MOBILE FLEET BUDGET & AVAILABILITY FORECASTING

Using Reliability Centred Maintenance and Reliability Block Diagrams to Forecast Fleet Availability for Mobile Equipment with Different Ages

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Summary: Mobile fleet size and vehicle model selection can significantly impact mine throughput. Both existing mines and new or expanding mines can derive benefit from modeling the fleet to determine optimal servicing regimes and major planned rectification/replacement work.

This paper presents a Reliability Centered Maintenance and Reliability Block Modeling approach to evaluating optimal service regimes and fleet sizes. Once complete the models can be used to predict budgets, maintenance labour and resource requirements and spares usage.

Keywords: Reliability Centered Maintenance, Mobile Fleet, Simulation, Reliability Block Diagram, Budgets, Resource Profile

1 INTRODUCTION

Mobile equipment such as shovels, trucks, and excavators which are successively commissioned over a number of years creates a fleet of vehicles with varying ages. For machines with dominant wear-out failure characteristics, it is important to understand the forecasted availability profile of the entire fleet given that each machine is at a different stage of its wear-out life.

By initially conducting a Reliability Centered Maintenance (RCM) study, all the likely & the dominant failure modes are identified and analysed. Also, by completing this process, the maintenance strategy for the machine can be formulated or identified. This is particularly important for mobile equipment in comparison to fixed plants, as there is typically little online maintenance that can be done for mobile equipment.

Once the failure characteristics of each major component have been analysed and the equipment maintenance strategy created, then this information can be used to construct a Reliability Block Diagram (RBD) model. This model takes into account the impact of each failure mode identified in the RCM process to the overall availability of the machine.

Once an availability profile of a machine has been derived, then it can be replicated to represent each vehicle in the fleet. By assigning each vehicle with its age, then the availability profile of each machine, overlaid on top of each other can be plotted. This plot then provides an overview availability plot of the entire fleet, given the wear-out life and expected maintenance outages of each mobile vehicle.

2 RELIABILTY CENTERED MAINTENANCE (RCM)

Reliability Centered Maintenance (RCM) is a systematic approach that focuses on preserving function rather than preserving the asset. It addresses only failures that matter using a logical process for making maintenance decisions.

During this process, the mobile equipment is broken down to the lowest maintainable item. The failure causes for each maintainable item are then identified and analysed. If reliable failure/maintenance history is available, then this can be used to establish the failure rate or expected life of each failure cause. However, more often than not this information is not readily available or it's accuracy is not very reliable.

In such cases this information can be estimated based on technical, operational and maintenance experience on similar machines, as well as general engineering knowledge. The maintenance strategy for each failure cause identified must also be derived. These strategies may be predictive maintenance, preventive maintenance or a run-to-fail strategy.

As part of the RCM process, the failure effect or failure consequence is assigned to each failure cause. It is important to identify the failure causes that have a potential impact on the availability of the equipment so that the vehicle can be correctly modeled when the data is transferred into the Reliability Block Diagram.

Mobile fleet maintenance is often "service-based maintenance" and is typically quite mature. The application of the improvement process RCM, provides refinement of the current strategies, and generates complete and concise documentation. It also provides the knowledge to underpin why maintenance tasks are performed which helps ensure the maintenance strategies are implemented.

3 RELIABILTY BLOCK DIAGRAMS (RBD)

Reliability Block Diagrams (RBD's) are a tool used to carry out a system availability analysis and produce performance predictions. An RBD is made up of series and parallel relationships that represent equipment dependencies and redundancy levels. When reliability and maintenance data is added to the RBD, it can be used to predict downtime, the number of interruptions and the Mean Time Between Failures (MTBF).

The information collated during the RCM process is a good source of data to feed to the Reliability Block Diagram (RBD) model. .

In this exercise, any failure cause that has no impact on the equipment availability are disregarded.

4 APPLYING TO MOBILE FLEET

The application of reliability modeling to mobile fleet naturally has the benefit of duplication. Only one of each vehicle type needs to be modeled which can then be duplicated to represent the fleet. Different ages can then be assigned to the different vehicles, to generate a truly representative prediction, over any future time period.

5 EXAMPLE ANALYSIS

This method of analysis has been applied to several new mines and mine expansions. The following represents a typical application of RCM and RBD modeling to a mobile fleet.

The study begins by collating as much information that was available, including:- equipment lists, recommended service sheets, existing vehicle data such as:- work order history; downtime logs; current service plans; performance data and any previous RCM study data. . This information is used to develop a "Desktop" Reliability Centered Maintenance (RCM) model using the simulation software package RCMCost*.

The functional asset hierarchy was built using RCMCost based on area: system: subsystem: maintainable item relationships. This step is necessary as a precursor to the implementation of the Computerised Maintenance Management System (CMMS) such that it can be electronically uploaded when appropriate. With the asset hierarchy developed the next stage of the process was to define equipment functions, functional failures and failure modes. This was predominately completed using available information and where available equipment experts and/or manufacturers and suppliers. The input of these specialists is necessary to overcome any lack of maintenance history and assist in the collection of original equipment manufactures (OEM) maintenance manuals.

