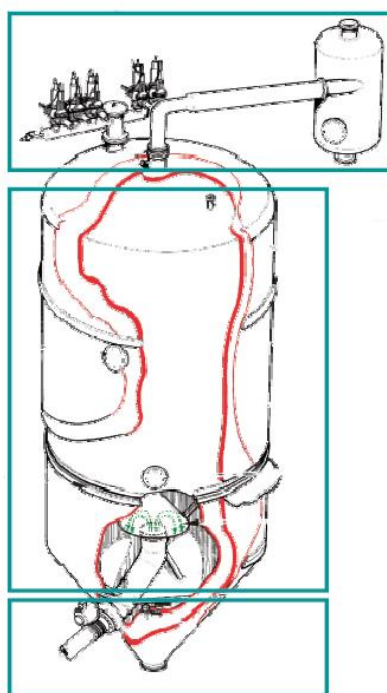


This slide from John Bowie advises us that there is a best way to layout a schedule. The schedule in the slide has work allocated to various work groups. It tells each group supervisor what their team must do and when, but it does not identify the coordination and cooperation required amongst the teams. A Project Manager using a schedule laid out in such a way would never be sure how the whole job was progressing.





## Scheduling logic

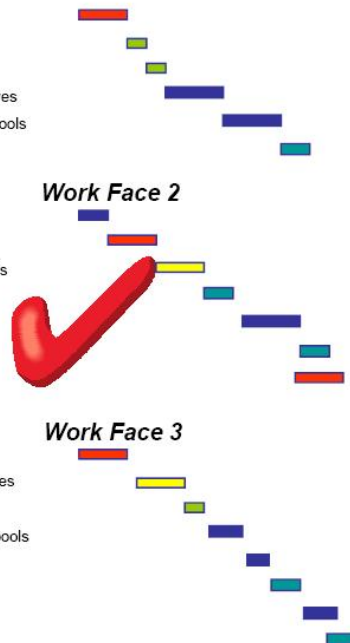


- Tank Top Externals**
- Erect scaffold
  - Disconnect Electrics
  - Disconnect instruments
  - Remove PSVs and safety valves
  - Unbolt flanges and remove spools
  - NDT Inspect.....
- Tank Internals**
- Open Manway door
  - Erect internal Scaffold
  - Pressure clean dome and walls
  - Inspect lining
  - Repair lining as necessary
  - Final inspection
  - Remove Scaf.....
- Tank Base External Work**
- Erect Scaffold
  - Pressure clean Pies and flanges
  - Disconnect instrument lines
  - Unbolt flanges and remove Spools
  - Remove expansion joint
  - NDT Inspect nozzle
  - Weld repairs as required
  - Final Inspection

### Work Face 1

### Work Face 2

### Work Face 3



John Bowie – Palm Crest Consultants Pty Ltd

www.palmcrest.com.au

John Bowie shows us what is a better work schedule layout. Each work face is organized in a program where the necessary skill groups are known and it is also evident when they are needed at a work face. The layout makes the message to the supervision clear. This layout permits the Project Manager to see immediately if a work face is running late or not.



## Scheduling Logic and the CMMS

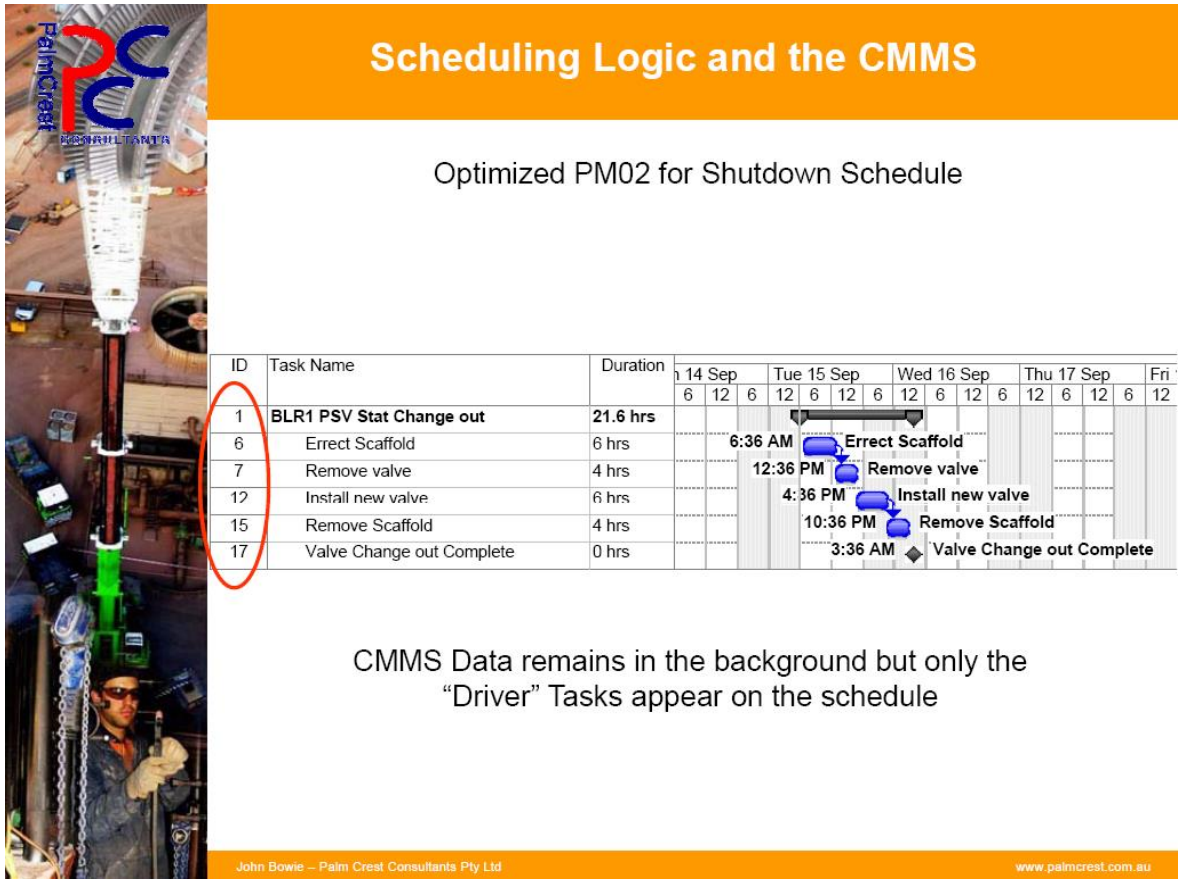
### Typical long winded PM02 imported to a Shutdown Schedule

| ID | Task Name                        | Duration | 14 Sep | 15 Sep   | 16 Sep | 17 Sep |
|----|----------------------------------|----------|--------|----------|--------|--------|
| 1  | BLR1 PSV Stat Change out         | 21.6 hrs | 6      | 12       | 6      | 12     |
| 2  | Quote for valve removal          | 0.5 hrs  |        | 6:00 AM  |        |        |
| 3  | Isolate valve                    | 1 hr     |        | 6:30 AM  |        |        |
| 4  | Risk assesment                   | 0.5 hrs  |        | 6:30 AM  |        |        |
| 5  | Quote to build scaffold          | 0.1 hrs  |        | 6:30 AM  |        |        |
| 6  | Errect Scaffold                  | 6 hrs    |        | 6:36 AM  |        |        |
| 7  | Remove valve                     | 4 hrs    |        | 12:36 PM |        |        |
| 8  | Crane to assit                   | 4 hrs    |        | 12:36 PM |        |        |
| 9  | Rigger to assist                 | 4 hrs    |        | 12:36 PM |        |        |
| 10 | Franna to take valve to workshop | 1 hr     |        | 4:36 PM  |        |        |
| 11 | Order gaskets from store         | 0.5 hrs  |        | 6:30 AM  |        |        |
| 12 | Install new valve                | 6 hrs    |        | 4:36 PM  |        |        |
| 13 | Crane to assist                  | 4 hrs    |        | 4:36 PM  |        |        |
| 14 | Rigger to assist                 | 4 hrs    |        | 4:36 PM  |        |        |
| 15 | Remove Scaffold                  | 4 hrs    |        | 10:36 PM |        |        |
| 16 | Housekeeping and clean up        | 1 hr     |        | 2:36 AM  |        |        |
| 17 | Valve Change out Complete        | 0 hrs    |        | 3:36 AM  |        |        |

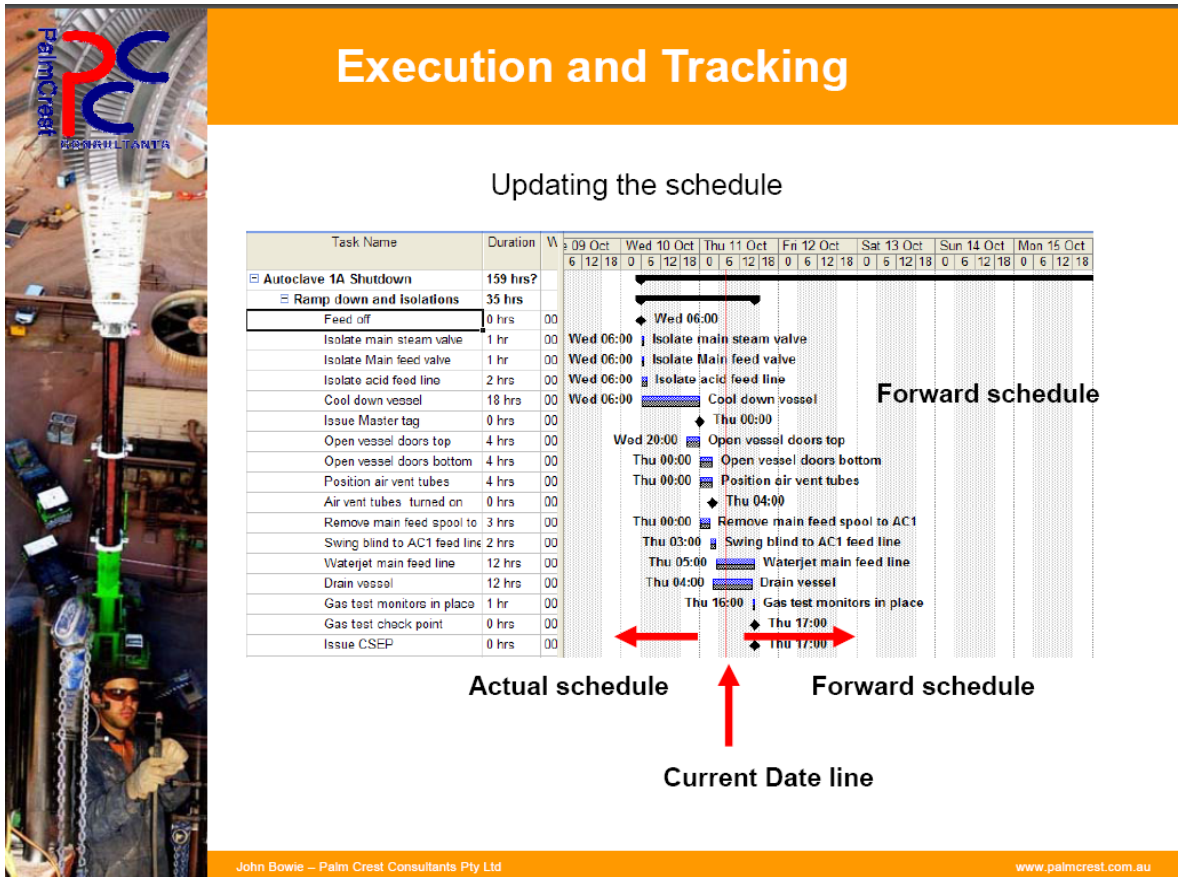
John Bowie – Palm Crest Consultants Pty Ltd

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The slide above and the next tell us that a job schedule requires to be structured with both the work details to control the job, and a summary to provide managers and supervisors an overview of what is to be achieved. The scheduling software needs to have such functionality.

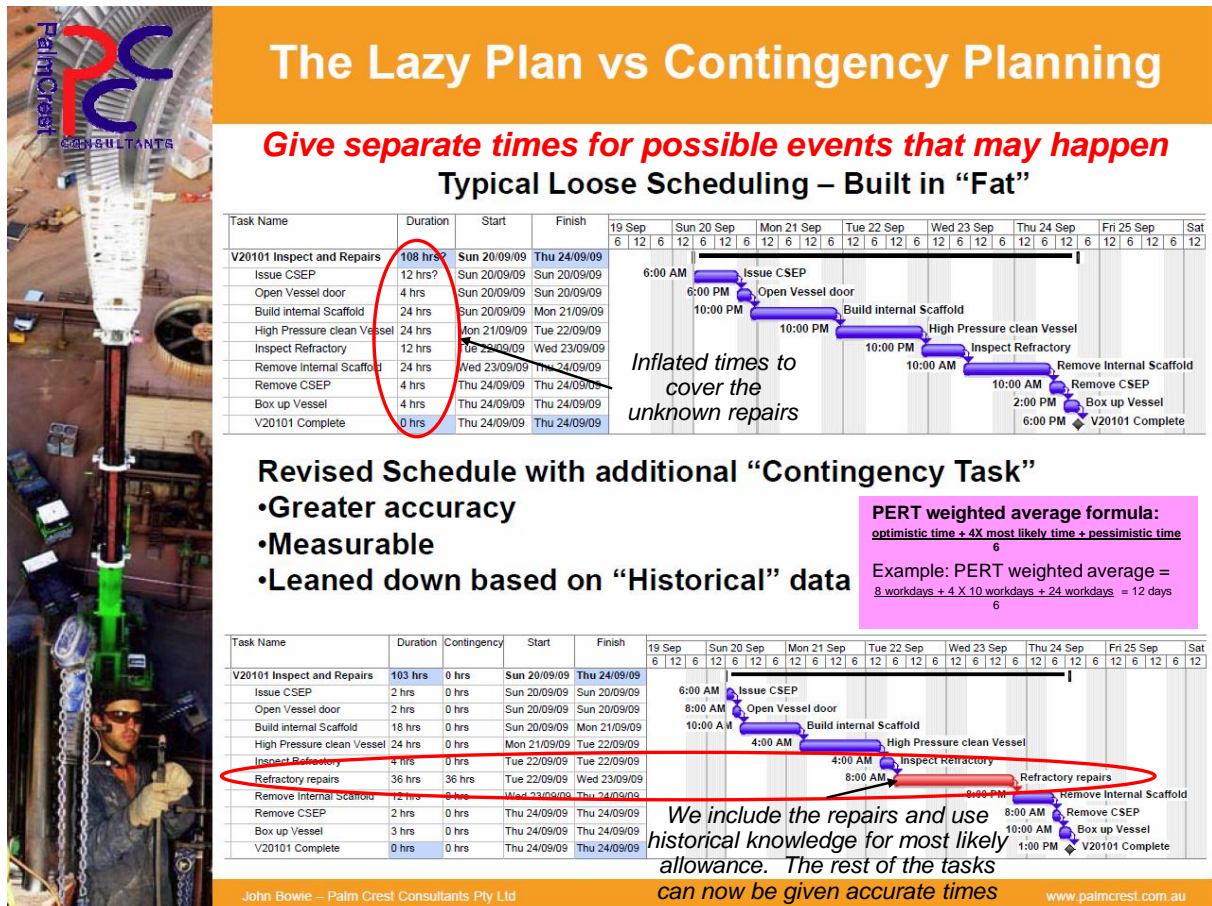


The job is now rolled up into a summary format.





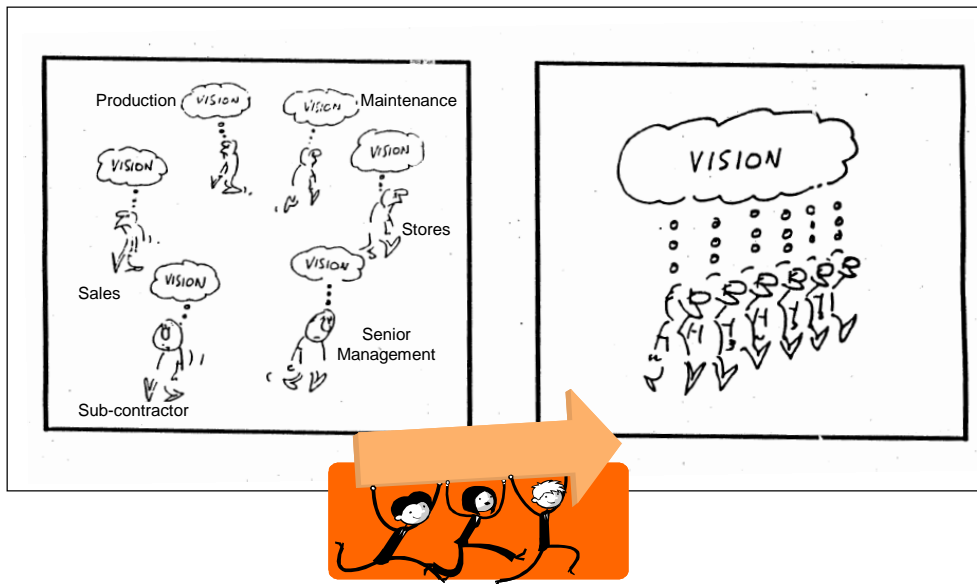
The job schedule is used by supervisor and worker to track work progress against the intended timeline and to identify future work to be done, along with its time frame for completion.



Often Planners are tempted to include extra time into tasks to cover for unknown factors or events that may happen. It is better to recognise the dilemma and separately give time for events that may occur in a job. If they do happen then the situation is covered, if they do not happen the job simply comes-in early. We can then review whether these uncertain event can be better controlled and even removed in future.

In the above slide John Bowie warns Planners to estimate accurately those tasks that can be accurately estimated. When task times are unknown then show them in the schedule by indicating the estimate in a different colour. John asks the Planner to be true and accurate in estimating activities and only add contingency onto a task when there is real uncertainty. For the red work task in the job schedule the extent of repair work is unknown and can only be clarified once people get to the work face. Time has been allowed for the worst possibility. Should less repair work be needed then the job task will finish sooner and the job will be completed earlier.

# The Power of a Shared Vision

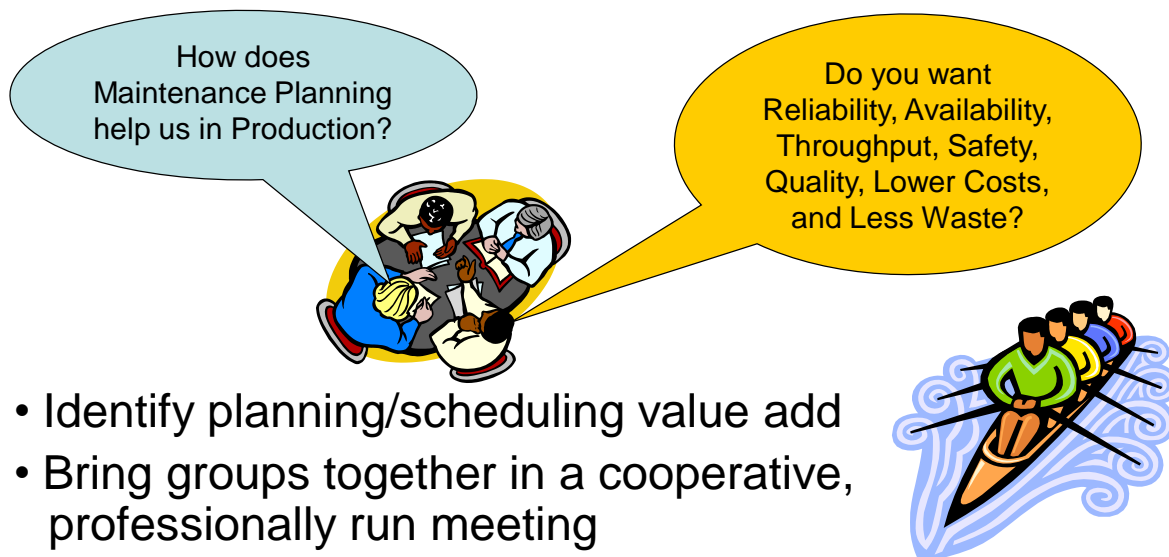


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Completing maintenance work successfully needs a shared purpose between the people involved in the process. Once people are aligned there is a common understanding and desire to hit the shared target. There is greater willingness to assist each other and work together. Maintenance, Stores, Operations, Finance, and Management work more harmoniously when all agree that they are after the same result.

