Risk Based Maintenance Analysis - Further Considerations for Managing Maintenance in a Changing Business Environment

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SUMMARY: The development of an asset maintenance plan that supports the assets of any business can be a complex task. Typically, a large number of assumptions are made relating to the required use of equipment, the likely operating environment and of course, the available support resources through life.

However, the situations on which these assumptions are based can, and do, change over time. Such typical changes include:

- Changed asset performance requirements;
- Reductions to the maintenance budget;
- Increase in the remaining life; and
- Reductions to the available maintenance (shut down) periods.

Without completely re-developing the maintenance and support plan for every change, how can any organisation cope with such changing requirements and maintain the technical integrity and safety of the plant?

Risk based analytical processes provide that opportunity and equally importantly, the ongoing ability to monitor the production, personnel safety and environmental risks form the non achievement of asset maintenance..

Real time tailoring of the original maintenance plan to suit the current circumstances (whatever ever they are) can be accomplished through the use of a risk assessment of the planned and corrective maintenance activities.

This paper is developed from last year's paper and highlights a continuing Case Study where the client had a real need – the maintenance programme was under severe pressure to reduce both the number and scope of the required maintenance tasks, in an environment of changing operational/production circumstances, and needed an approach that would provide:

- A quick and auditable response to those challenges;
- The ability to play "what if" games;
- The ability to readily analyses the risks from the non-completion of programmed maintenance tasks; and
- The ability to document and measure the residual production, safety and environmental risks!

1. Introduction

The common goal of all maintenance managers is the development and enactment of a maintenance plan that will deliver the required reliability of equipment at an acceptable cost. The well supported maintenance manager uses maintenance analysis techniques such as Reliability Centred Maintenance (RCM) to develop technically excellent maintenance plans, which are then loaded into a Computer Aided Maintenance Management System (CMMS) for implementation by a well trained and well staffed maintenance team.

Such maintenance plans are developed based on a number of assumptions including:

- the required level of performance from the assets;
- the out-of-service periods available for maintenance;
- the available maintenance budget (for both in house and contractor labour);
- the availability of certain skills and spares.

Accordingly, changes to any of these conditions are likely to present the maintenance manager with considerable difficulties - especially where a variation from the authorised[1] maintenance plan is considered. Such scenarios could include:

- an increase to the required level of performance from the assets above the current authorised maximum;
- a reduction in the time available to complete maintenance, such that the authorised maintenance plan is un-achievable;
- a reduction in the maintenance budget such that the authorised maintenance plan is un-achievable; and
- significant changes in technology which render obsolete (either in terms of reduced implementation costs or increased effectiveness) the older maintenance tasks.

Except in the most stable of production environments, the above scenarios are relatively commonplace.

In situations where the performance of equipment is critical, and especially where a regulatory framework covers the operation and maintenance of equipment, any decision to vary from the authorised maintenance plan must be both:

- carefully considered; and
- normally based on formal tolerances (eg. the maximum length of cracking tolerable in an airframe before grounding the aircraft).

Maintenance plans with sufficient integrity to enable variation from a baseline operating requirements require extensive investigation and are therefore costly to develop. Such considerations are normally excessive except in situations where Government regulation so decrees.

The emerging requirements for workplace safety[2] are, however, placing increasing requirements on employers to adequately consider, and possibly document, any decision to vary from an authorised maintenance plan, even in a relatively benign workplace. Given the level of detail and supporting information associated with most maintenance plans, how can the maintenance manager responsibly deviate from an authorised maintenance plan in response to any of the above scenarios?

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[1] 'Authorised' in this case, and throughout this entire document, is taken to mean that which has been sanctioned by an organisation or entity responsible for the performance and safety of equipment and processes. This organisation is normally the employer and in some cases acts in cooperation with a regulating body such as a government department or third party organisation.

[2] The reader is referred to current OH&S requirements for plant such as those covered in NOHSC 1010 – National Standard for Plant or relevant current state OH&S legislation.