## Team Building / Relationship / Partnership



- Identify planning/scheduling value add
- Bring groups together in a cooperative, professionally run meeting
- Request others' improvement ideas and do them
- Continual communication: changes and assistance

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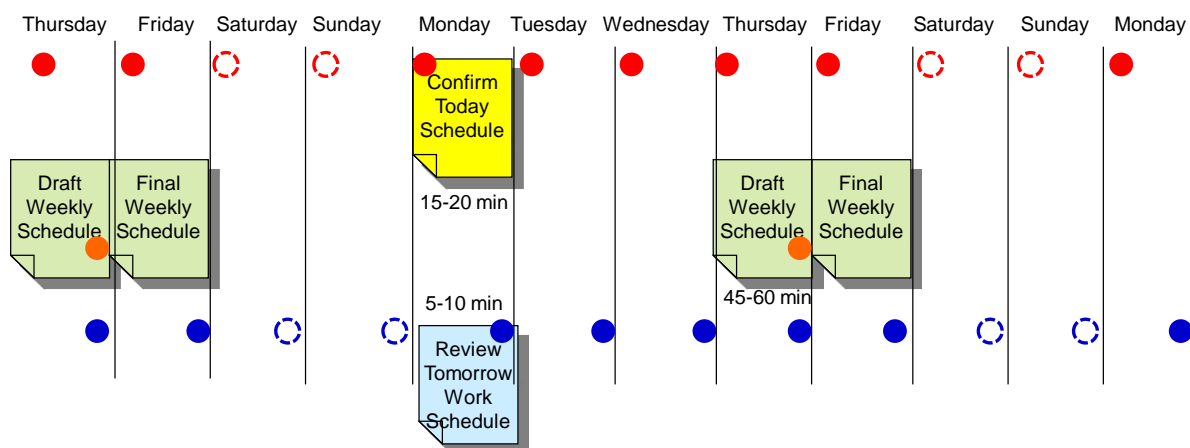
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Scheduling is one visible sign of the Production-Maintenance partnership. A partnership is a two-way interaction in which members meet their obligations to the others. How well Production and Maintenance work together is a reflection of the strength and depth of the relationship. Building a relationship requires a commitment to helping each other, to protect each other, to seek to understand each other and to learn wisdom from each other. Relationships are all about mutually beneficial cooperation.

## Meet Enough to Control and Communicate

### Morning meetings: ●

- 1) confirm handover preparations,
- 2) confirm resources e.g. cranes, subcontractors, parts
- 3) address overnight changes,
- 4) allocate people to work and responsibilities



### Afternoon meetings: ●

- 1) prevent emergency changes,
- 2) allow confirmation of resources e.g. cranes, subcontractors, parts
- 3) give people warning to prepare e.g. handovers, special tools

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Completing maintenance work on-schedule requires discussion, review and agreement from all parties. After which it is necessary to do the agreed actions in sufficient time to hold the schedule. Much can happen each day to interfere with work scheduled last week. Because things are so fluid in an industrial operation it is necessary to put time aside for all party's to purposely meet regularly to manage the situation.

You do not want to meet more often than necessary, but you must meet often enough to retain control of the workplace and to ensure jobs are prepared and organised properly and that work is done safely.

As well as a weekly meeting to agreed to the work to be done in the next fixed period, it is necessary to meet early each day to review the day ahead and how the work due to be done will be achieved at better than 95% scheduled compliance. It may even be necessary to meet the afternoon before so that changes which occurred during the day can be factored into the activities to be done tomorrow.

The afternoon meeting is more about preparation for the following morning workload than it is about communicating changes that happened during day. If events on that day cause the schedule to change it is much better to correct the schedule and reissue it in the afternoon than do nothing to advise people of the changes until the next morning meeting.

The afternoon meeting also allows Production and Maintenance to organise and prepare handovers and gather materials and equipment together so that everything needed for the first jobs to start next morning are ready to go.

# The Weekly Scheduling Meeting

- Purpose of the meeting is to set priorities, fix times, resource management and allocate responsibilities
- Right mix of people – Production decision makers, Maintenance decision makers, scheduler/planner: plus electrical, mechanical, engineering, OHSW reps
- Professional meeting practices – Room booked, Agenda, Meeting Timeline, Action minutes listing responsible persons and due dates
- Report back on KPIs, actions performed and their success
- A face-to-face, people process (trust, belief, honesty, laughter)



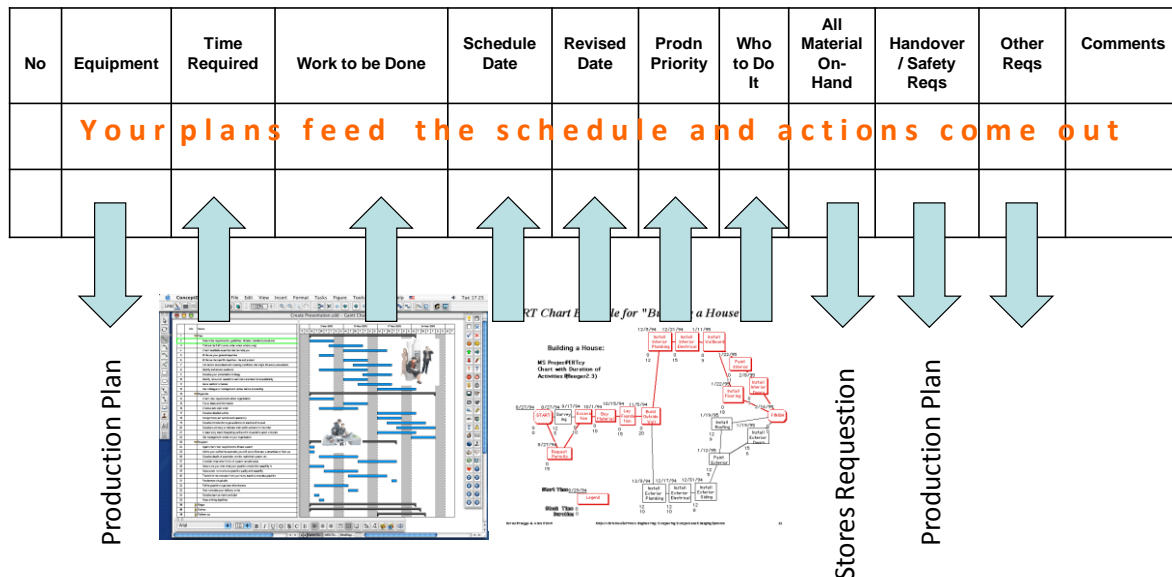
(Hugh Blackwood, 'Proactive Planning: essential component to total proactive maintenance', Alcoa Mt Holly USA, 2002)

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In this slide from Hugh Blackwood, he advises that the Weekly Scheduling Meeting is intended to discuss the sequencing of the planned work and the CMMS automatically generated work. Production persons have the final say since it is their equipment and operation which is under risk and they best know their operating processes and operating risks.

The scheduling meeting is held early in the week prior the week being scheduled so there is time to confirm details before the next week's work is 'locked' into place and not changed unless dire conditions require it. The meeting is between people seeking a common outcome and there needs to be obvious evidence of mutual respect and enjoyment in doing good things together.

# What's Discussed at the Weekly Scheduling Meetings?



Scheduling meetings review and discuss the current planned work orders' situation and required time and resource commitments. The schedule meeting minutes makes clear the work preparation status and the obligations to be met by all parties involved in the process to do the work. The work that Production must do to prepare for maintenance needs to go into the Production Plan so everyone in the operations group are aware of its presence and their obligation to do it, so that they can prepare for it ahead of time.

## The Daily Morning Scheduling Meeting

- Purpose of the meeting is to get today's WO's done (What has changed from the plan?)
- Output is an agreed list of work for the day showing the men and the time to do them
- Right mix of people – Production decision makers, Maintenance decision makers
- Fix times, safe access to equipment , activities and responsibilities to do it!
- Professional meeting practices – Room booked, Agenda, Meeting Timeline, Action minutes listing responsible persons and due dates
- Report back on actions performed and their success
- A face-to-face, people process





The Daily shift start Scheduling Meeting is intended to get the scheduled work due today done today. It is a 15 minute get together to confirm what has changed (if there are no changes the meeting is shorter) from the work scheduled yesterday for today. It acts to align all people in Operations, Stores and Maintenance toward achieving the day's scheduled jobs. Only the exceptions to the drafted schedule are discussed, along with any safety issues and risk management required in the work to be done that day. Production have the final say since it is their equipment and operation which is under risk and they best know their operating processes and operating risks. The scheduling meeting is held first thing each day to confirm details and commit people and resources.

## The Daily Afternoon Scheduling Meeting

- Purpose of the meeting is to set tomorrow's WO's
- Output is an agreed list of work for the next day showing the men and the time to do them
- Update schedules in Production and Maintenance
- Right mix of people – Production decision makers, Maintenance decision makers
- Fix times, safe access to equipment , activities and responsibilities to do it!
- Professional meeting practices – Room booked, Agenda, Meeting Timeline, Action minutes listing responsible persons and due dates
- Report back on actions performed and their success
- A face-to-face, people process



The Daily Afternoon Scheduling Meeting is intended to set the scheduled work to be done tomorrow. It is a time management maxim that you cannot plan for today, today; today must be planned no later than the day before. Hence this 5 minute meeting the prior afternoon is to set tomorrow up to be successful. In the afternoon meeting a draft Schedule for tomorrow is already available and those persons attending just discuss what needs to be changed or updated to accommodate any changes that they know about. What forewarnings need to be given to people and what preparations need to be made, such as preparing and organising to handover plant and equipment, can be advised to the appropriate persons to do overnight. Production have the final say since it is their equipment and operation which is under risk and they best know their operating processes and operating risks.

The afternoon scheduling meeting is held as late each day as the Scheduler has time to develop tomorrow's work schedule and post it for all to view.

# Scheduling Meeting Factors

- Team work of equal partners
- Honesty in communication, trusting that each has the best interest of the business, its people and its future at heart
- Credibility through commitment to agreements and the continual improvement of the operation and its people
- Consistency of intent by attending regular weekly meetings, providing participants, actioning decisions and delivering results.

(Hugh Blackwood, 'Proactive Planning: essential component to total proactive maintenance', Alcoa Mt Holly USA, 2002)

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For maintenance scheduling meetings to work well Hugh Blackwood advises us that necessary human factors need to be present and need to be evident to all.

# Weekly Maintenance Scheduling Meeting Agenda and Record

## Operating Site Name

**Venue:** Meeting Room Present at Meeting: \_\_\_\_\_

**Date:** \_\_\_\_ / \_\_\_\_ / \_\_\_\_

**Time:** 0930 hrs

**Topics:** \_\_\_\_\_

1) Manning Issues

2) Last Week Performance Review

No of Jobs Scheduled (previous week): \_\_\_\_\_ No of PM's Scheduled \_\_\_\_\_

No of Scheduled Jobs completed: \_\_\_\_\_ No of Scheduled PM's completed \_\_\_\_\_

Total number of all jobs completed: \_\_\_\_\_

Reasons for Variances: \_\_\_\_\_

3) Current Week

Hand out preliminary leveled draft schedule for each working day next week and the work outstanding report

Review mandatory and statutory jobs  
(commit these jobs)

Review work outstanding  
Review draft schedule day by day

Adjust daily schedule to priorities (add or  
deduct work)

Commit to doing agreed scheduled jobs

4) KPI Graphs/Reports

Hand out KPIs for last week and discuss performance and trends  
Identify issues and set action plans to address problems

5) Review Status of Follow-up Actions Due By Today

6) General Business

7) Record Follow-up Actions and Decisions from this Meeting

| Responsible | Description | Date Required | Complete |
|-------------|-------------|---------------|----------|
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |

Compiled By : \_\_\_\_\_

**Distribution:** Attendees, Production Control Room, Maintenance Manager, Production Manager, General Manager

# Daily Maintenance Scheduling Meeting Agenda and Record

## Operating Site Name

**Venue:** Meeting Room      Present at Meeting: \_\_\_\_\_

**Date:** \_\_\_\_ / \_\_\_\_ / \_\_\_\_

**Time:** Start of Shift

**Topics:** \_\_\_\_\_

- 1) Time each Work Order can be done this shift
- 2) Contractors Required On-Site
- 3) Permits Required for each WO
- 4) Review Status of Follow-up Actions Due By Today
- 5) Expectations/Preparations for Tomorrow
- 6) Rescheduled Work

| WO No | Reason for Reschedule | New Date Required |
|-------|-----------------------|-------------------|
|       |                       |                   |
|       |                       |                   |
|       |                       |                   |
|       |                       |                   |
|       |                       |                   |
|       |                       |                   |

- 7) Previous Days Performance/Problems
- 8) Record Follow-up Actions and Decisions from this Meeting

| Responsible | Description | Date Required | Complete |
|-------------|-------------|---------------|----------|
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |
|             |             |               |          |

Compiled By : \_\_\_\_\_

Distribution: Attendees, Production Control Room, Maintenance Manager, Production Manager, Maintenance Planner

# Backlog Management

## Managing Backlog involves getting the planning and scheduling right.

The key aspects of successful backlog management are:

- » Setting objectives
- » Setting/agreeing priorities
- » Establishing the organisation's responsibilities and relationships
- » Implementing the processes to met the objectives
- » Measuring the performance
- » Reviewing the performance, and
- » Auditing the process

This framework for managerial action will produce a formal management system for the control of maintenance backlog, and is an essential component in managing maintenance.

The details of managing backlog involve:

- » Managing work requests.
- » Developing work orders, job preparation and repair procedures.
- » Work scheduling.
- » Job execution and follow up of work in progress

### 1. The first step in managing the backlog requires that the work be properly identified and prioritized by maintenance and operations together.

(For more see '**Manage Backlog, a Start in Managing Maintenance!**' article in Course Book)

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Once work has been requested it becomes the responsibility of the Maintenance Planner and Maintenance Work Scheduler to manage the backlog in consultation with Production and the Maintenance Crew.

## Manage Backlog: A Start in Managing Maintenance!

This article, by David Finch, explains how to manage a maintenance backlog in a structured and well organised fashion that keeps the maintenance backlog under control.

### Abstract:

*Manage Backlog, a Start in Managing Maintenance!* A maintenance manager can commence a maintenance improvement programme by simply creating opportunities for individuals and groups to make high performance contributions. One way to do this is to manage the Maintenance Backlog.

Keywords: Maintenance backlog, backlog management

There are numerous definitions of Backlog. The definition I use is "planned maintenance work waiting to be scheduled". Note: We only schedule 1 week at a time, therefore it's the bucket of future work. However, if there is a high load of preventive maintenance about to occur then it is important to know about this work for planning purposes.

Others refer to Backlog as the work not completed by the due date. Personally, I use priorities, but not 'due dates' for corrective work. I believe that people raising work requests can rarely understand the planning processes required to be implemented to turn a request into an order.

It is important that whatever the definition used, be sure that everyone in the organisation knows the meaning. The caveat is, it is incumbent on the Planner to ensure that once work requests are authorised

planning goes ahead to convert the work request to a work order. It has been known for planners to delay their planning activities so that performance indicators on Backlog look good.

Deferred Maintenance is usually high-cost work that must be postponed as a result of inadequate planning, lack of opportunity and/or funding. Examples include roof replacement, HVAC system replacement and window replacement. Deferred maintenance adds to the backlog of maintenance and repairs, but is not included in the backlog calculations. It tends to be specific to the public sector.

The key aspects of successful backlog management are:

- Setting objectives
- Setting/agreeing priorities
- Establishing the organisation's responsibilities and relationships
- Implementing the processes to meet the objectives
- Measuring the performance
- Reviewing the performance, and
- Auditing the process

This framework for managerial action will produce a formal management system for the control of maintenance backlog, and is an essential component in managing maintenance.

The details of managing backlog involve:

1. Managing work requests.
2. Developing work orders, job preparation and repair procedures.
3. Work scheduling.
4. Job execution and follow up of work in progress

**1. The first step in managing the backlog requires that the work be properly identified and prioritised by maintenance and operations together.**

A rigorous examination of the work requested needs to be carried out. This will remove duplicate work, finished work, unwanted work and modifications (modifications need to go through the 'management of change' process, modifications need engineering and fiscal approval, a modification is not maintenance work) out of the list.

**2. Planning maintenance, including, looking at resources, estimates and parts (how to do the job!). It is the development of a detailed programme to achieve an end.**

- It is the advanced preparation of a specific job
- It ensures the task is performed in an efficient and effective manner
- It ensures that all necessary logistics have been coordinated for the job execution phase to take place at a future date
- It is the process of detailed analysis that determines and describes the work to be performed, the sequence of associated tasks, methods to be used for their performance, and the required resources, including:
  - skills,
  - crew size,
  - man hours,
  - parts,
  - materials,
  - special tools and equipment
- An estimate of the total cost
- identification of safety precautions

- required permits
- communication requirements
- reference documents - vendor manuals, drawings, wiring diagrams etc

### **Co-ordination**

- Encompasses the logistical efforts of assembling all necessary resources so that the job is ready to be scheduled.
- Interfaces with:
  - Purchasing
  - Stores
  - Operations
  - Engineering
  - Maintenance
- Reviewing all jobs ready to be executed and decides on priority.

Planners need to know how to estimate the work. A good planner is a good estimator!

Repair procedures save time when executing corrective work. Do you have any?

### **3. Scheduling (when to do the job!)**

- Is the process whereby the labour, resources and support equipment are allocated / appointed to specific jobs at a fixed time (often when operations can make any associated equipment / system available).
- The schedule represents when the organisation expects the task to be carried out, and when the resources are available.

### **4. Job execution and follow up of work in progress.**

Is the right maintenance work being completed at the right time with the right resources?

Managing Backlog involves getting the planning and scheduling right.

To help the planning process it is normal to run with approximately 2 man weeks of Backlog per technician. If you are constantly below that figure then you could be over-manned. If the Backlog climbs to 4 man weeks then consider overtime working or bringing on additional resources.