The above scenarios are representative of the situation of one of CBD's clients has found itself and have been the subject of significant attention and effort over the past few years. Simply stated the client's problems are:

- *Insufficient resources (both time and money) to complete the authorised maintenance plan; and*

- *Unknown risks that result from the non-achievement (that is, completed at the due date/time etc) of any maintenance task.*

CBD's client has a well-developed maintenance planning environment that has been the subject of consistent "salami slicing" reductions in its maintenance budget over the past decade. As a result of this situation, the maintenance managers believe they will soon be in a position where they cannot complete the maintenance prescribed by the authorised maintenance plan. As usual, this situation is not as clearly stated, as it seems! The derivation of the authorised maintenance plan has been lost in time and as a result, may or may not be based on current hazards and may or may not produce a currently acceptable residual risk!

Further, in view of the emerging OH&S requirements and existing duty of care issues, legal advice sought by those managers, has suggested that any decision to not meet the authorised maintenance plan could result in significant liability on behalf of the individual maintenance managers, in the event of an untoward incident.

1.1 The Details

Currently a shutdown maintenance package is 'considered' by as many people as possible within the client's organisation, to determine the best value for money and, where the available budget falls short of that required, some planned maintenance activities are simply not completed. Early approaches at resolving this situation involved rules for deferring maintenance activities, however this resulted in a large 'backlog' of tasks.

A later approach involved virtually re-developing the entire maintenance plan, as part of a RCM style analysis, to take into account all the possible variations in budget or performance requirements. This approach proved complex, costly and was unable to respond in a time frame acceptable to the changing needs of the operators. The current initiative developed by CBD, involves a two pronged approach:

- continuing development of the authorised maintenance plan based on the long term requirements of the organisation; and
- development of a suitable process where short term variations from the authorised maintenance plan are appropriately developed, and knowingly endorsed and approved.

The long-term approach continues to involve analysis of failure information and the application of RCM and reliability engineering techniques.

The short-term approach involves the development of decision processes used to tailor the authorised maintenance plan, developing a full understanding of the resultant residual risks from the non-achievement of some maintenance tasks and then enacting those as part of the normal shut down maintenance planning process. An important aspect of this short-term approach is that the decision-making processes must be within the competency and capacity of maintenance planning staff.

As both maintenance and safety management plans are based on risk analysis and management techniques, a documented risk analysis, based on AS 4360 forms the basis of the short-term approach. The short-term approach has been called Risk Based Maintenance Planning (RBMP).

The RBMP approach has been recently very successfully trialled for a number of major shut down maintenance periods.

2. Risk Based Maintenance Planning - Objectives

The objective of Risk Based Maintenance Planning is to allow maintenance managers to systematically manage the changes in risk (often viewed as an increase) associated with shortfalls in the budget and time allocated to support the Authorised Maintenance Plan (AMP).

Specifically, the enabling objectives of RBMP are to:

- Identify the OH&S, operational and environmental risks associated with the inability to conduct specific AMP items within a specific shut down period;
- Identify the most appropriate risk mitigation strategy for implementation within the available maintenance budget and timeframe, consistent with agreed levels of acceptable risk, statutory requirements, the required production profile and future capacity requirements;
- Develop appropriate changes to the content of the shutdown work packages for completion within current and planned future shut down periods; and
- Develop any necessary changes to operational maintenance schedules.

While RBMP will deliver some reductions in the maintenance required to support the plant, RBMP provides a technically acceptable approach for managing the effects of budget shortfalls and production scheduling, ie. ***RBMP maintains the technical integrity of the plant, both "Fit for Use" and "Safe to Use".*** Equally, RBMP enables maintenance technicians to document the residual risks (production, safety and environment) that result form the non-achievement of maintenance tasks.

In order to maintain the technical integrity of the plant, the RBMP processes:

- formalise the existing ad-hoc processes;
- follow current standards for safety and maintenance (ie. risk based – AS 4360);
- form part of the normal shut down maintenance planning processes (ie. analysis completed and results developed within 2-10 days);
- are able to be incorporated in to the quality system of the organisation (ie auditable); and
- utilise the resident skills of the maintenance managers and planners, supplemented as necessary by equipment specialists.

The RBMP processes addresses the following categories of risk:

- Personnel Safety,
- Production, and
- Environmental Damage.

Other categories being considered by CBD for inclusion in the future include public relations and capital equipment value.