Trending the Backlog aids management decision making. There are several different ways to measure Backlog. These are:

- Measuring Total Backlog
- Discipline Backlog (Backlog be mechanical, electrical, instrument discipline etc.)
- PM Backlog (the PM not completed in the month it was due), and
- Safety-critical Backlog

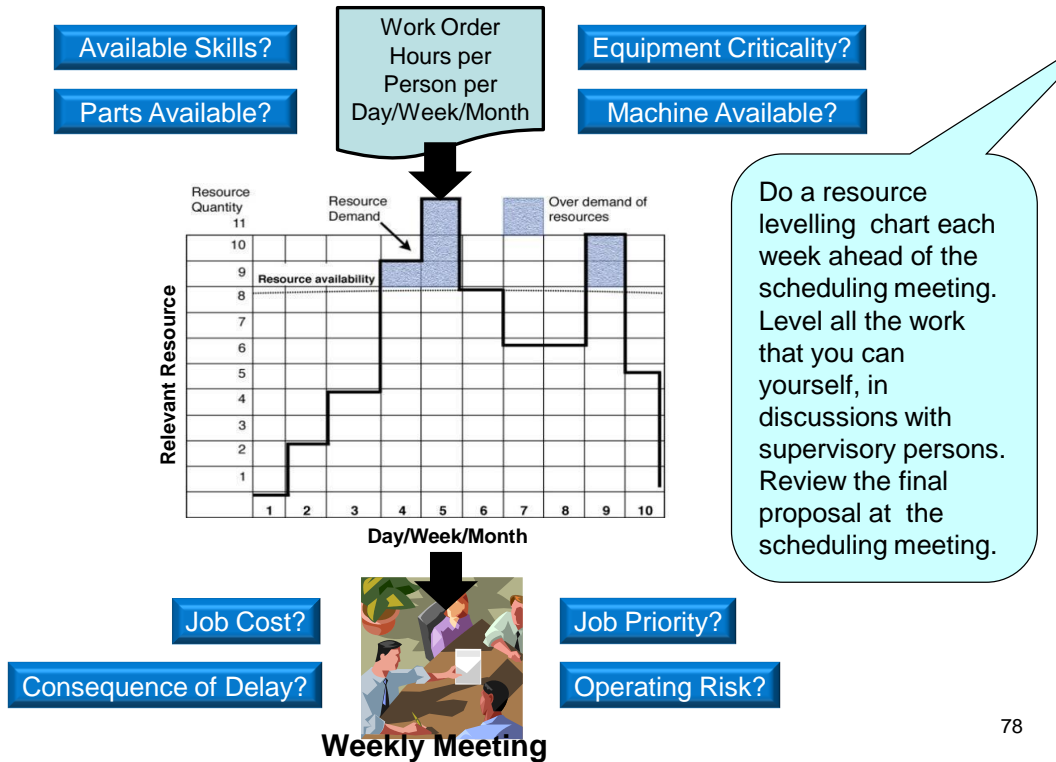
All are excellent performance indicators and give you an overall picture where work is building up, scarce, or critical, allowing you to manage maintenance operations.

Best regards,

*David Finch, MSc, MIEAust, CEng, FSOE, AIMM,  
Operations & Maintenance Manager  
Clough AMEC JV*

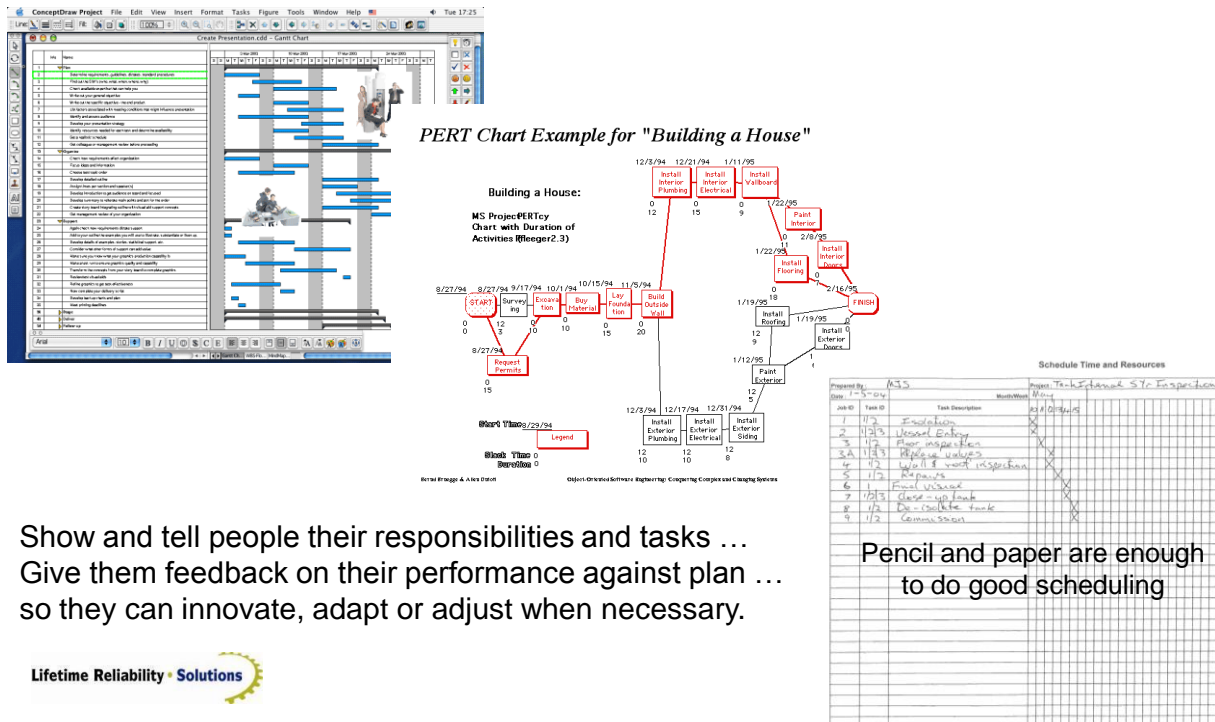


## Level Work to the Available Resources



Scheduling includes making sure that a resource is not overloaded and is available when required. The resource levelling chart above is the document used to identify which resources need to be levelled and is prepared by the Scheduler weekly.

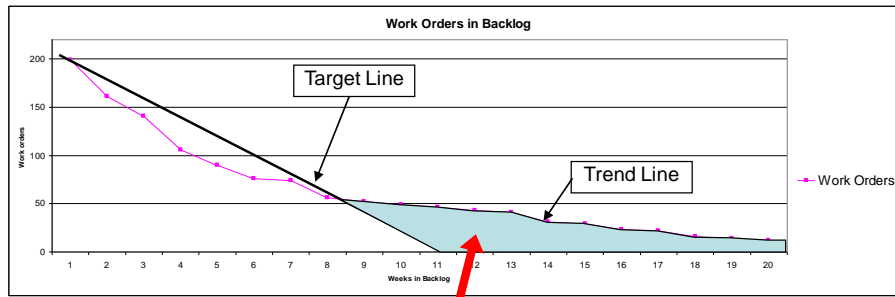
## Display the Schedule and Responsibilities: Who Does What By When!



Scheduling produces physical documents that guide people's decisions and actions. They are visual management tools and need to be displayed. Equally important is to use schedules to give feedback on performance against the plan. This lets people know how well things are going so that changes can be considered, approved and made if necessary.

## Setting and Increasing Work Order Priority

Set work priority based on reducing the risk to production plant equipment, only to be overridden when opportunity arises during production to do the work earlier.



**Overdue work means a growing risk (Risk = Chance x Consequence)**

If a job is valid, then not doing it increases the risk of failure from breakdown. Jobs that start with a low priority never get done, unless your work order system lifts their priority as they get older.

Use job categories to classify jobs waiting for a particular situation to arise  
e.g. next planned shutdown, capital project, etc. so you can separate them from normal work.

Priorities always change in a busy workplace. There needs to be a recognised process to set the schedule for doing a maintenance job based on its impact on reducing the operating risk. As a start you can use the equipment criticality rating to set work priority, but bear in mind that maintenance work not done means increased chance of a failure happening during the time it is sitting in the backlog.

To prevent a low priority task letting a failure happen, we must increase the job priority as the risk grows bigger and bigger with time passing. Each work order must be assessed as to what risks will rise if the work is not done when intended.

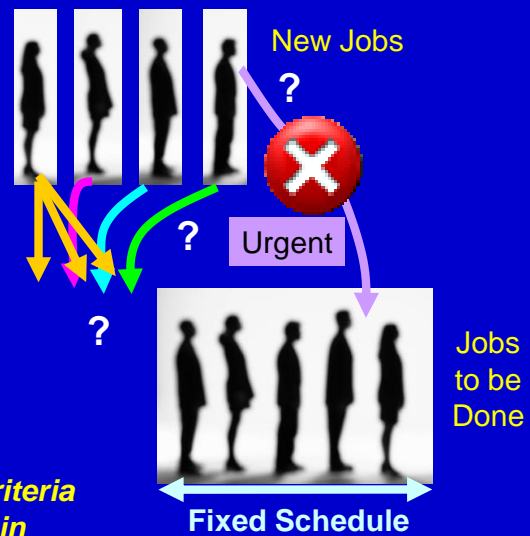
# Rescheduling can lead to Queue Jumping

One company put work into the backlog with a due-by-date and then never tracked its progress. None of the work ever got done on time. They were forever telling their customers that their jobs would be done as soon as they could be.

The scheduling method had defaulted to doing the oldest work first, and when anyone complained that a job was late, they would do that job next, thereby making every other job late as well.

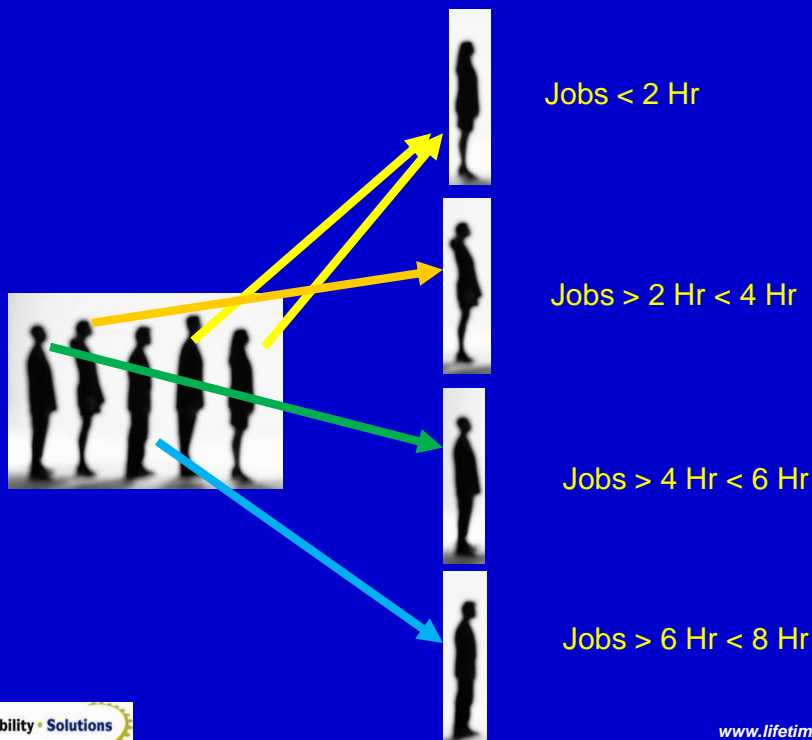
What would you do to solve this problem?

1. **Match resources required to the queue criteria**
2. **Schedule resources to become available in job priority order** (How to decide the priority?)
3. **Hold the schedule** (That way > 95% of work can get done on schedule.)



The best way to work through a queue of work is to set the queue up in priority order, and then take each item one by one in that order, until it is complete. As soon as you start putting new work into a scheduled queue all the previous planned work gets delayed.

## Queuing Theory for Maintenance Jobs



My bank just put in a queuing solution. You go through the front door and in front of you is a panel with four buttons. The top button is to see a bank teller to do your transactions. The second button down is for advice about bank accounts, like starting one or closing one. The third button is for financial queries, like superannuation or a loan, and the fourth is for everything else.

Once you get your printed ticket you go and sit in your allocated queue and wait your turn. But the most interesting part is what happens next.

There are enough bank tellers so that anyone who wants an over-the-counter transaction gets served within two minutes of joining the queue (usually it is much sooner). There are enough service staff that if you have a long financial query of 15 to 30 minutes duration you are seen by one of them within ten minutes (often it so much sooner). The bank has scheduled its resources to match the times that their typical range of work activities take.

Maintenance work orders can be handled the same way. You divide your backlog into definable queuing criteria and allocate your maintenance resources accordingly to get through each queue. The image below shows how the bank's queuing solution can be used in maintenance work scheduling.

Once the work is subdivided you put the high priority jobs in each queue to the front of its category. Your manpower, equipment and other job resources and requirements can then be allocated to the queue. The maintenance crew work through the schedule from the top priority to the least until the queue ends.

By doing your maintenance work order scheduling using queues you will get through your backlog jobs faster. Your people and resources get 'fine-tuned' to do that particular type of work very efficiently. They do the work faster and they find the simple and easy ways to get through the queue.

The work order queuing categories are your own choice that makes sense for your operation. You can include your resource constraints into the queue criteria, like the need for specialist access equipment, such as the overhead access device noted in the list below.

- Less than two hour using only standard tool kit
- More than two hours and less than four hours using only standard tool kit
- Less than four hours and requiring overhead access equipment
- More than four hours but less than eight hours and requiring overhead access equipment
- Etc, etc

# Backlog Report Layout for Planning and Monitoring in Backlog Management

|   | A                          | B               | C        | D          | E          | F               | G           | H             | I           | J                 | K              | L            | M              | N        |
|---|----------------------------|-----------------|----------|------------|------------|-----------------|-------------|---------------|-------------|-------------------|----------------|--------------|----------------|----------|
| 1 |                            |                 |          |            |            |                 |             |               |             |                   |                |              |                |          |
| 2 | Maintenance Backlog Report |                 |          |            |            |                 |             |               |             |                   |                |              |                |          |
| 3 |                            |                 |          |            |            |                 |             |               |             |                   |                |              |                |          |
| 4 | Job Number                 | Job Description | Equip No | Equip Desc | Equip Crit | Date WO Created | WO Priority | WO Crit Ratio | WO Category | Hours to Complete | 1st Sched Date | Resched Date | Completed Date | Comments |
| 5 |                            |                 |          |            |            |                 |             |               |             |                   |                |              |                |          |
| 6 |                            |                 |          |            |            |                 |             |               |             |                   |                |              |                |          |

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Once work has been requested it becomes the responsibility of the Maintenance Planner and Scheduler to manage the backlog. Backlog management involves monitoring all the work in the backlog and insuring that it is prioritised and completed in time before unwanted effects and consequences arise. This is typically done using a backlog report to view the work load and the rate at which work categories are being completed. A sample backlog report is shown in the slide. The report shows what is happening to all maintenance work orders.

The dates from the backlog can be used for performance measure such as 'On-time Completion' percentage. **This backlog report layout is missing an important piece of information... the business priority for each job!**

# Calibrated Job Prioritisation Risk Matrix

| W/O Issuing Priority (based on Risk Level) |  | Asset Impact (Max Likely Consequences)                       |   |  |  |  |   |  |
|--|--|--|---|--|--|--|---|--|
| Risk Level                                 | Response   |  | Negligible  | Low  | Important  | Serious  | Severe  | Catastrophic   |
| Red = Extreme<br>8, 9 & 10                 | Immediately allocate all necessary resources, and do job | Health and Safety  | No threat to Safety or Health if work not done      | Can lead to health issues, injuries or ailments not requiring medical treatment                                    | Can lead to health issues, injuries or ailments causing a minor injury or First                                  | Can lead to serious health issues, injury or ailments causing hospitalisation or         | Can lead to life threatening health issues, injury or multiple serious                            | Can lead to health issues or injuries causing death or multiple life                         |
| Amber = High<br>6 & 7                      | Immediately plan and prepare, then do the job            | Environmental  | No threat to Environment if work not done           | 1) Below license requirements<br>2) Contamination contained in immediate plant area and addressed by local workers | 1) Within license requirements<br>2) Contamination contained within site boundary and addressed by own resources | 1) Exceed license limits<br>2) Contamination requires mobilisation of external resources | 1) Grossly exceeds license limits<br>2) Major contamination and local emergency services required | Major contamination and national emergency services required                                 |
| Yellow = Medium<br>4 & 5                   | With priority, plan the work and then schedule the job   |  |   | 1) Quality approaching unacceptable limits   | 1) Occasional Quality problem detected   | 1) Quality problems often detected   | 1) Customer sends repeated quality complaints   | 1) Contract terminated due to Quality problems total Production stopped for more than 5 days |
| Green = Low<br>2 & 3                       | In a timely manner, plan the work and schedule the job   | Production and Quality                                       | No threat to Production or Quality if work not done |  |  |  |   |  |
| Blue = Slight<br>0 & 1                     | Gather work together and do as a scheduled campaign      |  |   |  |  |  |   |  |
|  |  | Financial  | <\$100  | <\$1K  | <\$10K   | <\$100K  | <\$1,000K   | >\$1,000K  |
|  |  | PM Work  | 0   | 1  | 2  | 3  | 4   | 5  |
|  |  | Requested Work   | 5   | 6  | 7  | 8  | 9   | 10   |
|  |  | Certain problems - if done after first scheduled date        | 5   | 6  | 7  | 8  | 9   | 10   |
|  |  | Item has failed or failure is imminent                       | 5   | 6  | 7  | 8  | 9   | 10   |
|  |  | Almost certain problems - if done after first scheduled date | 4   | 5  | 6  | 7  | 8   | 9  |
|  |  | No effect if done within 3 days                              | 4   | 5  | 6  | 7  | 8   | 9  |
|  |  | Likely problems - if done after first scheduled date         | 3   | 4  | 5  | 6  | 7   | 8  |
|  |  | No effects if done within 10 days                            | 3   | 4  | 5  | 6  | 7   | 8  |
|  |  | Possible problems - if done after first scheduled date       | 2   | 3  | 4  | 5  | 6   | 7  |
|  |  | No effects if done within 1 month                            | 2   | 3  | 4  | 5  | 6   | 7  |
|  |  | Unlikely problems - if done next scheduled date              | 1   | 2  | 3  | 4  | 5   | 6  |
|  |  | No effects if done within 3 months                           | 1   | 2  | 3  | 4  | 5   | 6  |
|  |  | Negligible problems - if rescheduled several times           | 0   | 1  | 2  | 3  | 4   | 5  |
|  |  | Negligible effect if done within 30                          | 0   | 1  | 2  | 3  | 4   | 5  |

Witt – Sondalini W/O prioritisation table

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Each work order needs to be assessed for its importance to the business. If you only use asset criticality to prioritize work orders you may end up painting hand rails around a critical asset and let a machine fail that that stops the operation because its criticality was not as high as the asset whose hand rails you painted. This situation is clearly a nonsense. Each work order requires us to look at it for its importance to keeping the business in business.

In the table the likelihood values have been altered to represent the frequency that a failure arises should a work order not be done by a specified date. Now every work order can be assessed on equal ground—what impact does each work order have on the business risk and not only how important is the machine to be worked on.

Prioritising maintenance work with a matrix like that in the table highlights the great importance of doing scheduled PM work. Many times scheduled work will be delayed when resources are not available because of apparently higher priority work (Often PMs are mistakenly cancelled to wait for the next time they come due.). But this is crazy because scheduled work is there to prevent a failure. If a scheduled predictive maintenance (PdM) job, or condition monitoring (CM), or a preventive maintenance (PM) job is not done when due, you increase the likelihood of breakdown. Delay doing those jobs long enough and you guarantee failure. Doing PM and CM work is the first principle of maintenance management because you proactively keep your equipment healthy.