3. Key Features of RBMP

RBMP is based on the premise that the existing maintenance plan was developed in response to a "fixed in time" operating and support scenario, that was considered at the time to be the "worst case' - from a maintenance perspective. Further exacerbating the problem, that scenario is now either lost in time or has been superseded many times over!

Given this "out of touch" situation, much maintenance required by the extant maintenance plan is now attempting to solve the wrong operational/production needs - and is no longer appropriate for the current situation.

In situations where the maintenance budget or time available for maintenance is constrained, identification of inappropriate (excessive) maintenance activity is critical to completing the appropriate maintenance for the plant. Figure 1 shows the relationship between maintenance and production requirements, in particular the effect of unnecessary maintenance and periods where existing maintenance may be inadequate.

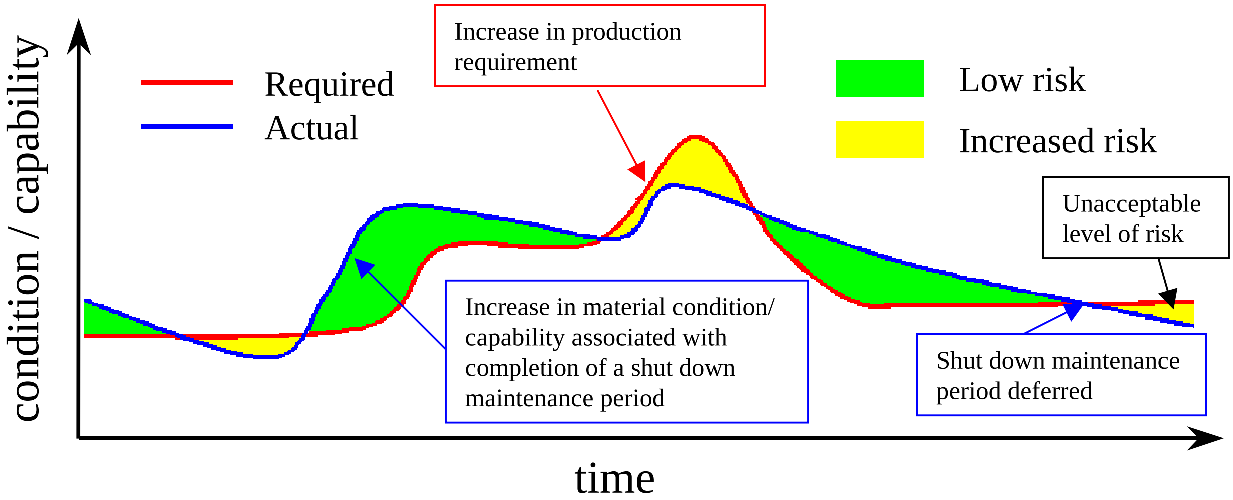

Figure 1 – Theoretical Relationship Between Maintenance and Production Requirements

The key capabilities of RBMP that enables the identification of unnecessary maintenance in a manner that does not jeopardise the technical integrity of the plant are:

- the level of acceptable risk associated with each maintenance period is agreed and documented by senior management;
- RBMP uses a structured, systematic and documented risk analysis technique to recognised Standards, similar to those employed in safety management and maintenance analysis; and
- the skill/experience requirements to conduct the analyses, are within the normal range of maintenance managers and planners.

3.1 Level of Acceptable Risk

In order that a consistent risk analysis can be completed for each maintenance task, agreed definitions for levels of consequences and likelihood are required for each risk category. Further, so that risks in one category can be compared with another, each risk level must be identified as either "acceptable" or "unacceptable" by senior management.

By documenting the level of risk in each category, maintenance activities can be prioritised and alternative risk mitigating strategies can be evaluated, if necessary. Further, the resultant residual risks from non-completed maintenance tasks, can be determined and documented in a similiar manner.

RBMP also enables users to redefine the risks for each maintenance period analysed, reflecting the real life situation where the levels of acceptable risk may change with the changing company priorities and business circumstances.

The RBMP risk matrices used by CBD are shown below.

Table 1 – Personal Safety Risk Matrix

PERSONNEL SAFETY		Consequence			
		Catastrophic (Permanent Disability)	**Critical** (Hospitalisation)	**Marginal** (Sickbay)	**Nil** (Nil Significant Effect)
Likelihood	**Frequent** (> One Person affected every 5 yrs)	High	High	Medium	Low
	Probable (> One Person affected every 10 yrs)	High	Medium	Low	Low
	Remote (> One Person affected every 15 yrs)	High	Low	Low	Low
	Improbable (Not Likely)	Low	Low	Low	Low

Table 2 – Production Risk Matrix

PRODUCTION		Consequence			
		Catastrophic (Immediate cessation of current production run)	**Critical** (inability to produce alternative product lines)	**Marginal** (Reduced production levels)	**Nil** (Nil Significant Effect)
Likelihood	**Frequent** (Within next 9 Mths)	High	High	Low	Low
	Probable (Within 9 – 15 Mths)	Medium	Medium	Low	Low
	Remote (Within 15-30 Mths)	Low	Low	Low	Low
	Improbable (Not Likely)	Low	Low	Low	Low

Table 3 – Environmental Protection Risk Matrix

ENVIRONMENT		Consequence			
		Catastrophic (External assistance. Required to clean up)	**Critical** (Local resources used to clean up)	**Marginal** (minor effect not requiring continued attention)	**Nil** (Nil Significant Effect)
Likelihood	**Frequent** (Within 6 Mths)	High	High	Medium	Low
	Probable (Within 6-12 Mths)	High	Medium	Low	Low
	Remote (Within 12-24 Mths)	Medium	Low	Low	Low
	Improbable (Not Likely)	Low	Low	Low	Low

3.2 Structured and Documented Risk Analysis

Given that the underlying analytical processes for safety management and maintenance analysis are risk based, AS 4360 – Risk Management was used as the basis for the RBMP processes. In general the RBMP process follows the following steps:

- Prepare Task List – Collation of shut down tasks from the various sources of the company (planned maintenance, defect repair and configuration change installation). This is an existing shut down maintenance period planning activity.
- Planning Information – Identifying the task management information such as time and skill requirements, estimated cost and dependencies on other tasks etc. These aspects are part of the existing shut down maintenance period planning activity, however in order to provide the appropriate context for the risk assessment and analysis the relationship of the task to the production plan, safety of personnel and the environment are also noted.
- Identify Consequences – Identification of hazards (risks) associated with not completing the proposed maintenance task at the proposed shut down period. The resultant hazards are categorised by their risk type. There may be more than one hazard and each hazard may result in more than one type of consequence. The severity of consequences associated with each hazard is assessed as part of this step. Tasks where the hazard severity is acceptable are assessed as "low" risk tasks and no further risk assessment s completed. Specialist advice may be sought to identify hazards, however assessment of the severity is provided by the maintenance manager/planner.
- Identify Likelihood – Where the resultant hazards associated with not completing a proposed maintenance task are unacceptable, the likelihood of the hazard being experienced before the next planned maintenance shutdown, is assessed. Measurement of equipment condition may be required to identify the likelihood of a hazardous event and specialist advice may also be sought.
- Assess Hazards – The risks associated with each hazard are then evaluated in accordance with the risk matrices.
- Identify Alternative Mitigating Strategies – Alternate mitigating strategies (as opposed to the original proposed maintenance task) are investigated as part of this step and evaluated according to their ability to mitigate the identified hazards. Alternative Mitigating Strategies can include, but are not limited to, combinations of:
    - Alternative maintenance or repair activities that achieve similar outcomes, such as a repair of an item rather than its replacement;
    - Deferral of a task to a future date;
    - Changes to the Long Term Maintenance Plan;
    - Implementation of a condition monitoring task to monitor a developing situation;
    - Alternative arrangements for continued production or supply in the event of equipment failure.
- Prioritise Task List – The task list is prioritised according to the risk associated with not completing each task. Where effective alternative strategies have been identified, these tasks are included in the task list in place of the original task. The prioritised task list is then analysed to identify a suitable scope of the shut down maintenance period commensurate with any constraints, such as cost and schedule, so that the resultant risks fall within the acceptable range.
- Implement Plan – The plan to be implemented includes the scope of the current shut down maintenance period, any tasks identified for future shut down maintenance periods, short term changes to operational maintenance activities and proposed changes to the long term maintenance plan.
- Monitor and Review – Monitoring and review of the risks associated with all tasks are part of the existing maintenance management processes.