The priority table warns us about one more important maintenance management principle—a maintenance group cannot do both urgent work and important work at the same time. In the table the urgent work is shown separate to important work that is not urgent. The group responsible for urgent work focuses on getting good at reactive maintenance done to high reliability standards. The group focused on important work gets good at doing high quality work to create high reliability (so that there will be no urgent work in future). Each group needs a different mentality that cannot be shared within one group of people—reactive work will always win and kill reliability growth work unless you separate the two.

# Risk Based Work Order Prioritisation

## W/O prioritisation is based on criticality/risk principles

Likelihood and priority codes are set on a log<sub>10</sub> basis with consecutive numbers varying in impact by an order of magnitude (x10)

(Some risk professionals say to set Asset Impact on worst likely event – i.e. pessimistic but not Maximum Credible worst Consequences, but I use worst possible since we need to be sure they won't happen)

To reduce risk we would make defensive provisions to ensure the chance and/or consequence associated with this scenario was adequately low.

E.g. It is possible that the only High Voltage(HV) power supply transformer(TX) to a site could fail. So regular PM and CM testing are specified to keep the likelihood, **and thus** the risk, low.

**However, the Item retains the Impact associated with the consequences of this failure.** The credible but highly unlikely possibility that the TX could also catch fire is usually excluded on the basis that safety systems W/Os (PMs and CMs) **are always completed on schedule.**

By doing the WOs we gain more information about the TX **current condition and its risk**. But failure to complete a PM or CM task will move us from the design criticality towards the unmitigated risk due to our lack of knowledge of TX condition

**Thus in terms of Operating Risk: a PM or CM on a HV T/X may be higher priority than a repair to a failed lower Impact Item**

Thanks to Howard Witt for the content



Read the slide. It explains the reasoning as to why each work order must be prioritized independently of the asset it applies too.

## W/O Prioritisation - Example

The W/O risk priority scores are the sum of log Asset Impact – Unmitigated Risk (risk without taking account of maintenance) plus log Impact of delaying work.

For all Assets other than OTF the Design risk is lower because of planned maintenance.

So if we do not do planned maintenance we move back toward the unmitigated Risk.

The impact of delay in implementing W/O has a score 0 to 5.

### Example 1

W/O (to repair an already failed) Asset with Impact 0 gets assigned W/O priority 5 (W/O delay score = 5)

### Example 2

W/O (to repair if "almost Certain problems") with an Asset with the Impact 2 (<\$10K) gets assigned W/O priority 6 (W/O delay score = 4)

### Example 3

W/O on an Asset with Impact 5 (>\$1M) gets assigned W/O priority 7 just because there are "Possible Problems" if job done late (W/O delay score = 2).

### Example 4

W/O (to repair an already failed) Asset with Impact 5 (>\$1M) gets assigned W/O priority 10 (W/O delay score = 5).

| W/O Issuing Priority (based on Risk Level)                   |  | Asset Impact (Max Likely Consequences) |   |  |  |  |   |  |
|--|--|--|---|--|--|--|---|--|
| Risk Level   | Response   |  | Negligible  | Low  | Important  | Serious  | Severe  | Catastrophic   |
| Red - Extreme<br>9, 9.5, 10                                  | Immediately allocate all necessary resources, and do job | Health and Safety                      | No threat to Safety or Health if work not done      | Can lead to health issues, injuries or ailments requiring medical treatment  | Can lead to health issues, injuries or ailments causing a minor injury or First                                  | Can lead to serious health issues, injury or ailments causing hospitalisation or                   | Can lead to life threatening health issues, injury or multiple serious                            | Can lead to health issues or injuries causing death or multiple life                               |
| Amber - High<br>6 & 7  | Immediately plan and prepare, then do the job            | Environmental                          | No threat to Environment if work not done           | 1) Below license requirements<br>2) Contamination contained within immediate plant area and addressed by local workers | 1) Within license requirements<br>2) Contamination contained within site boundary and addressed by own resources | 1) Exceed license limits<br>2) Contamination requires mobilisation of external resources           | 1) Grossly exceeds license limits<br>2) Major contamination and local emergency services required | Major contamination and national emergency services required                                       |
| Yellow - Medium<br>4 & 5                                     | With priority, plan the work and then schedule the job   | Production and Quality                 | No threat to Production or Quality if work not done | 1) Quality approaching unacceptable limits<br>2) Production uses work-around to keep plant running                     | 1) Occasional Quality problem detected<br>2) Minor Production capacity reduction for less than 1 hour            | 1) Quality problems often detected<br>2) Major Production capacity reduction for less than 1 shift | 1) Customer sends repeated Quality complaints<br>2) Total Production stopped for more than 1 day  | 1) Contract terminated due to Quality problems<br>2) Quality problems stopped for more than 5 days |
| Green - Low<br>2 & 3   | In a timely manner, plan the work and schedule the job   |  |   |  |  |  |   |  |
| Blue - Slight<br>0 & 1                                       | Gather work together and do as a scheduled campaign      |  |   |  |  |  |   |  |
| Work Order Priority (Impact of Delay)                        |  | Financial                              | <\$100  | <\$1K  | <\$10K   | <\$100K  | <\$1,000K   | >\$1,000K  |
| PM Work  | Requested Work   |  | 0   | 1  | 2  | 3  | 4   | 5  |
| Certain problems - if done after first scheduled date        | Item has failed or failure is imminent                   | 5                                      | 5   | 6  | 7  | 8  | 9   | 10   |
| Almost certain problems - if done after first scheduled date | No effect if done within 3 days                          | 4                                      | 4   | 5  | 6  | 7  | 8   | 9  |
| Likely problems - if done after first scheduled date         | No effects if done within 10 days                        | 3                                      | 3   | 4  | 5  | 6  | 7   | 8  |
| Possible problems - if done after first scheduled date       | No effects if done within 1 month                        | 2                                      | 2   | 3  | 4  | 5  | 6   | 7  |
| Unlikely problems - if done next scheduled date              | No effects if done within 3 months                       | 1                                      | 1   | 2  | 3  | 4  | 5   | 6  |
| Negligible problems - if rescheduled several times           | Negligible effect if done within 30                      | 0                                      | 0   | 1  | 2  | 3  | 4   | 5  |

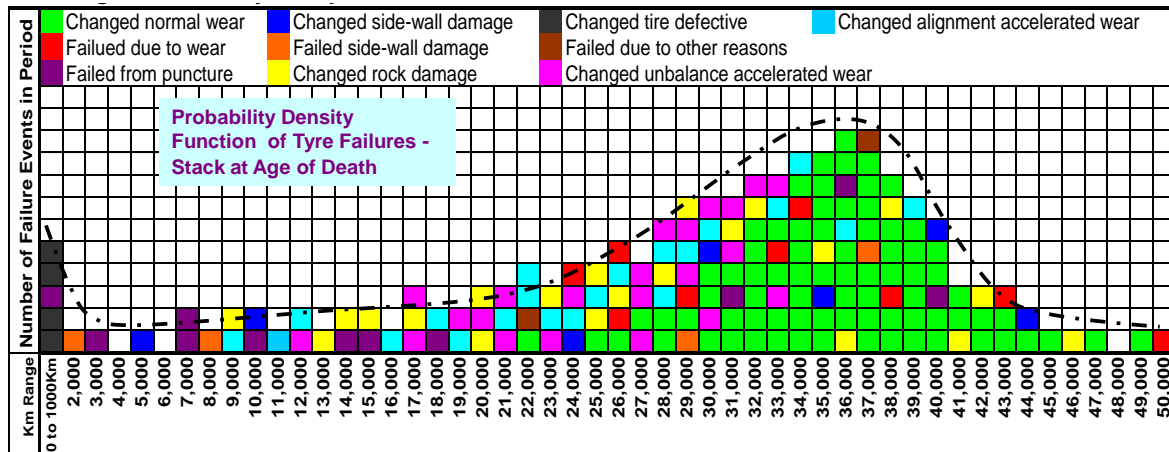
Thanks to Howard Witt for the content

Work through the examples to see how the table is used.



# Failure History Analysis to set PM Frequency

Requires more data than above method. X (time) axis broken into time intervals  
Failures stacked as in a series of histograms



Note X axis is “km” not “Time” – The term “time” can be replaced by another measure of “exposure” to degradation processes.

Note use of colours –Failures have been coded according to Cause of Failure – Very important, as not all causes are wear related.

Source: Howard Witt Consulting, Sydney, Australia, 2008

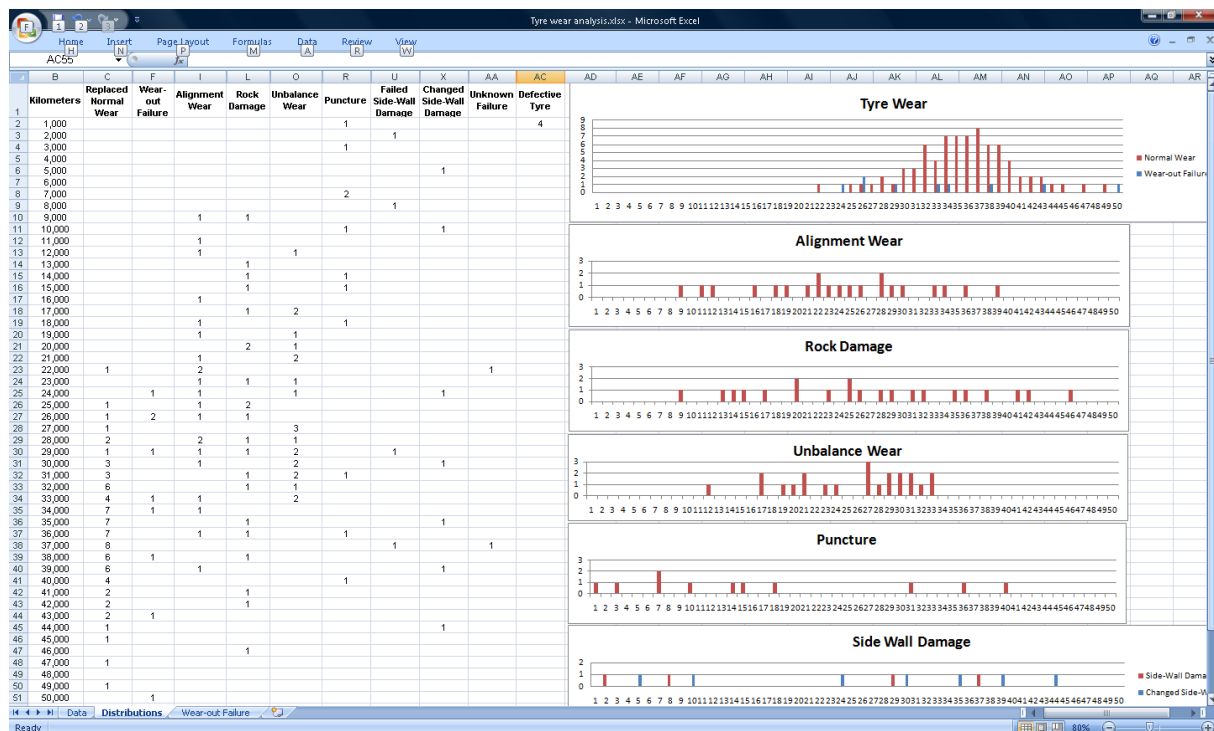
(NOTE that incomplete or Censored data is handled in a different way)

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You can use the maintenance and repair history of your equipment to help decide the schedule for doing maintenance work. In the slide someone has categorized their mining truck tire failures and replacements by the failure causes.

Differentiating maintenance by the failure cause is a vital necessity to use this approach, since you will select specific maintenance activities to address each cause. If you do not know the real cause of a problem you will not know exactly what maintenance work to do and may select maintenance activities that have no value in addressing the real failure cause. You will be sending your people out to do maintenance that does not keep the equipment reliable.

# Useful Analysis of Maintenance History



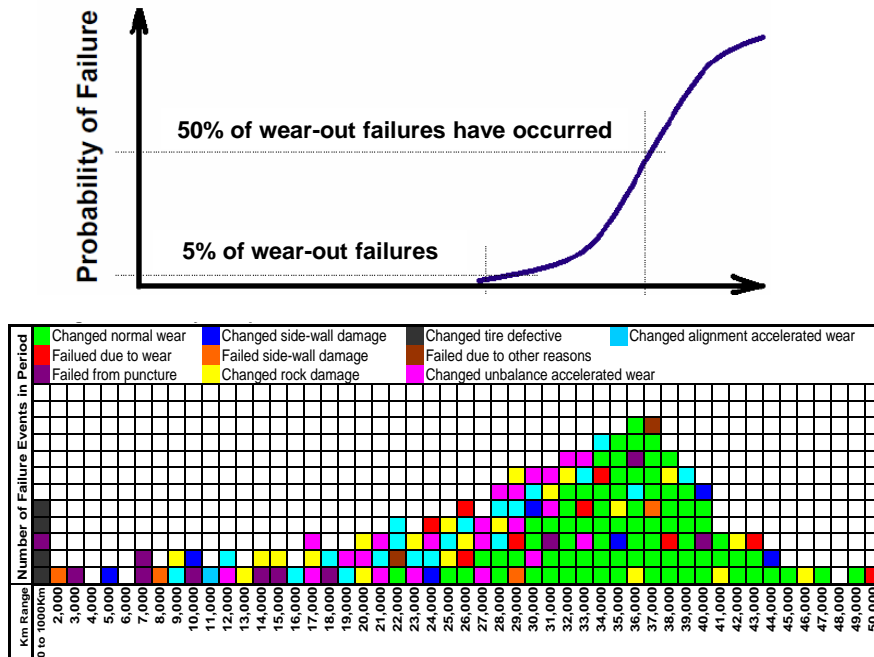
In this slide the distribution curves for more of the failure causes have been plotted against distance travelled. The curve show some interesting things happening and helps us to make good choices.

Notice that alignment wear and unbalance wear start at about 10,000km—it would be a good idea to realign and rebalance every 10,000km.

See how punctures and rock damage can happen at any time. There is no maintenance that we can do to prevent rock damage to tires, but if there were no rocks on the road there would be no damage. It would make a lot of sense for the mine site to remove the rock by grading or bulldozing the road at least every day. Again this decision should be based on a financial analysis of the money saved by clearing away rocks daily verses leaving things as they now are and suffering the damaged tires. It might be less costly to not do the rock removal.

I repeat my previous warning.... Differentiating maintenance by the failure cause is a vital necessity to use this approach, since you will select specific maintenance activities to address each cause. If you do not know the real cause of a problem you will not know exactly what maintenance work to do and may select maintenance activities that have no value in addressing the real failure cause. You will be sending your people out to do maintenance that does not keep the equipment reliable.

# Using the Probability of Failure from a Age or Usage Cause to Schedule PM

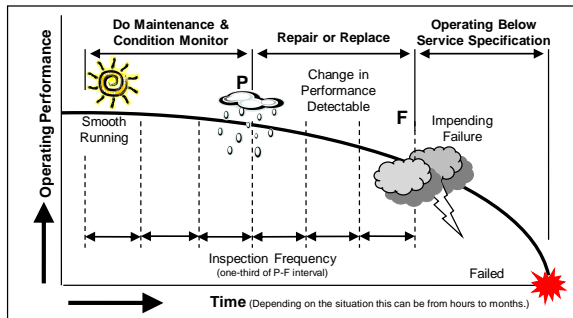


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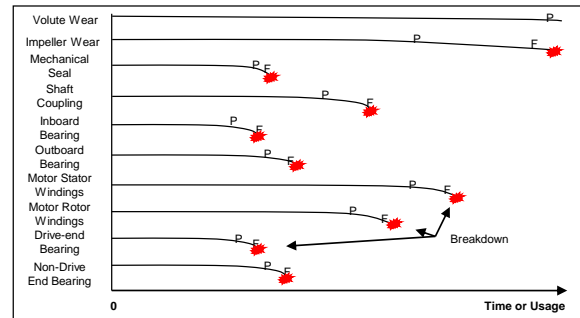
Using the dates of the repairs or replacements a curve of the probable life of a part can be developed. The curve is used to set the dates to do maintenance work. If you want to have few tyres wear out, say no more than 5%, the curve advises you to schedule all tyres to be replaced at 30,000km. If you are willing to let 50% of the tires wear then set the scheduled tire replacement to 37,000km.

Which point you chose should be based on the least cost to the business. You really need to do a financial model of the costs incurred by the whole business at every 1,000km to locate the least cost distance (the optimal point) and set that distance as the scheduled replacement point.

# Uncertain Component Degradation Rates mean Uncertain Equipment Failure Dates and Costs



Degradation Curve Concept



Each Part has a Degradation Curve



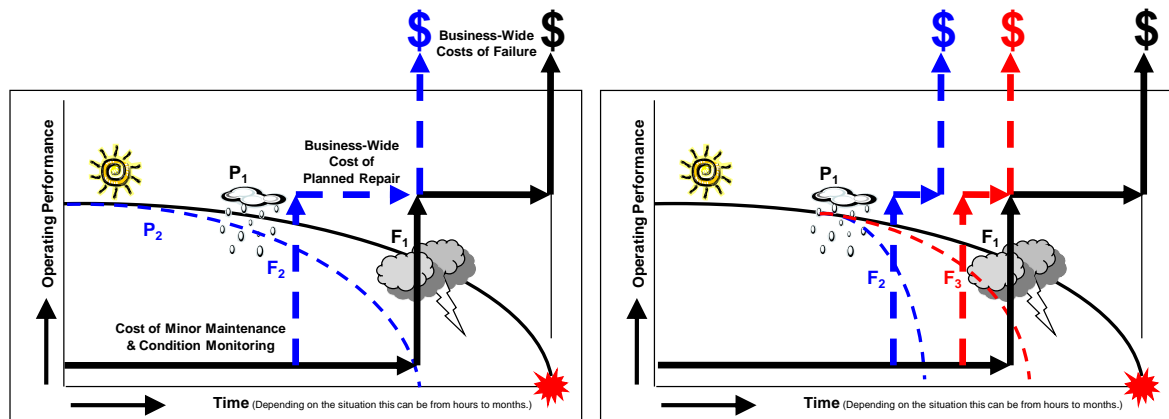
Direct Coupled Centrifugal Pump

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If any of the 10 parts of the pump shown in the slide were to fail the pump would also fail. Since every part in an item of plant degrades there will come a time when each part will fail. That time depends on how much stress and fatigue the components' material of construction has suffered.

Each part fails in response to its life service conditions the whole pump is at risk of stoppage from many causes. The day and time of failure is thus unknown and probabilistic. To gauge more closely the condition of a part we do condition monitoring of it so we can better estimate its end of life. With the actual day and time of failure being uncertain we are in a risk scenario—the final consequential cost of a failure event is unknown and when it will happen depends on the working conditions it suffers, and the conditions may change for the worst at any time.

# Uncertain Operating Life Remaining with Business-Wide Costs and Losses = RISK DECISIONS



Future Costs and Losses Arise when a Failure is Initiated

Fluctuating Degradation Rate Introduces Uncertainty in Timing and Amount of Expenditure

Business-Wide Costs = maintenance cost + production costs + production losses + all other business-wide losses/costs

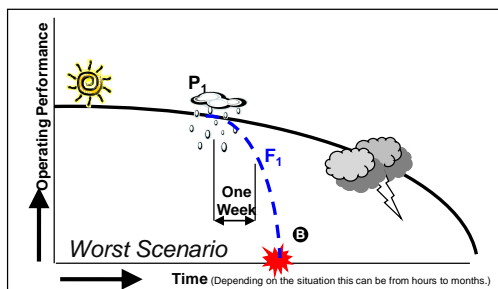
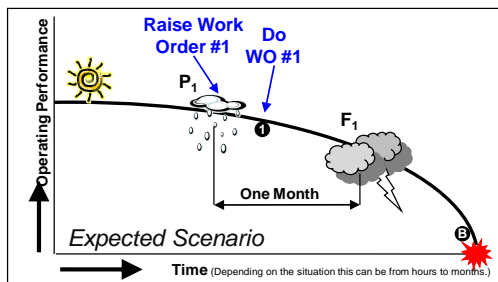
**We have a probabilistic situation!**

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Should a breakdown occur there will be resulting business-wide costs from the failure. If the equipment is a stand-alone duty item the cost of failure will be the maintenance cost + production costs + production losses + all other business-wide losses, which maybe a vast quantity. If there is a standby equipment item that comes into operation then the cost of failure will be the maintenance cost + production costs + production losses, which substantially minimises the impact of the original breakdown.

The uncertainty of cost and the likelihood of the failure makes our decision making a risk situation and we thus need to apply risk analysis and consider the influence of probability when we make choices.

# Selecting Maintenance Timing



| Likelihood of Equipment Failure Event per Year |                         |                   |   | Event Risk 'Envelope' |    |    |    |    |    |    |    |    |     |     |     |     |     |     |     |
|--|-------------------------|-------------------|---|-----------------------|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| Event Cost per Year                            | Time Scale              | Descriptor        | Historic Description  | C1                    | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 |
| 100  | Twice per week          |                   |   | L1                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 50   | Once per fortnight      |                   |   | L2                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 10   | Once per month          | Certain           |   | L3                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 5  | Once per quarter        |                   |   | L4                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 1  | Once per year           | Almost Certain    | Event will occur on an annual basis                           | L5                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.5  | Once every 5 years      | Likely            | Event has occurred several times or more in a lifetime career | L6                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.1  | Once per 10 years       | Possible          | Event might occur once in a lifetime career                   | L7                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.05   | Once per 30 years       | Unlikely          | Event does occur somewhere from time to time                  | L8                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.01   | Once per 100 years      | Rare              | Heard of something like it occurring elsewhere                | L9                    | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.005  | Once every 500 years    |                   |   | L10                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.001  | Once every 1,000 years  | Very Rare         | Never heard of this happening                                 | L11                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.0005   | Once every 5,000 years  |                   |   | L12                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.0001   | Once every 10,000 years | Almost Incredible | Theoretically possible but not expected to occur              | L13                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |

Note: Risk Level: L1 Risk Boundary is set at 'LOW' level. L13 Risk Boundary is set at 'VERY HIGH' level. L1-L13 are based on IEC 60050-1004 Risk Management. L1-L13 are based on IEC 60050-1004 Risk Management. L1-L13 are based on IEC 60050-1004 Risk Management. L1-L13 are based on IEC 60050-1004 Risk Management.

How long are you willing to wait to do WO #1?

Planned Work = \$50K business-wide costs

Breakdown Work = \$300K business-wide costs

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Once a failure event has started we need to decide when to rectify the problem(s) with the equipment for the least production disruption and the least maintenance costs. Because the rectification decision is a business risk decision we can map the situation onto a risk matrix.

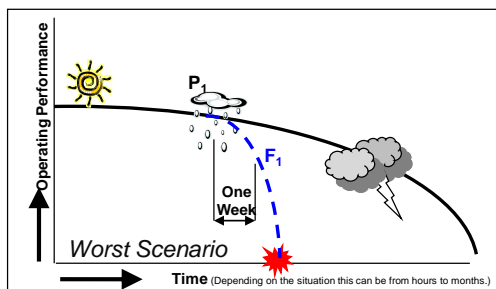
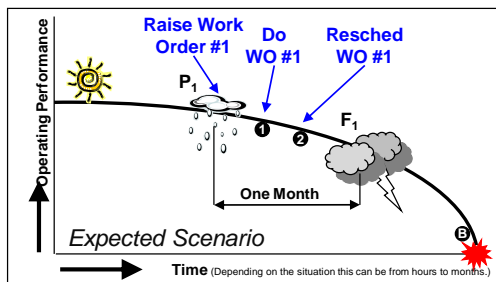
In the scenario shown in the slide a work order was raised when the evidence of failure initiation was first detected. From the combined knowledge and experience available in the operation it was agreed that under the required operating regime the equipment would become unusable in about a month time. There was also recognition that in the worst case the equipment could become inoperable within a week.

Since there is uncertainty when the event will actually occur we generate an 'envelope' of the range of business risk that exists because of the situation. The location of the risk envelope on the matrix warns us of the seriousness of the situation.

Point 'B' is the intersection of the calculated business-wide cost of a breakdown should it happen and the worst scenario time before the equipment is unusable. Point '1' is the intersection of the least rectification cost option and the expected time before the equipment becomes unusable (it is as good an outcome as we could expect in the situation).

Once the size of the risk envelope is identified matching actions can be taken to address the situation. In this case it is clear that the work order is vital and must be done as soon as possible. It is already a bad situation for the operation to be in because even the least cost rectification is a high cost to the business. To wait for more than a week to do the work order will surely increase the chance of a very expensive breakdown.

# Choosing WO Rescheduling Dates



| Likelihood of Equipment Failure Event per Year |                          |                  |  | RAPI Cost per Event |    |    |    |    |    |    |    |    |     |     |     |     |     |     |     |
|--|--------------------------|------------------|--|---------------------|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| Event Count per Year                           | Time Scale               | Descriptor Scale | Historic Description                         | C1                  | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 |
| 100  | Twice per week           | Certain          | Event will occur on an annual basis          | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 10   | Once per month           | Certain          | Event will occur several times per year      | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 1  | Once per year            | Certain          | Event will occur once in a lifetime career   | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.1  | Once every 10 years      | Possible         | Event might occur once in a lifetime career  | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.01   | Once per 100 years       | Uncertain        | Event does occur somewhere from time to time | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.001  | Once every 1,000 years   | Very Rare        | Event does occur somewhere from time to time | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.0001   | Once every 10,000 years  | Incredible       | Event does occur somewhere from time to time | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |
| 0.00001  | Once every 100,000 years | Incredible       | Event does occur somewhere from time to time | L                   | M  | M  | M  | M  | M  | M  | M  | M  | M   | M   | M   | M   | M   | M   | M   |

How often are you willing to reschedule WO #1?

Planned Work = \$50K business-wide costs

Breakdown Work = \$300K business-wide costs

Cost of Scheduling Misjudgement = \$250K loss

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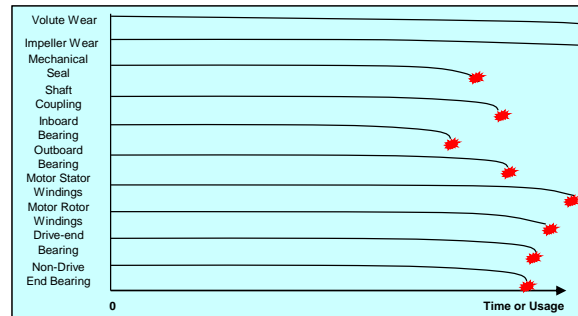
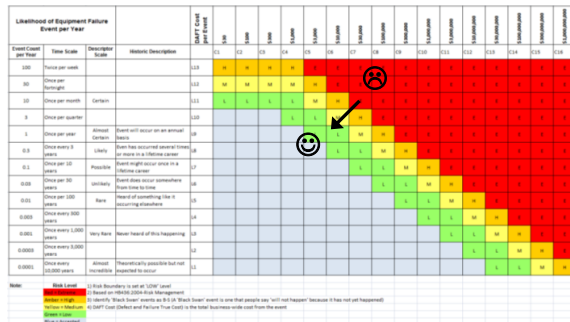
When work orders are rescheduled it is important to appreciate that the risk of failure increases. In the scenario shown on the screen the work order first raised when the failure initiation was detected was not completed when planned and now needs to be rescheduled. While the rectification work remains undone the chance of failure keeps rising since the equipment is still in service receiving stresses on its failure prone part(s). The business risk continually moves towards the worst catastrophe. The longer the rectification is delayed the more certain it becomes that there will be the unwanted breakdown we are trying to prevent.

Points 'B' and '1' are identified as noted in the previous slide. At Point '2' two weeks have passed and two weeks remain to the expected failure. The work order is still a 'planned' job but the chance of failure has risen. Point '2' is the intersection of the rising likelihood of failure and the cost of planned rectification. If we misjudge and the equipment breaks down the event goes from a \$50K job to a \$300K job; the scheduling decision cost the business \$250K.



# Risk Based WO Scheduling Tips

- Know the worst case business-wide financial loss of a failure event.
- Make the risk visual by identifying the risk 'envelop' on a risk matrix.
- Let people that know the chance-of-failure 'envelope' make the WO scheduling decisions.
- Measure and track the rate of degradation when an impending failure is identified.
- Use stress reduction and degradation management controls to reduce the odds of a breakdown.



**Good** – use suitable CM to detect 'P' potential failure point sufficiently early.

**Better** – use risk based prioritisation to schedule work orders with increasing risk acknowledged and approved up the command hierarchy.

**Best** – use proactive degradation management to extends operating life and delay 'P'.

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Once a failure has started we must address it. This slide lists the considerations you need to go through in making the best choices to prevent an initiated failure event from becoming a breakdown . You analysis is greatly helped by the use of a risk matrix.

But the better operating strategy is to use methods and practices to remove the chance of parts failing and prevent situations arising that then jeopardises the operating life of the equipment.

## Case Study 2 – Use a Risk Cost Calculator to Understand Scheduling Risk

|                         | On Breakdown     | ASAP            | Next Week       | Next Shutdown    |   |
|-------------------------|------------------|-----------------|-----------------|------------------|---|
| Urgent job premium cost | \$10,000         | \$2,000         |                 |                  | Additional cost associated with organising an urgent task - staff have to drop what they are doing and go back to it later this is a real cost                            |
| Scheduled job cost      | \$7,000          | \$6,000         | \$5,000         | \$5,000          | Cost of parts in work kit, repair labour - actual on tools time probably take longer as urgent job as greater chance that job kit incomplete or some improvisation needed |
| Plant outage cost       | \$300,000        | \$50,000        | \$45,000        | \$500            | With B/D no chance for orderly S/D, with ASAP slightly more disruptive than fully scheduled. - Next shutdown only include incremental cost of also including this job     |
| <b>Total Cost</b>       | <b>\$317,000</b> | \$58,000        | \$50,000        | \$5,500          |   |
| Chance of B/D           |                  | 2%              | 5%              | 50%              |   |
| B/D \$Risk              |                  | \$6,340         | \$15,850        | \$158,500        | N.B. If left to next shutdown we do NOT expect to pay exactly \$161,250   |
| <b>Total Risk Cost</b>  |                  | <b>\$63,180</b> | <b>\$63,350</b> | <b>\$161,250</b> | We will either be lucky and pay \$5,500 (50% chance)<br>Or be unlucky and pay \$317,000 (50% chance)<br>\$161,250 is only an "expectation" in the mathematical sense      |

The slide shows a risk cost calculator used to highlight the consequences of delaying a maintenance intervention. It helps people to realise the business risk in a situation and to prioritise their risk management/mitigation activities. It can be developed to include whatever business costs one cares to separately identify when estimating the business-wide costs of a failure.

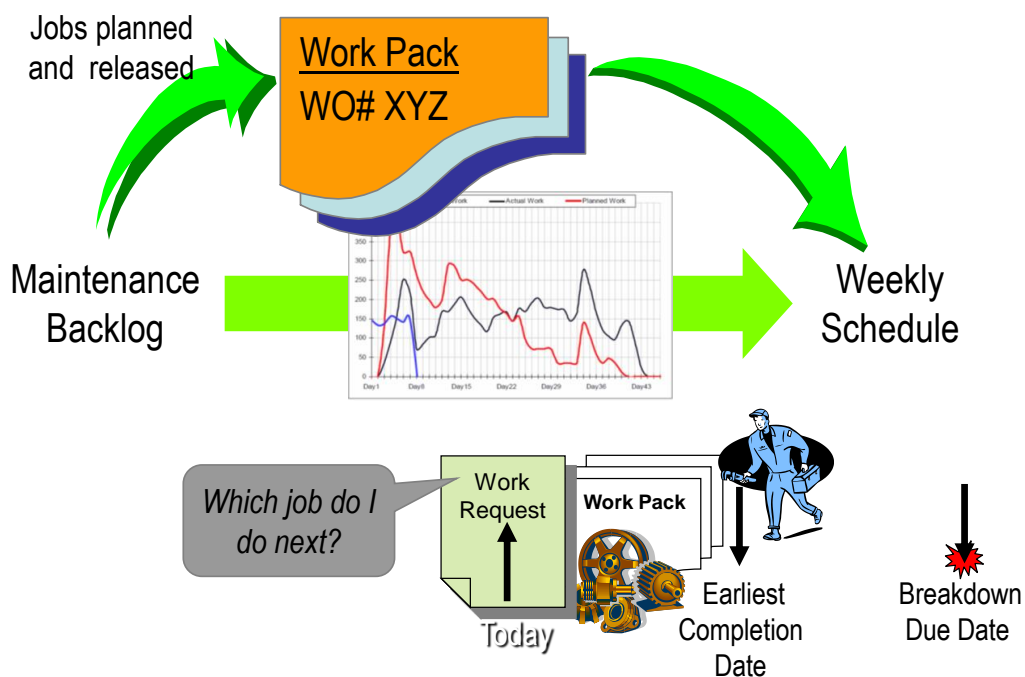
# Risk Review Approach to Rescheduling Work

| PM NOT COMPLETED SIGNOFF   |                                      |  |                                     |  |
|--|--------------------------------------|--|-------------------------------------|--|
| I have made the decision that the planned maintenance is not to occur as scheduled. In doing so, I accept the risks detailed by the technician/reliability engineer below. |                                      |  |                                     |  |
| I acknowledge and accept accountability for making my equipment susceptible to premature failures, which may have safety, environment, or production impacts.              |                                      |  |                                     |  |
| <b>Risk Description</b>  |                                      |  |                                     |  |
| <b>Maximum Residual Risk Ranking Assessment – Delaying or Cancelling Work</b>  |                                      |  |                                     |  |
| Residual Risk 3 or less  | Maintenance Co-ordinator Signature   |  | Production Co-ordinator Signature   |  |
| Residual Risk is greater than 3 but less than 30   | Maintenance Superintendent Signature |  | Production Superintendent Signature |  |
| Residual Risk is 30 and greater  | Maintenance Manager Signature        |  | Production Manager Signature        |  |

ESCALATE AUTHORITY

Use of a risk matrix when making scheduling and rescheduling decisions is currently practiced at the Kalgoorlie Nickel Smelter owned by BHP Billiton. The slide shows an extract of the sign-off section on a work order where the situational risk is used to determine when a job is to be done. The higher the risk the further up the organisational hierarchy is the scheduling decision made. This approach makes the range of inherent risk in an event visible to everyone and provides people with the opportunity to deeply understand the implications when making risk based choices.

## The Job Sequencing Challenge



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It is always a dilemma as to when to schedule maintenance work orders. When maintenance work first arises it comes with a due-by-date set by the CMMS for PM work and by the Requestor when it is corrective work. In both cases the due-by-date is an arbitrary selection that is intended to prevent an eventual plant item failure. The work now needs to be planned, prepared, organised, scheduled and performed. That sequence of activities is the time it takes to process the work request and it must be done before the plant fails and stops production.

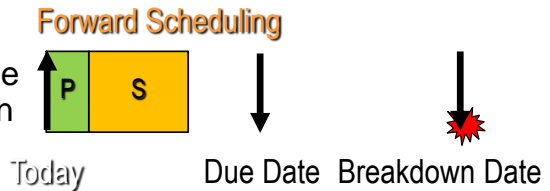
# Scheduling Choices for Maintenance Work

## WHY SCHEDULE MAINTENANCE... MINIMISE WASTE

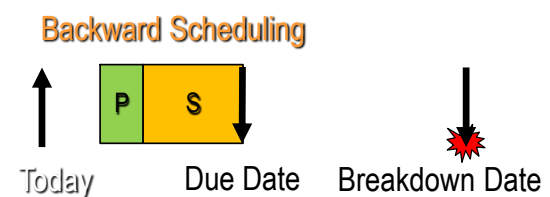
- Minimize **completion time**
- Maximize **utilization** (make effective use of people and equipment)
- Minimize **stores inventory** (keep parts levels low)
- Minimize **production wait time** thereby maximising production
- Delivers greater **return from capital investment**

**Forward scheduling:** begins the schedule as soon as the job requirements are known

- jobs performed soon after request arrives
- scheduled compliance is high even if due date is missed
- often causes backlog of work
- does not consider job priority



**Backward scheduling:** begins with due date of completion; schedules jobs in reverse order



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Scheduling brings benefits to an operation by its ability to minimise waste of time and resources. Because maintenance work is done to rectify an existing problem or prevent a problem arising that if not addressed will lead to an equipment failure, the due date for completion is a key driver in scheduling maintenance work orders. The nearer the due date gets to the breakdown date the greater the priority for the work to be done.

## Sequencing Rules for Scheduling

- Specifies the order that jobs will be done
- Sequencing rules

### First come, first served (FCFS)

- The first job to arrive at the Planner is processed first
- Average performance on most scheduling criteria
- Appears 'fair' and reasonable to customers

### Earliest due date (EDD)

- The job with the earliest due date is processed first
- Widely used by many companies
  - If due dates important
  - If MRP used (due dates updated by each MRP run)
- Performs poorly on many scheduling criteria

### Shortest processing time (SPT)

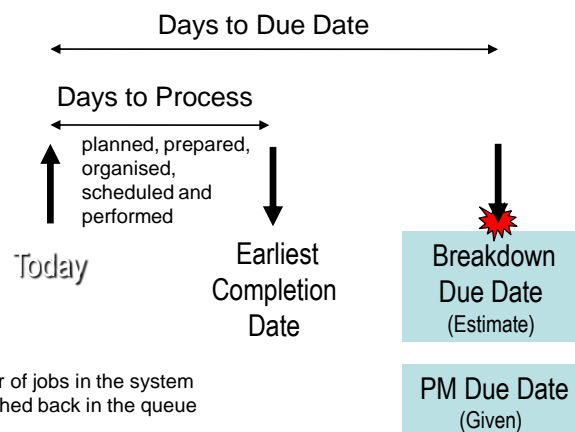
- The job with the shortest processing time is done first
- Usually best at minimizing job flow and minimizing the number of jobs in the system
- Major disadvantage is that long jobs may be continuously pushed back in the queue

### Longest processing time (LPT)

- The job with the longest processing time is done first
- Usually the least effective method of sequencing

### Critical ratio (CR)

- The ratio of time remaining to due date to required processing time remaining is calculated, and jobs are scheduled in order of increasing ratio
- determine the status of a specific job
- establish a relative priority among jobs on a common basis
- relate both PM and Corrective jobs on a common basis
- adjust priorities and revise schedules automatically for changes in priority and WO progress
- dynamically track job progress through backlog



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Work can be sequenced using rules long established for production scheduling jobs through a production shop. Maintenance work is not that different to manufacturing an item since we still have to match manning resources to a job that has a due-by-date for completion. The scheduling methods of production planning give us an insight into how we can schedule maintenance jobs as well.