The use of a specially designed risk analysis tool allows rapid completion and documentation of the above risk assessment. The Figures below demonstrate such a computer based tool.

Figure 2 –RBMP Tool

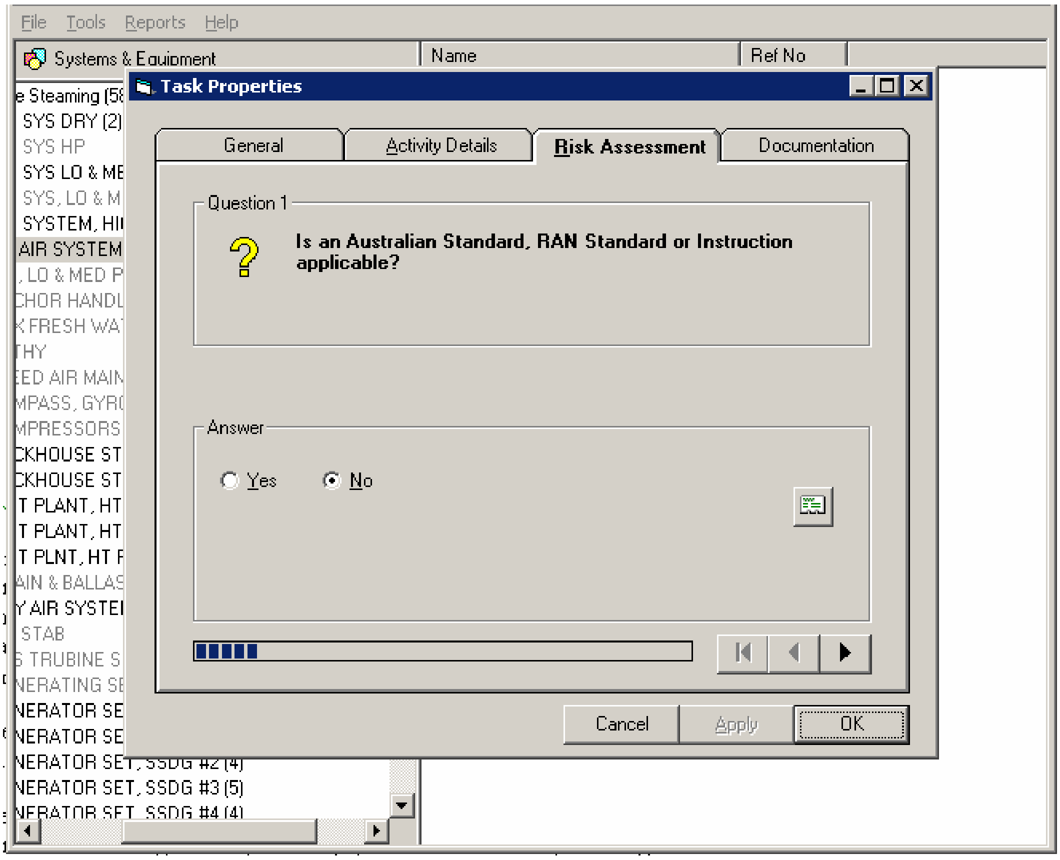

Figure 3 RBMP Risk Assessment Start Page

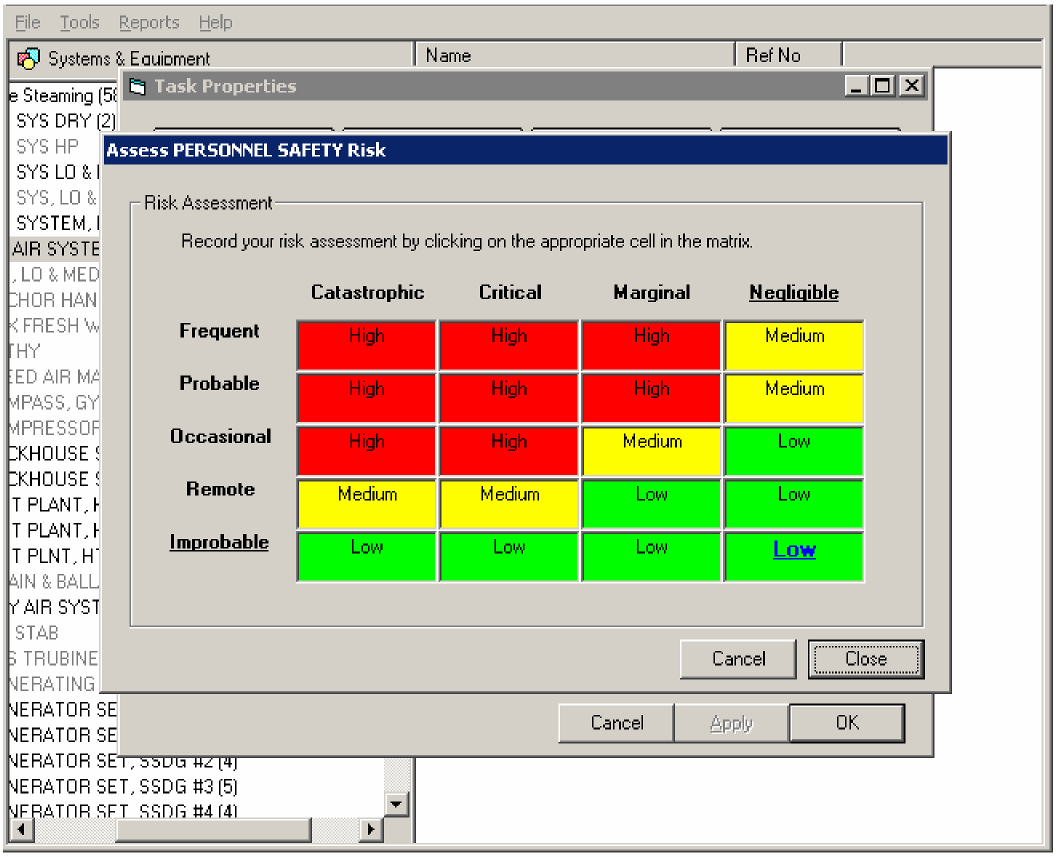

Figure 4 Safety Risk Assessment from the RBMP Tool

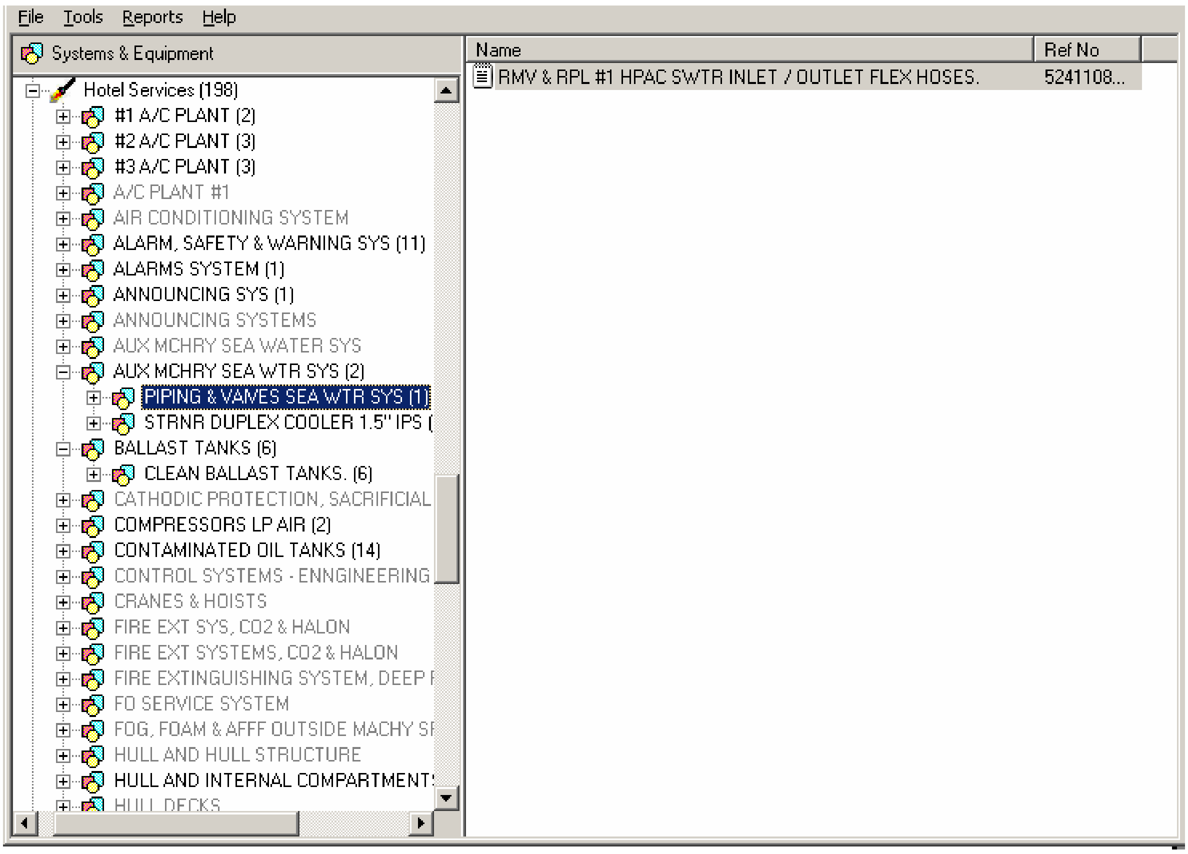

Figure 5 Functional Hierarchy used within RBMP Tool

3.3 Skill Requirements of Maintenance Managers and Planners

In view of the attempt to partially reverse engineer the original analyses that gave rise to the authorised maintenance task list[3], maintenance managers and planners using RBMP techniques require experience in both safety and asset maintenance analysis, together with the use of risk analysis techniques. In this regard, the authors believe that MESA is currently reviewing Professional Maintenance Engineering Competency standards to incorporate these aspects.

Given the recent experience of CBD, such capabilities are resident in most maintenance practioners, even if they are not always formally recognised!