The most common way in maintenance to decide when to plan a job before it can be scheduled is a mix of LPT, longest processing time (i.e. time taken to plan the work) and EDD, earliest-due-date (i.e. when the work must be done so that the equipment does not fail) . But the experience in production scheduling is that both sequencing methods are not an effective ways to handle a lot of jobs with a wide range of days-to-process. EDD causes everything to always be a rush because the due date seems to always be today—i.e. the urgent work gets done now. LPT makes us do planning for simple jobs and not leave time to plan difficult jobs well; and those are the jobs that need thorough planning and take more time.

It seems that the common scheduling rules used in Maintenance do not assist Planners to decide when they need to start the planning so that all work order is prepared and ready for scheduling before the equipment approaches certain failure. What Planners can do is to use the Critical Ratio to identify which jobs need to be planned first.

## Critical Ratio For Work Orders of **Same Priority**

### ◆ Ratio of time remaining to work time remaining

◆ *Process jobs with smallest CR first*

$$CR = \frac{\text{Time remaining to due date}}{\text{Days work remaining}} = \frac{\text{Due date - Today's date}}{\text{Work (lead) time to completion}}$$
  

|   |  |
|---|--|
| $CR = \frac{45}{20} = 2.25$<br>$CR = \frac{30}{20} = 1.5$ | <p>Timeline diagram showing two jobs. Job 1: Today (up arrow 20 days) to Earliest Completion Date (down arrow 25 days) to Breakdown Due Date (Estimate) marked with a red star. Job 2: Today (up arrow 20 days) to Earliest Completion Date (down arrow 10 days) to Breakdown Due Date (Estimate) marked with a red star. Both jobs have a PM Due Date (Given) further to the right.</p> |
|---|--|

**Calculate the critical ratio and use it to draft the Rolling 4-Weekly Schedule and to order the work orders undertaken by maintenance planning**

The Critical Ratio method of scheduling is useful in maintenance scheduling because we can make the due-date the earliest date we might expect a breakdown if the job is not done. The days to process from a work request to the completed job can be estimated with reasonable confidence. Once we have those two dates we are able to calculate the critical ratio and use it to draft a schedule for the work orders (the 4-weekly schedule) and to prioritise the work orders undertaken by maintenance planning.

Using the Critical Ratio applies to work orders of the same priority. If a work order is a low priority from its risk based priority setting it is naturally less important than work of greater risk to the business. Once there are many work order of high risk priority the Critical Ratio lets you order those equal priority work orders into a sequence of planning them.

# Limitations of Rule-Based Scheduling Systems

- Scheduling is dynamic; therefore, rules need to be revised to adjust to changes in process, equipment, product mix, etc.
- Rules do not look upstream or downstream; idle resources and bottleneck resources in other departments may not be recognized
- Rules do not look beyond due dates

Use rules as a means to draft a schedule, BUT the final decision on which work orders go into the Fixed Week Schedule is left to the Maintenance Scheduling Meeting.



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This is another case of using models which are insufficiently robust to handle all factors. These scheduling limitations need to be considered and where scheduling rules are used they are only for drafting a schedule, the final decision is left to the Scheduling Meeting since it will consider the dynamic nature of what is happening in the operation.



## On time Every Time Ensuring Success

### Ensuring the Right Parts at the Right time in the Right Condition and for the Right Price!

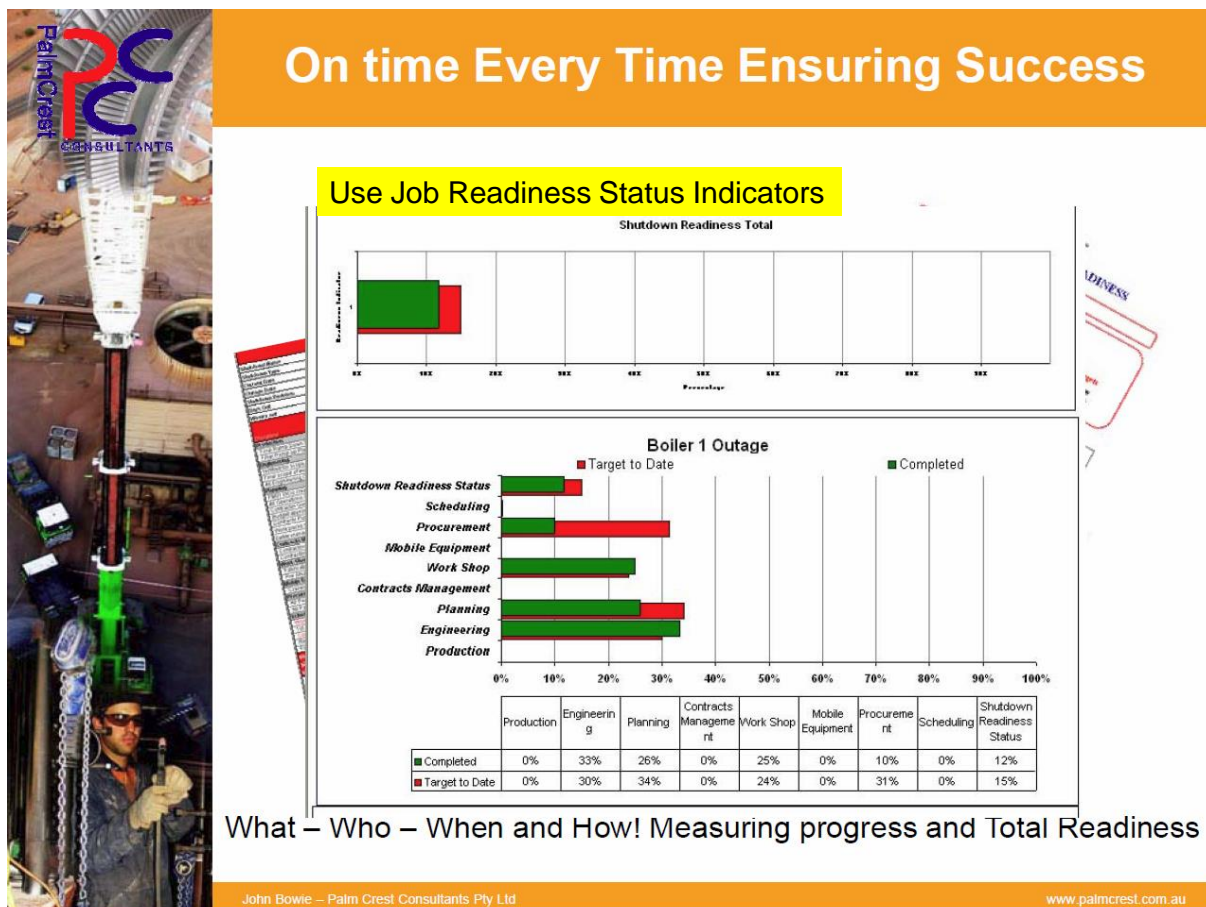
- Identify long lead items
- Order early
- Compare quotes and quality
- Build on previous successes
- Always challenge the status quo
- Arrange site visits to other assets
- Engage a readiness measurement system

John Bowie – Palm Crest Consultants Pty Ltd

[www.palmcrest.com.au](http://www.palmcrest.com.au)



John Bowie advised that the parts needed for a job need to be available on-site before the job can be added to the fixed-week work schedule. The Scheduler will need to be certain that the right parts, in the right quantities, are available and are allocated to the work order. It may require the Scheduler to follow-up Suppliers and expedite deliveries.



Your scheduling process needs to identify the progress of preparation, procurement and coordination activities so that you know the status of a job and how close it is to being able to be done. Charts like the Job Readiness indicators shown in the slide are used to quickly indicate the status and progress of activities needed to get work done.



## On time Every Time Ensuring Success

| WO # | WOT #  | Duration | Parts Required | Blank | Readiness Indicator                      | Work Group | Parts Ordered | Parts Received | Scoped | Challenged | Crane | Scaffold | Mon 1 Sep | Tue 2 Sep |
|------|--------|----------|----------------|-------|--|------------|---------------|----------------|--------|------------|-------|----------|-----------|-----------|
| 58   | 370185 | 20       | 2 hrs          | ✓     | Readiness Indicator: 100                 | 1          |               |                |        |            |       |          | 30        | 30        |
| 53   | 399521 | 1        | 1.5 hrs        | ✓     | Seat plug & confirm                      | 100        | EMS           |                |        |            |       |          | 30        | 30        |
| 20   | 493801 | 10       | 1 hr           | ✓     | Repair & calibrate flowmeter             | 100        | EMS           |                |        |            |       |          | 30        | 30        |
| 2    | 494306 | 1        | 0 hrs          | ✓     | Measure internals and inspect as req'd   | 100        | POS           |                |        |            |       |          | 30        | 30        |
| 3    | 494308 | 1        | 30 hrs         | ✓     | CYCLONES: Structural Inspection          | 100        | PM1           |                |        |            |       |          | 30        | 30        |
| 24   | 494654 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 100        | PM1           |                |        |            |       |          | 30        | 30        |
| 27   | 494657 | 1        | 6 hrs          | ✓     | SAG MILL: 2 Month Inlet Chute Inspection | 100        | PM5           |                |        |            |       |          | 30        | 30        |
| 28   | 494658 | 0.5 hrs  | ✓              | ✓     | BALL MILL: 6 Monthly Gear Inspections    | 100        | PM1           |                |        |            |       |          | 30        | 30        |
| 55   | 495226 | 1        | 12 hrs         | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 100        | PM1           |                |        |            |       |          | 30        | 30        |
| 1    | 493800 | 1        | 2 hrs          | ✓     | FAULT CONTROL UNIT BATTERY INSPECTION    | 100        | EM1           |                |        |            |       |          | 30        | 30        |
| 5    | 494308 | 10       | 1 hr           | ✓     | Readiness Indicator: 75                  | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 7    | 494345 | 5        | 1 hr           | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 8    | 494345 | 5        | 1 hr           | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 12   | 494374 | 1        | 30 hrs         | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 37   | 494395 | 1        | 3 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 39   | 494397 | 1        | 3 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 40   | 494397 | 2        | 1 hr           | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 26   | 494554 | 1        | 0.5 hrs        | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 23   | 494554 | 0.5 hrs  | ✓              | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 54   | 399522 | 1        | 1.5 hrs        | ✓     | BALL MILL: Condition Monitoring          | 75         | PM12          |                |        |            |       |          | 30        | 30        |
| 15   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 16   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 17   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 18   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 19   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 20   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 21   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 22   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 23   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 24   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 25   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 26   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 27   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 28   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 29   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 30   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 31   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 32   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 33   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 34   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 35   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 36   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 37   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 38   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 39   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 40   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 41   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 42   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 43   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 44   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 45   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 46   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 47   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 48   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 49   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 50   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 51   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 52   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 53   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 54   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 55   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 56   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 57   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 58   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 59   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 60   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 61   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 62   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 63   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 64   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 65   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 66   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 67   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 68   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 69   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 70   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 71   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 72   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 73   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 74   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 75   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 76   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 77   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 78   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 79   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 80   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 81   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 82   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 83   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 84   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 85   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 86   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 87   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 88   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 89   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 90   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 91   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 92   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 93   | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 94   | 493800 | 1        | 2 hrs          | ✓     | VARIABLE SPEED DRIVE ELECT. INSPECTION   | 75         | EM1           |                |        |            |       |          | 30        | 30        |
| 95   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 2 Monthly Inspections          | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 96   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 97   | 493800 | 1        | 2 hrs          | ✓     | Assist to transport cyclone workshop/POO | 75         | PM5           |                |        |            |       |          | 30        | 30        |
| 98   | 493800 | 1        | 2 hrs          | ✓     | Measure internals and inspect as req'd   | 75         | POS           |                |        |            |       |          | 30        | 30        |
| 99   | 493800 | 1        | 2 hrs          | ✓     | CYCLONES: 3 Monthly Inspections/Overhaul | 75         | PM1           |                |        |            |       |          | 30        | 30        |
| 100  | 493800 | 1        | 2 hrs          | ✓     | ELECTRICAL MOTOR INSPECTION              | 75         | EM1           |                |        |            |       |          | 30        | 30        |

A Schedule Readiness Measurement System

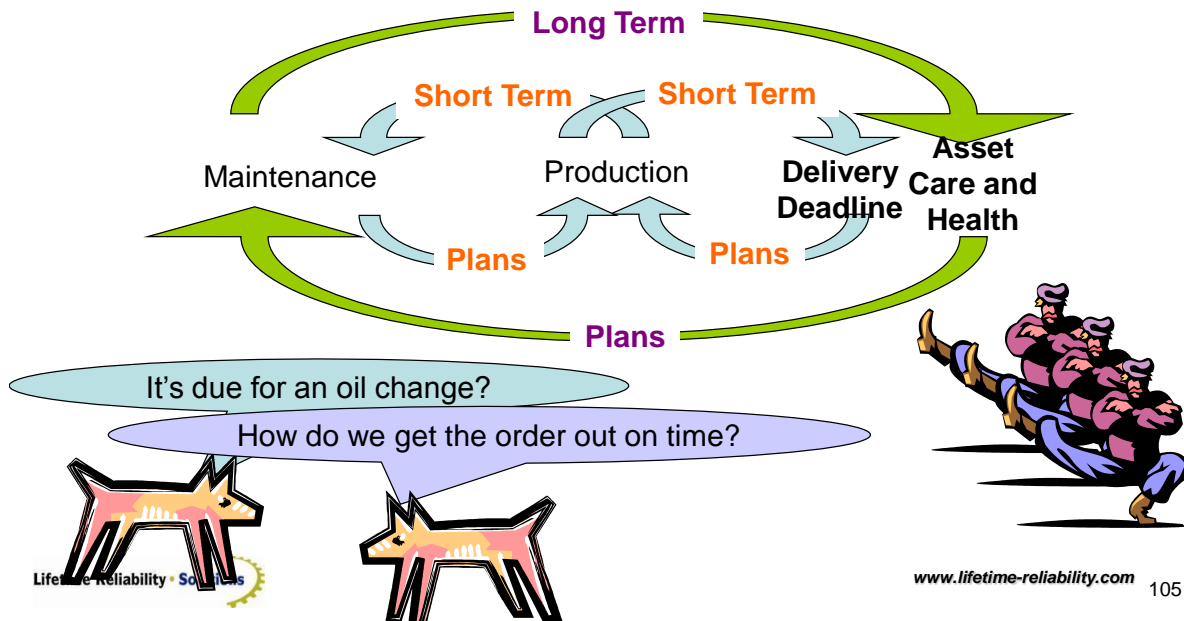
John Bowie – Palm Crest Consultants Pty Ltd

www.palmcrest.com.au

This is an example of a schedule readiness measurement system. Note how the steps in the purchasing and delivery process are each tracked to ensure they are being actioned towards meeting delivery by the require date.

## Production: Short View; Maintenance: Long View *There in lies the problem!*

Make short and long term plans together so production can meet the schedule with equipment kept in good health and top running condition.

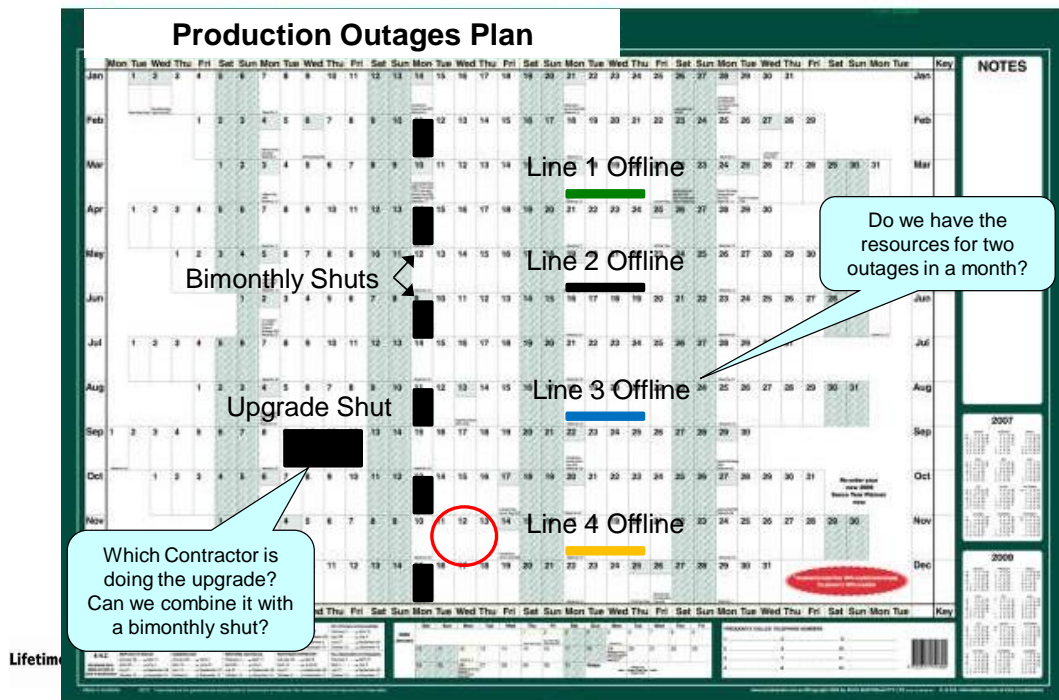






# Production Maintenance Shuts

Prepared the year prior by Production and Maintenance.  
A copy goes to Sales Group and Senior Managers.



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To coordinate Production and Maintenance it is necessary that each group sees what the other requires. In fact it is necessary to see what is going to happen many months ahead of its occurrence so there is time to optimise activities and reduce outage time. Advising people of production impacts is most easily done using a rolling annual planner such as the one shown in the slide. The annual planner warns of major outages in the coming months and permits discussion to find ways to reduce the effect on production.

# Production and Maintenance Monthly Plan

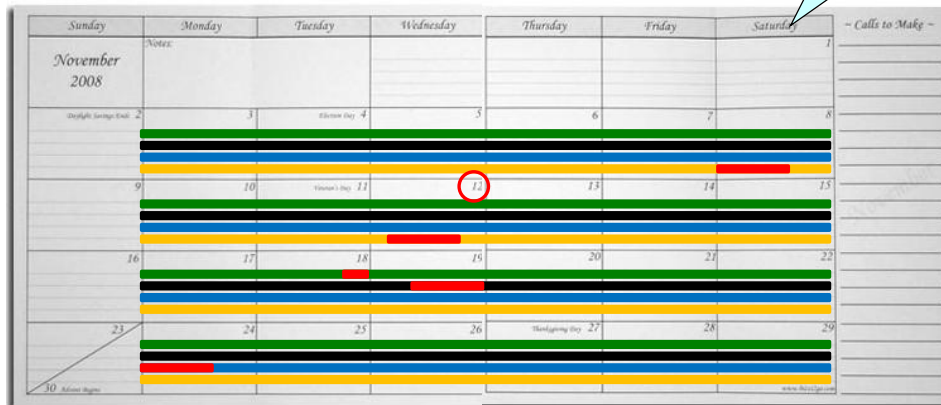
Prepared the month prior by Production and Maintenance.

A copy goes to Sales Group and Senior Managers

## Production Monthly Plan

Line 1   
 Line 2   
 Line 3   
 Line 4   
 Maintenance Offline  
 Maintenance Online

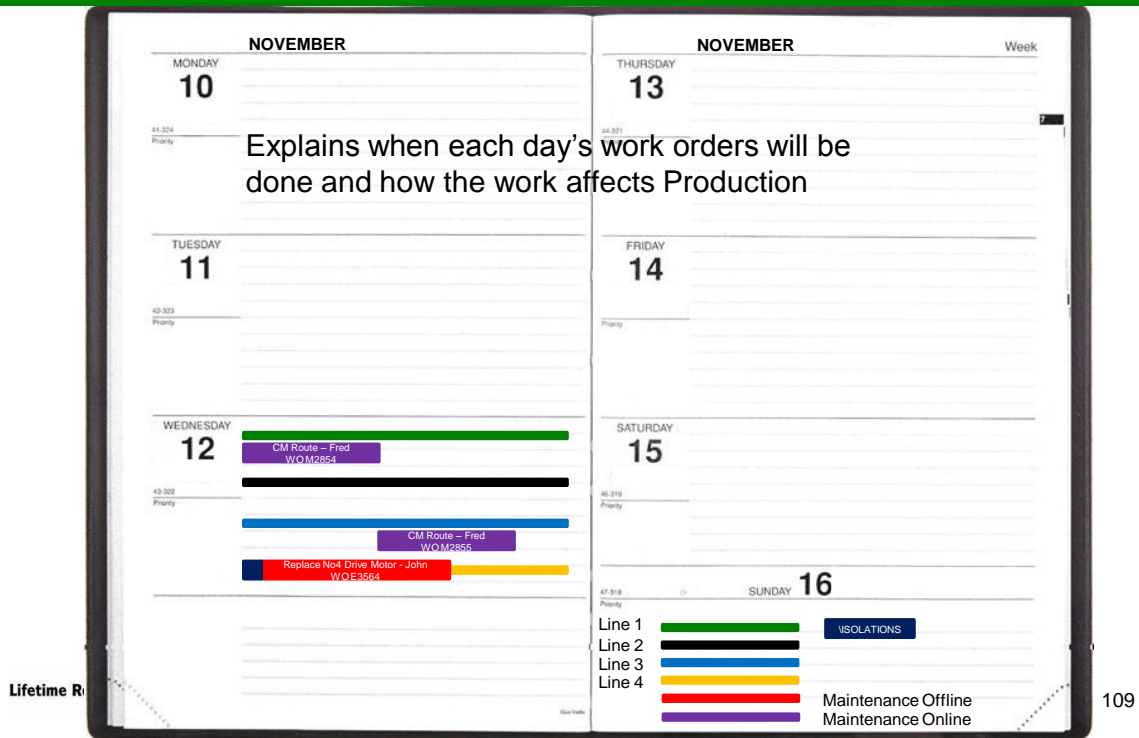
Check who wants to work Saturday. Do I need specialist skills?



Each month a detailed schedule of forecast maintenance work per production plant can be provided and shown in the Production plan. The slide aims to use visual management methods to quickly make clear to viewers what is happening in the month ahead for each plant. This plan is also a rolling forecast that is adjusted and fine tuned to its final version as discussion and information make clear what are the choices to make.

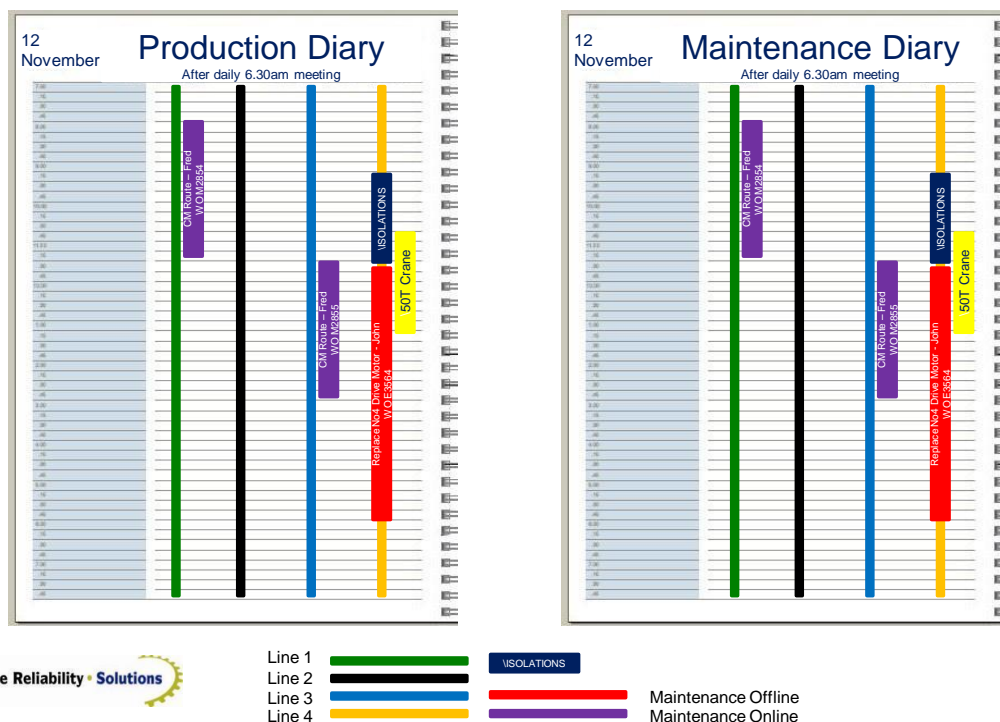
# Production and Maintenance Fixed Week

Complied after weekly scheduling meeting



Partially completed is the weekly fixed plan that explains when each day's work orders will be done and how the work affects Production

## Same Production & Maintenance Daily Plan



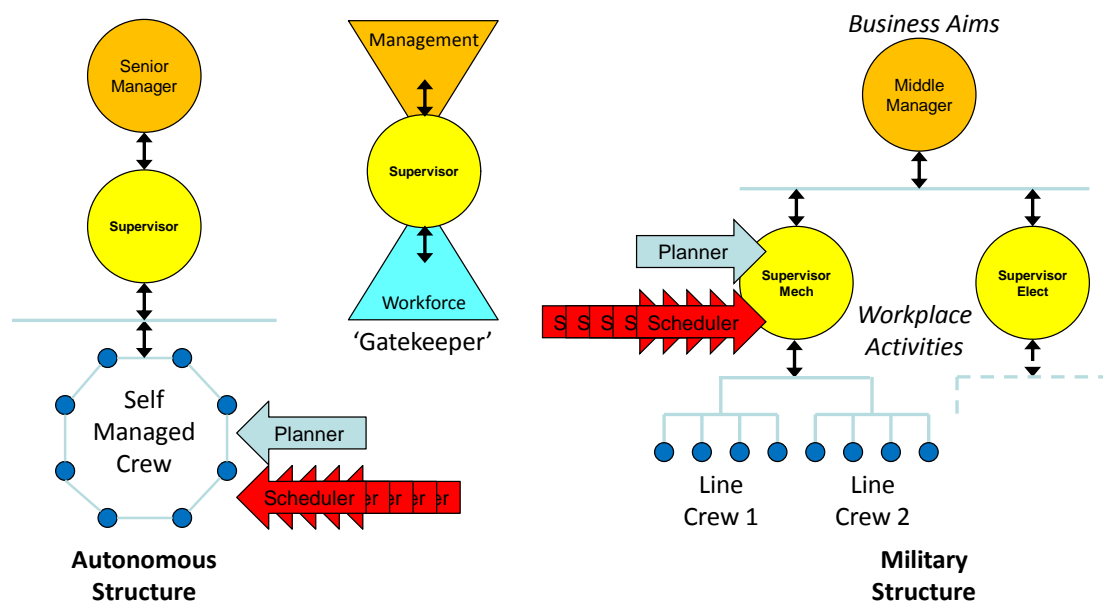
Each day both Production and Maintenance work off the same Plan. There is only one plan that each group is working to achieve.



flow is disrupted. They each carry the responsibility to do what they do to a high standard and to support the proper functioning of the planning and scheduling process. When doing their work they are permitted to unearth changes and suggest improvements to the planning and scheduling process.

When a job is fully scoped and reviewed for completeness it becomes clear what resources – men, tools, equipment, parts, time, quality, money – is needed. Since they are finite these resources must be controlled and managed. That role belongs to the Maintenance Supervisor. It is the Supervisor who will allocate persons from their Crew to a job. The Scheduler and Supervisor need to work closely together to ensure that work is resourced with suitable skilled and knowledgeable people who can do the tasks correctly, safely and to time. The Supervisor must take the work plan and preparation done by others and turn it into a finished job. The Scheduler needs to get involvement and support from the Supervisor and ensure the Supervisor is not alienated by not being told important information or not being asked for important details about a job.

## Planner/Scheduler/Supervisor Interaction



Before we can discuss the duties of a maintenance supervisor we first need to understand the role in the business. The maintenance supervisory role is the link between the business' management and the business' workforce. Because the role is a link between an organisation's management and its workforce it is critical to the successful operation of the whole structure. If the role is not done well and the link 'fails' both the workforce and its management will suffer.

As a mechanical business structure the organisation has the duty to achieve the business owner's plans, (That obligation is there because the organisation is paid by the business Owner to do the work wanted by the Owner and the employment contract obligates people in the organisation to provide the necessary service that they are paid to give.) while also ensuring the organisation delivers products or services that satisfy its customers. The 'mechanical' function of a supervisory job is to make sure the workforce does what a business' senior management wants (because the management is under instructions from the Owner to achieve the required outcomes.). But people are not machines so we must also add humanity into the role.

To summarise the business function of a supervisor, they are responsible to ensure the workforce acts correctly to achieve the business aims. From that requirement we can draw the necessary duties of the role and the necessary capabilities needed to do the role well.

### **Duties of a Maintenance Supervisor**

These duties are in no particular order. Each becomes important at various times in the range of situations a supervisor is required to handle.

**Clarity:** A supervisor needs to clearly know the business aims he is responsible to deliver and what their manager will support them doing in order to ethically achieve those aims. For a maintenance group the business aims are usually to keep plant and equipment operating in a state that delivers the planned production capacity and required product quality for the least maintenance cost.

**Organise:** This duty is to ensure that each day maintenance work runs to schedule and to a plan.

**Prioritise:** When necessary decisions must be made on allocation of resources in situations of constraint. The supervisor is responsible for labour allocation that brings the greatest benefit to the organisation. Which choice brings the greatest benefits is usually agreed with the immediate manager during information gathering discussions before publicising the final decision.

**Lead:** This responsibility of leadership means to always be at the forefront by example. It means not sending people into situations that you would not first go into yourself. It includes being prepared to assert yourself when you see danger and risk, not on a negative way that destroys progress, but in a way that provides better, safer alternatives to achieve the aim.

**Set Standards:** The supervisor is the keeper of work quality standards. The craftsmanship standards a supervisor supports will be the skill standards their people will meet. A supervisor must be in no doubt of what excellence looks like as equally as they must be in doubt what inadequacy looks like. A maintenance supervisor with low work quality standards will allow the 'gremlins' that cause equipment failure to flourish in their company. Gremlins are imaginary demons living inside machines whose job is to destroy equipment. It explains why we have breakdowns. Of course the gremlins are us.

**Coordinate:** The duty entailed with coordination is to ensure everyone doing a maintenance job, and affected by any maintenance work, knows exactly what is going on before it happens and after it happens. Every department that uses the maintenance group's services need to be aware well ahead of time what the maintenance work is and how it will affect them. Ideally ever operations supervisor and operator know by the end of their last shift what maintenance work is planned on their next shift. By early each shift each operation person affected knows the maintenance impacts for that shift.

**Supervise:** This means knowing exactly what is going on in good detail with every job at all times. You need to go and see for yourself and not be told stories by someone else. At least half your day will be involved in understanding how well each work face is progressing and how well a job is being done. It will need a mix of formal meetings and personal visits to each workplace.

**Monitor:** This means keeping an indicator of work progress against the plan. At least every hour the progress on each work front is updated to its current status. Well before the main shift break you need to know if the day is highly likely to end successfully or not.

**Report:** Daily, weekly, monthly and yearly you keep management fully informed of the workforce performance and the issues the workforce is confronting. The daily management feedback includes formal and informal meetings with operations and maintenance management, the weekly feedback will include current progress and plans for coming week and month, the monthly comments will include performance KPIs and progress against the annual improvement plan, the annual feedback is a report on



the successes and problems resolved in the past year and your plans over the coming two years to achieve the business aims.

**Liaison:** A supervisor responsible to get maintenance work completed on-time, on budget and safely will work closely with persons planning the work and procuring materials. They will also work closely with persons arranging and readying the work. They will work closely with the supervisors and managers in the Operations Group, and when necessary with the Technical Support function.

From the planning function a supervisor wants to see how the workload in the coming weeks is developing and what the work being prepared and gathered together requires of the maintenance group. From the scheduling function the supervisor needs to know each day when a job can be safely started. The planning makes the future successful, while the scheduling makes today successful. The supervisor meets with the Planner near the end of the work week to learn what the next week and month holds in store. They meet with the Scheduler near the end of each shift to plan tomorrow in detail and at the start of each shift to confirm the work that will be done that day.

**Mentor:** A supervisor needs to work through people to get those tasks done that achieve the business aims. The role carries the responsibility to guide the maintainers to do the right work rightly. A supervisor will regularly talk to each of their people offering assistance to improve performance if needed, provide honest and useful feedback when quality and performance standards drop, and actively build cohesion amongst the group so it works like a team.

**Loyalty:** The supervisor is first loyal to the organisation and its management ahead of the workforce. The duty they fulfil is to do what the organisation requires and obligates the supervisory role to put the well-being of the business first. The supervisor always carries the imperative to behave ethically and humanely and ensure no harm is knowingly done to the business or any of its people.

**Manage Risk:** This responsibility is far more than ensuring that all maintenance work is done safely. The requirement covers all risks, including commercial risks, legal risks, regulatory risks, environmental risks and occupational health and safety risks.

**Training and Education:** The supervisor and all their people must be continually educated in new and better ways that need to be adopted to make maintenance more efficient and effective in reaching the business aims. Learning to be better at our jobs is everyone's responsibility and the maintenance supervisor makes sure moneys are budgeted for a week or two of training and retraining each year for all in the crew.

**Business Acumen:** A maintenance supervisor is a vital part of operational success. Their decisions and judgment calls will heavily impact the operation of plant and equipment, which in turn improves or degrades the business performance. A supervisor must have business sense and not put an operation into jeopardy with its customers.

**Financial Responsibility:** Understanding financial reports is a requirement of a supervisory role. A supervisor needs to understand where the money goes in the business of maintenance. They will need to develop financial reports and budgets for monthly and annual reports.

**Technically Able:** The supervisor in charge of a maintenance crew must know and understand the technical, engineering and quality requirements of their operating processes and the plant and equipment used in the process. They must be suitably technical able that crew members have confidence in the supervisor's judgement on day-to-day technical matters the crew is required to perform.

**Continual Improvement:** A supervisor champions business process improvement and is always looking for simpler, smarter and more effective ways to do the work undertaken by the maintenance crew. Where

they see opportunity they investigate it and build a business case to explain to management how and why to proactively adopt useful changes.

**Ethical Behaviour:** Once a person does a supervisory role they fulfil a management function and take on the obligations of management. All their decisions must be to the benefit of the business. Impeccable ethical behaviour and judgement is what must be shown in all situations. Supervisors can be easily compromised if they are not wary of circumstances that can put them in ethical turmoil. It is best if a supervisor does not manage family members, friends and family of friends. Find them work under an uncompromised supervisor.

## Planner/Scheduler and Scheduler/Supervisor Communications

- **Team-up:** Common goal to maintain equipment at capacity, costs below budget and to improve equipment reliability
- **Meet and Review:** Get together daily review to explain and understand the next day's work, to organise the schedule for next day and to discuss future work
- **Feedback both Ways:** Use reports to advise of future jobs and spares into store; Advise how documents and work pack contents can be improved to help people understand the job better and improve task accuracy so improvement suggestions can be proactively incorporate in future work order planning. <sup>114</sup>



Getting work done always involves people working together. The better they communicate to one another and the better they understand a situation the more sure it is that they achieve good results.

# Preparations BEFORE Scheduling Starts

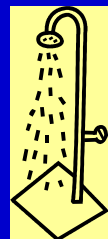
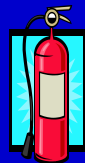
- Parts are in store and are the right ones
- Permits required are identified
- Work Pack complete
- Special tools/test equipment are available in time
- Production plant/equipment will be available
- Skilled people who can do the job well are available
- Specialist subcontractors can meet deadlines
- Job priorities are identified
- Completed jobs are removed from schedule



Only work orders ready to be done are scheduled. Until all parts, materials and external resources are confirmed to be available when needed a work order remains in the backlog. You do not want to start a job discover that it cannot be properly completed because parts, labour or important information for its restoration is missing.

## Preparations by the Equipment Owner Before the Job Starts

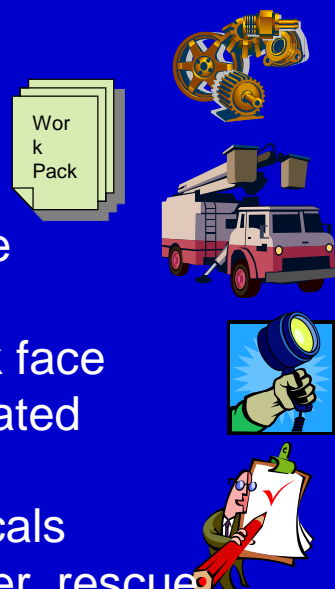
- Handover plan and isolation points drawings – process isolations, danger tagging, permits, etc
- Hazards removed from workplace
- Blank/spade flanges installed; process fluids drained
- Confined spaces made safe for entry
- Electrical safety isolations
- Plant/machine proven to be safe
- Handover/Safety permits signed-off
- Electro-static discharge (static electricity earthed)



The owner of the plant is responsible to provide safe access to equipment. Plant isolation and handover can take lot of time and need to be planned and organised so it goes well and is done quickly. Plant handover is done by persons who know the process and use of the equipment. That is usually the User of the asset, but it may also be the technical specialist on the process.

## Preparations by Maintenance before the Job Starts *(include costs in budget)*

- Parts at work face
- Passes and Permits complete
- Work Pack complete
- Special tools at work face
- Equipment to do the job available
- Production plant available
- Isolated with safe access to work face
- Test equipment ready and calibrated
- All safe work systems in place
- Site inductions, drug tests, medicals
- Emergency training e.g. helicopter, rescue



Your aim is to maximise 'tool time' of the maintenance technicians doing the work. To do this it is necessary that the workface is fully provisioned with all that the technicians will need to do the job. What they do not have at hand they will go and get, and that means the job is delayed.

Let's stop here Ted. Tomorrow we'll talk about how to handle unexpected changes when a job is underway.

Thanks Joe. See you in the morning.

Got another question for me to think about tonight?

Today I'll give you a rest. I'll save the hard questions for the final test.

What test!? Bill never said I had to pass an exam!

How else can I tell Bill that you're ready to take on the job? But don't worry; after this last month of meeting together, there is nothing you won't be able to handle.



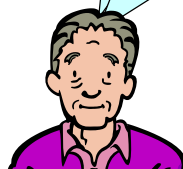
Their time today ends ...

Is this the last of our daily get-togethers Joe?

Yes Ted, today we finish these meetings. We'll cover the final part of scheduling today. Let me start by explaining what you do when the job starts to go wrong.

But why does a job go wrong, when it's been planned so well?