Where the possible consequences and likelihood of hazards are unable to be determined by the maintenance managers and planners, specialist advice may be sought and documented. This is particularly so when unique items of equipment are the subject of such analyses or where the current equipment condition may need to be determined by experts.

4.1 Result One

A major shut down maintenance period was chosen for the initial trial of the RBMP approach. The task list for the scheduled maintenance period involved a mixture of planned maintenance, defect rectification and configuration change tasks totaling approximately 450 individual tasks to the value of $2M.

The major difficulty faced by the maintenance managers was a request from the production planning department to advance the timing of the maintenance period by 4 months and to reduce the maintenance period from 6 weeks to 2 weeks in duration. The RBMP analysis for the availability was conducted over a period of a few days by a team of 5 personnel.

The results of the analysis suggested that the shut down time could be shortened to approximately 4 weeks with 70% of the original planned maintenance activities having a negligible increase in risk. The analysis also identified that shortening the shut down time to 2 weeks in duration would introduce a number of risks that were unacceptable to the production planning department.

As maintenance planners explicitly sought and gained production information from the planners, a significant non-technical benefit of the RBMP approach was that the outputs of the analysis were both supported by the operational planners and understood by them as well! The newfound level of co-operation between operational planners and maintenance planners became one of the key achievements of the RBMP!

Through word of mouth, the same RBMP approach is now being utilised by other sections of the client's business to allow other maintenance managers to responsibly manage conflicting priorities for maintenance.

4.2 Result Two

A major shut down maintenance period was chosen for the second trial of the RBMP approach. The task list for the scheduled maintenance period involved a mixture of planned maintenance, defect rectification and configuration change tasks totalling approximately 520 individual tasks to the value of $6M.

[3] The need to reverse engineer the risk analysis can be overcome by including the rationale for each maintenance task as part of the supporting information for the task. It is planned to provide this information as part of any maintenance task developed or implemented in the future.

The major difficulty faced by the maintenance managers was a request from the production-planning department to retard the timing of the shut down by some 6 months. The RBMP analysis for the availability was conducted over a period of a few weeks by CBD technicians assisted by specialist system/equipment knowledge from the client's maintenance planners.

The results of the analysis suggested that only some 7 maintenance tasks (if not completed) would have a residual high risk (one production/operations related and six safety related) with some 160 tasks having a medium risk, if not completed at the original due date. This means that of the 520 tasks to be completed by the authorised maintenance plan, only some 160 tasks (noting that the same maintenance task may have more than one consequence type) needed to be completed at the originally planned shut down period.

As a result, the original shut down period was considerably reduced in length and cost, with no significantly added risk.

4.3 Result Three

Another major shut down maintenance period was chosen for the third trial of the RBMP approach. The task list for this scheduled maintenance period again involved a mixture of planned maintenance, defect rectification and configuration change tasks totalling approximately 501 individual tasks to the value of $5M.

The major difficulty faced by the maintenance managers was another request from the production-planning department to retard the timing of the shut down by some 6 months (yet again!). The RBMP analysis for the availability was conducted over a period of a few weeks by CBD technicians assisted by specialist system/equipment knowledge from the client's maintenance planners.

The results of the analysis suggested that only some 25 maintenance tasks (if not completed) would have a residual high risk (10 production/operations related and 15 safety related) with some 90 tasks having a medium risk, if not completed at the original due date. This means that of the 501 tasks to be completed by the authorised maintenance plan, only some 95 tasks (noting that the same maintenance task may have more than one consequence type) needed to be completed at the originally planned shut down period.

As a result, the original shut down period was considerably reduced in length and cost, with no significantly added risk.

5. Current Development Activities

Further to these trialled RBMP activities, the client is now considering that the supporting risk information for all planned and preventive maintenance tasks will now include a documented rationale[4]. Where a RCM analysis was conducted and is available, the hazard analysis that supports that task will be made available within the RBMP tool, set in an asset functional hierarchy, which will underpin the RBMP information requirements. If RCM data is not available, the RBMP analysis data will be used.

Further, each maintenance task will be supported by a "First and Last" Completion Date, using a Completion Interval commensurate with the risks mitigated by that task - for example the periodicity for a maintenance task might determined as monthly, with a Completion Interval of plus or minus two days. In this way, the client can (in association with a CMMS):

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[4] This is a standard aspect of a RCM analysis. RCM and RBMP techniques are expected to form the basis of equipment maintenance analysis conducted in the future.

- Determine and implement the use of appropriate Maintenance Compliance KPIs (in association with the changing production risks) and the usual Safety and Environment risks (assuming some stability of these!). This may be in the form of Maintenance Backlog KPIs and Maintenance Non Completion KPIs.

- Determine and implement a weekly (or monthly) Residual Risks Scorecard for safety, production and environment risks associated with the non-completion of maintenance tasks. This information could also lead to the development and use of Production risk traffic lights (Green, Amber and Red), Safety traffic lights and Environment traffic lights as a central element of monthly and quarterly reporting for periodic management review.

6. Conclusion

To many people, the use of such risk based approaches to the problems of maintenance funding and planning shortfalls or changes to operational/production requirements etc may seem unachievable or even foreign. Our experience however, is that as long as RBMP is not viewed as a panacea for all ills, a structured, systematic and repeatable approach based upon the processes of AS 4360, can be used responsibly to provide solutions to a range of maintenance and production related problems.

Notably, these concepts can be expanded to provide very useful, if not key, technical and managerial information, in a full quality sense – the use of a comprehensive "Plan, Do, Check and Act" approach to maintenance!

Through the use of RBMP analytical processes and related risk based maintenance KPIs, the maintenance plan can be continually re-connected to the business needs - the primary objective of all maintenance plans!

In fact, the incorporation of the Risk Based Maintenance Planning processes into the maintenance management quality system will provide a means for assuring the continuance of the technical integrity of the plant, in circumstances of considerable business change- in manner that should satisfy any statutory requirement.

For further information, contact Peter Kohler at Capability by Design on 029 646 1811 or Email peterk@cbdesign.com.au.

References

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