The world is never going to be perfect Ted. All we can do is plan for what we know about. If during the job the unexpected happens, then we have to be ready to sort it out fast.



The last daily meeting ...

Joe, what can I do to be prepared for the unexpected?

Confucius told us the answer over 2500 years ago – “In all things success depends on previous preparation, and without such preparation there is sure to be failure.”

Ted, ... the best way to prepare for the unexpected is to plan for it ahead of time.

But what do I look for?

Luckily there are only three things to consider – people, processes and plant. The way I do it is to turn the job planned on the bar chart into a process diagram. Then I get together with the guys doing the job and we discuss each step and ask ‘What can go wrong?’. By doing that I pick-up things I missed and the guys are right-up to speed with what to do if they start having problems.

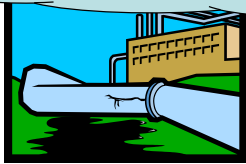


Ted asks an important question ...

## CONTINGENCY PLANNING: Addressing On-site Issues and Changes in the Plan

Houston, we have a problem.

Manure! Production won't like this.



### 'Emergency' Procedures

- Assess the impact ...
- Make it safe ...
- Contain consequences ...
- Rectify the problem ...
- Address the cause ...

How does the issue affect the job plan? What will change?  
Reschedule the work? Amend Work Order? Impact on Operation?  
**USE THE RISK ASSESSMENT AND TREATMENT TABLES**

The unexpected must be the Exception, not the Possible, if  
you want > 95% Schedule Compliance

At times a job does not go to plan from unintended or unknown complications that arise. The first consideration is to assess the impact of the disruption on the job and the knock-on consequence to Production. Address the issue as quickly as possible. Contain the damage, rectify the issue and then **act** to ensure it never happens again by adjusting your planning and scheduling procedures/checklists.

With high risk jobs where safety is a concern, or loss of containment is a potential, or where the financial costs of problems and errors are excessive it becomes necessary to do a risk analysis and put into place suitable mitigations and controls as part of the job preparation.

## Work Through a 3T Job Risk Analysis

Job Risk Analysis.xls [Compatibility Mode] - Microsoft Excel

**3T Job Risk Analysis Spreadsheet**

Flow Chart of a Pipe Flange Leak Repair

|                                | Task 1<br>Safe Work Handover   | Task 2<br>Separate Flanges  | Task 3<br>Clean Flange Faces   | Task 4<br>Pipe Alignment  | Task 5<br>Hole Alignment                                     | Task 6<br>Install New Gasket  | Task 7<br>Pull-up Snug Tight  | Task 8<br>Mark Nut Positions                            | Task 9<br>Tighten Nuts   | Task 10<br>Test Flange for Leaks              | Task 11<br>Clean-up   | Task 12<br>Recommission  |
|--------------------------------|--|---|--|---|--|---|---|---|--|---|---|--|
| <b>What can go wrong with:</b> | Task 1   | Task 2  | Task 3   | Task 4  | Task 5   | Task 6  | Task 7  | Task 8  | Task 9   | Task 10                                       | Task 11   | Task 12  |
| <b>Guide Words</b>             | Safe Work Handover   | Separate Flanges  | Clean Flange Faces   | Pipe Alignment  | Hole Alignment   | Install New Gasket  | Pull-up Snug Tight  | Mark Nut Positions                                      | Tighten Nuts   | Test Flange for Leaks                         | Clean-up  | Recommission   |
| <b>People</b>                  | Operator   | Operator  | Operator   | Operator  | Operator   | Operator  | Operator  | Operator  | Operator   | Operator                                      | Operator  | Operator   |
| <b>Work Process</b>            | Isolation  | Isolation   | Isolation  | Isolation   | Isolation  | Isolation   | Isolation   | Isolation   | Isolation  | Isolation                                     | Isolation   | Isolation  |
| <b>Plant</b>                   | Isolation  | Isolation   | Isolation  | Isolation   | Isolation  | Isolation   | Isolation   | Isolation   | Isolation  | Isolation                                     | Isolation   | Isolation  |
| <b>Target Controls</b>         | Operator provides isolation point drawing and walks circuit to show previous tagged isolations and open drains | Cover fasteners with anti-seize, back-off nuts half a turn in sequence and then a full turn, catch any drops of product from flange in suitable container, remove every second fastener and finally all fasteners but last one. Spring flanges with podgy | Bright, smooth, flat face, no groove damage or pitting, as good as new                 | Flanges unbolted and are in-line to within 1 mm                           | Flanges unbolted and holes in-line to within 0.5 mm          | Gaskets and studs fitted between flanges and centred without damage and studs/nuts lightly, pre-lubricated and fitted by hand | Wind nuts onto studs by hand so studs extend equal distance either side of flange. Tighten nuts finger tight and check that flanges are parallel to an accuracy of 0.1mm with the feeler gauges. Number the studs in the sequence of tightening. Pull all nuts on both flanges up snug tight in correct | Clearly match-mark the nut and flange                   | Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence | No leak whatsoever at full operating pressure | All equipment, tools and waste removed - area left spotlessly clean | Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use |
| <b>Tolerance</b>               | Operator has isolated plant & tagged isolations out-of-service & drained piping                                | Back-off all nuts half a turn in sequence and then a full turn, catch any drops of product from flange in suitable container, remove all fasteners but last one. Spring flanges with podgy  | Loose material removed, burr-free, flat face, no draw marks or pits deeper than 0.25mm | Flanges are unbolted and are in-line to within 2 mm                       | Flanges unbolted and holes in-line to within 2 mm            | Gasket slid between flanges and centred without damage and new studs/nuts fitted by hand                                      | Wind nuts onto studs by hand so studs extend equal distance either side of flange. Tighten nuts finger tight and check that flanges are parallel to an accuracy of 0.4mm with the feeler gauges. Pull all nuts on both flanges up snug tight in   | Clearly match-mark the nut and flange                   | Tighten nuts 1/4 of a turn in cross sequence and finally tighten nuts to 1/3 of a turn in cross sequence | No leak whatsoever at full operating pressure | All equipment, tools and waste removed - area left spotlessly clean | Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use |
| <b>Test Risk is Addressed</b>  | Isolation procedure is correctly done and proven safe  | All fasteners removed without damage to flanges or harm to personnel or other property  | Flange faces are totally clean and safely usable                                       | Measure misalignment with vernier callipers on flanges with studs removed | Measure with vernier callipers on flanges with studs removed | Only new gasket and new fastener components used  | Flanges come together square with stress-free alignment   | Scribed marks in correct position and easily observable | Fasteners correctly tensioned to required nut position in right tightening sequence                      | No leak whatsoever at full operating pressure | All equipment, tools and waste removed - area left spotlessly clean | Recommission procedure is written, reviewed and correctly done and plant proven safe for continued use |

**Lifetime Reliability Solutions**

[www.lifetime-reliability.com](http://www.lifetime-reliability.com)

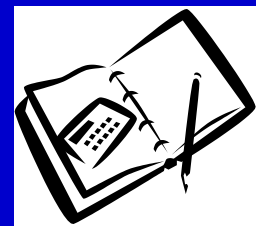
Risk analysis involves asking what can go wrong with each task. It works best in a brainstorming team environment. The Planner develops 'guide words' relevant to the situation and says them out loud to the team. The Planner records the concerns of each team member in doing a task and the team discusses how to resolve any real concerns. The means to resolve the problems is recorded as 'the controls' of the hazard.

The Planner includes the risk controls into the work plan so they become part of the job and time and resources are allocated to doing the risk mitigations.



# Actions Following Job Completion

- Make it a job task to have:
  - Clean and tidy work face
  - Permits completed and closed
  - Work Pack completed with full records
  - Special tools clean and ready to return
  - Plant and Equipment clean and ready to return
  - Isolated with safe access at work face
  - Test equipment clean and ready to return
  - Work Order closed off with correct codes
  - Information on equipment condition
- Remedial work recorded
- Engineering databases updated
- Lessons Learnt meeting

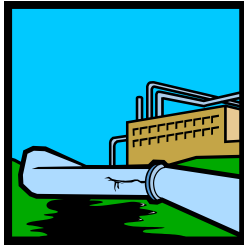


At the end of a job it is a sign of professional competency to leave it in better condition than you found it. Build the proper actions into the tasks for the job. Make it a task to complete all associated documentation and records so the people and time are made available to update the business systems.

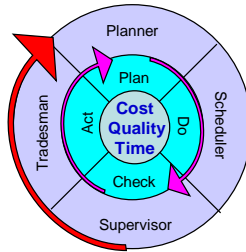
If you want to get better the 'lessons learnt' meeting is a must. But talking about things doesn't actually change them; only taking action does that.

# “If It’s Not Written Down, It’s Not Real”

Until something positive and ‘concrete’ changes the causes of a bad situation there has been no learning, and the problem will reoccur.



Learn from the experience ... **act** to correct your systems and processes so it doesn't happen again.



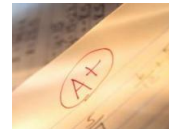
Improve the Planning Procedures and Forms



Improve the Job Procedures and Checks



Improve the Training and Competence



Follow-up and Support Correct Practices

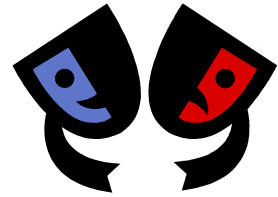


***“Until the new ways are documented, people are trained to do them right, and supervision supports them,... they will not happen in the workplace.”***

Unless something positive and ‘concrete’ comes out of a bad situation there has been no learning and the problem will reoccur. It cannot be otherwise because nothing has been done to correct and improve the situation.

Until action is taken to make the necessary changes permanent, there has been no change. These changes need to become improved ways of doing the planning and performing the maintenance. Until the new ways are documented, people are trained to do them right, and supervisors give open support to them... they will not happen in the workplace.

## *Activity 12 – Scheduling to Get the Job Done Right First Time*



In teams of two see the Work Book for details of creating a standardized Scheduling Procedure

### Review of Activity 10

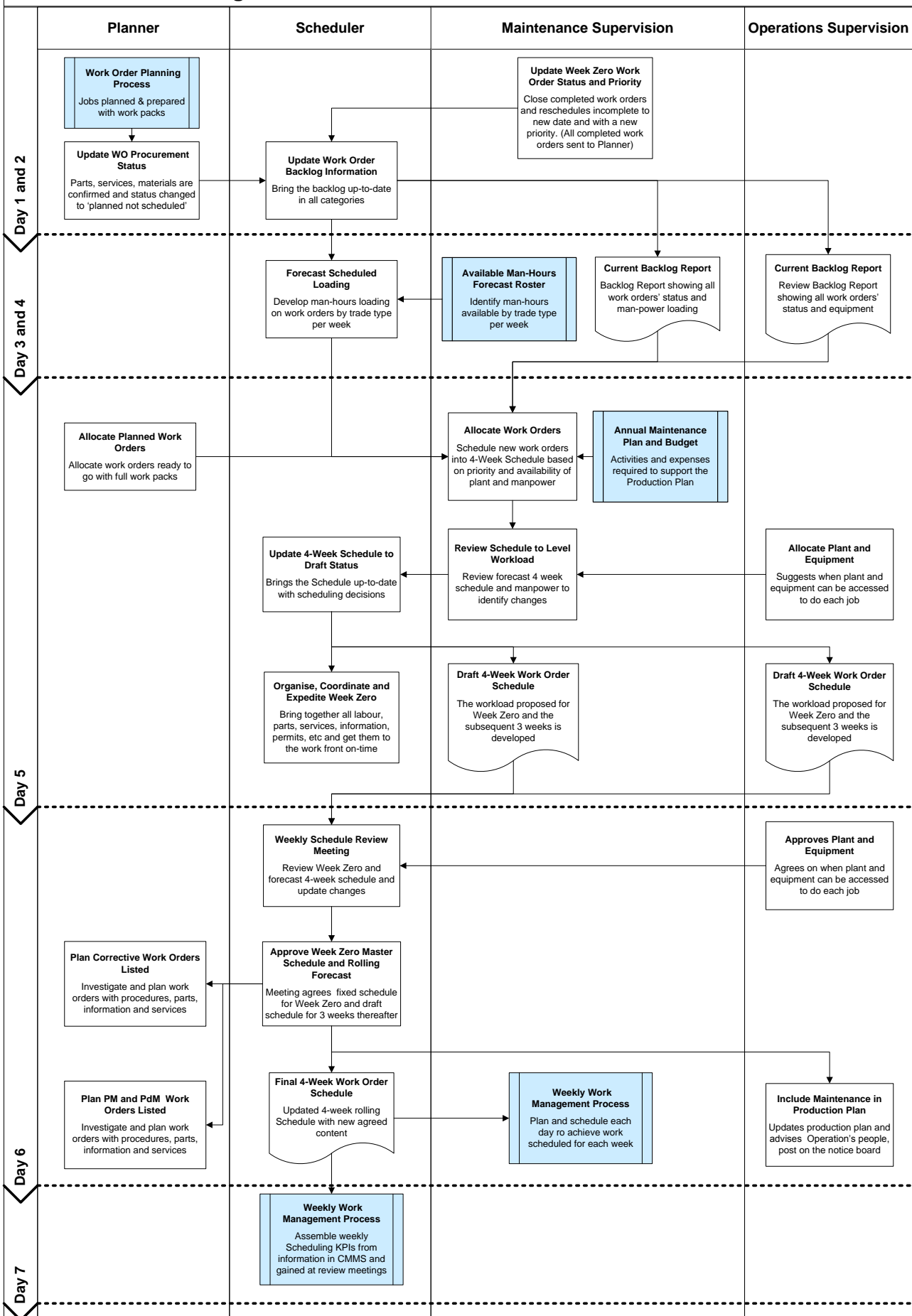
## Activity 12 – Create a Standardized Scheduling Process and Procedure

In a team of two people **1) sketch the flow diagram of the scheduling process you will use in your operation.** Use the course content and Maintenance Processes to work your way through the process flow that you need in your company.

**2) Then use the 3T format forms over the page to add 3T proof tests and standards to each step of the scheduling process** you will use.



# Work Order Scheduling Process



That's about it Ted. There is not a lot more to tell you. I'll touch-on the six key issues that I think are the important ones to make sure you get good at. After that you need to start doing the planning and scheduling and refine your style as you go.

Thanks Joe, you are wonderful to have helped me so much. But what about the final test?

Nah, there is no test that you have to sit for. The test will be what happens when you take over the job. Bill asked me to keep him informed of how you were going. I told him that your only going to need a couple of months hands-on experience and you will do this job brilliantly.

Let me wrap-up and you can go. Tomorrow drop-by and I'll pass you your first couple of jobs to take through to completion.



Ted finishes ...



## *The Purpose of Planning Maintenance*

1. Maximum trade 'tool time'
2. Work done 'right-first-time'

This all that you are trying to do when you do the role of Maintenance Planner, and of Maintenance Scheduler.

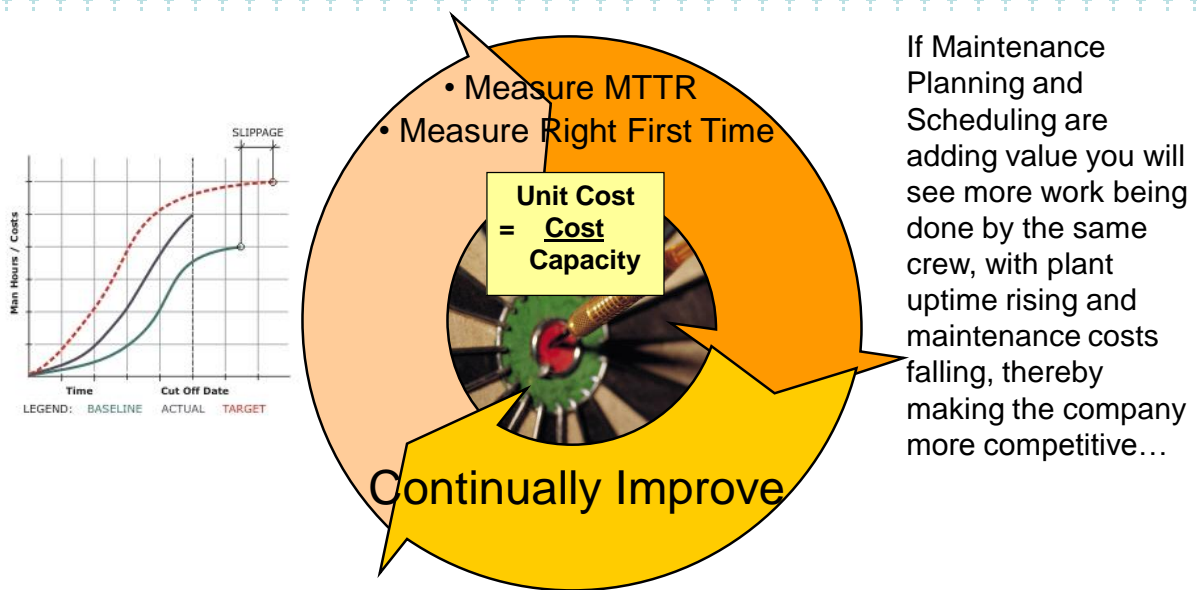
## *The Purpose of Scheduling Maintenance*

1. Minimum production disruption
2. Right resources and people to job on-time
3. Getting work done before there is a failure

Here we are at the end of the book. The intention of the training was to focus you on creating a planning and scheduling process that delivered each of the bullet points in the slide so that all your maintenance work is done efficiently and effectively.



# Monitoring The Value Contribution of Planning and Scheduling



**Is the right maintenance work being completed, at the right time, with the right resources?**

Make 'tool time' and work quality important by measuring them as a maintenance KPI. If your maintenance is fully prepared and coordinated and the work is done to high standards of craftsmanship, you will become a world class operation. Use the learning from using your process to continually improve your planning and work practices. When your process and methods are world class so too will be your results.

# Maintenance Planning Course Key Issues

1. ZERO failure is the aim
2. Use DAFT Costing to get management and production attention
3. Higher reliability means higher safety
4. Aim for efficient and effective use of maintainers
5. Poor planning and scheduling means poor performance
6. Equipment reliability is what maintenance offers
7. Build work task accuracy into the SOPs with ACE 3Ts
8. All work is a series process that can go wrong at any step
9. Production and Maintenance partnership works best
10. The machines are fine – improve the processes and the people

Start  
creating a  
quality ethos

What insights will you take away? Can you share them with us?



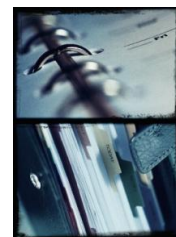
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These ten thoughts are the key take-aways to use in improving your planning and scheduling processes.

## Online Training Course Modules Content

### Maintenance Planning

1. The role of Maintenance Planning and Scheduling in Maintenance Management
2. Develop the planning workflow process
3. Design and install planning support systems
4. Identify, specify and confirm job requirements
5. Plan all steps to complete each task in the job
6. Do work and review performance for feedback



### Maintenance Scheduling

1. Develop the scheduling workflow process and support systems
2. Determine work order sequence and develop the fixed week schedule
3. Coordinate resources and prepare for scheduled work
4. Monitor schedule compliance of tasks

Get more information on online training you can do at:

<http://www.lifetime-reliability.com/training/online-training-courses.html>

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Throughout the world you can do our training courses.

# End of Course

... farewell and thank you from Joe.



- Please complete the Feedback Questionnaire and leave it behind

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Joe is now retired and enjoying himself in far away places.

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