RCMCost provided the capability to fully document the available knowledge and simulate the impact of the maintenance tasks on the lifecycle costs and risk levels. The simulations provide for rapid analysis, and allowed a lot of modelling to occur outside of meetings, ensuring meeting times were minimized yet effective.

Once the desktop model is complete the ARMS reliability engineer worked with appropriate specialists to reality check and challenge the model results. This is carried out by first examining the criticality Pareto chart that is developed in RCMCost. The criticality Pareto ranks the failure modes based on total cost which includes any business costs associated with failure, labour cost, spares cost and equipment cost. Figure 1 below shows this criticality Pareto chart. It identifies the critical failure modes impacting on performance and cost.

Using the criticality Pareto chart, the high cost failure modes were examined in detail by carrying out a validation of the failure mode information. Once validation was complete the criticality Pareto identified areas for improvement. The type of recommendations made for improvement included root cause analysis (RCA), equipment redesign and maintenance strategy optimization. The criticality Pareto chart was also configured to display failure modes which had a safety risk greater than the exposure threshold.

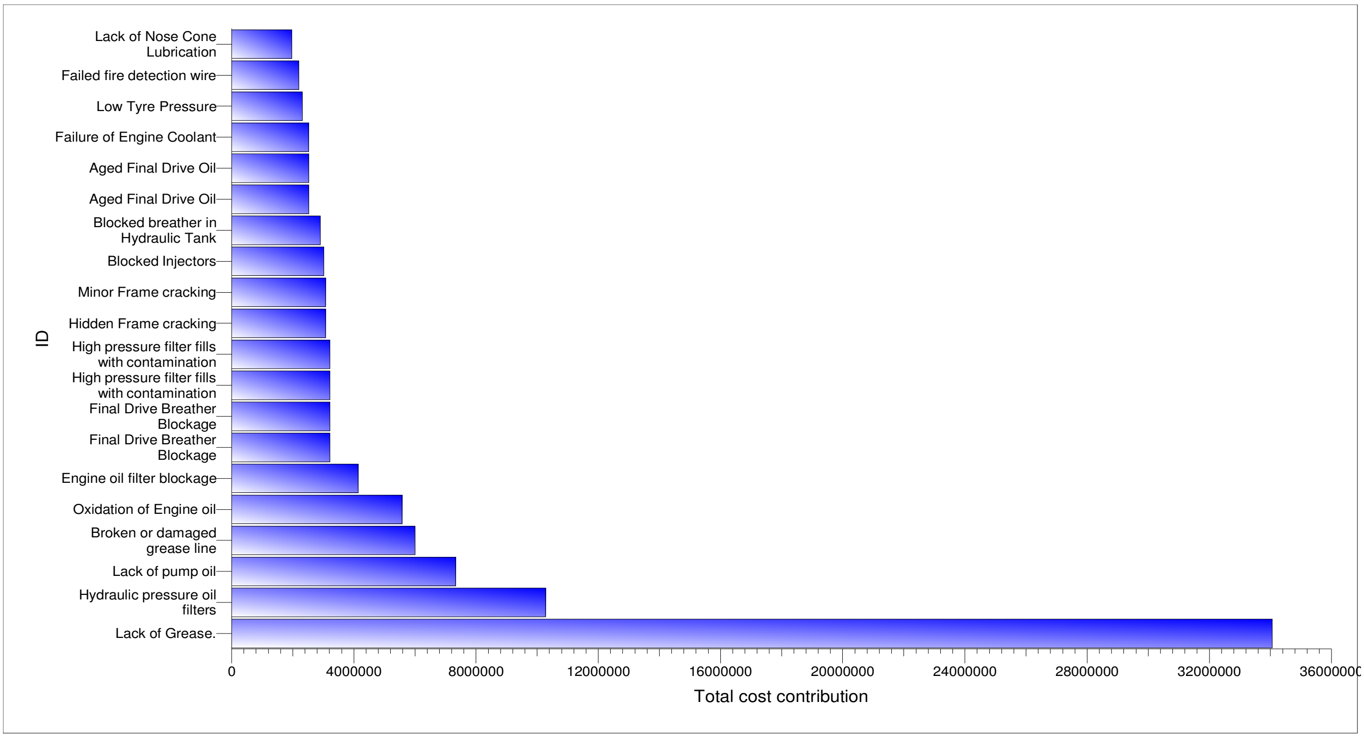


Figure 1 – Failure mode criticality Pareto based on total cost.

The second method used to challenge the model results was to examine the historical maintenance costs (where available) and compare to the budget prediction using RCMCost. The goal of this was not primarily to ensure the budget prediction matched the historical spend but rather to clearly understand the reasons for any discrepancies in the results. Using RCMCost the budget prediction could be interrogated at many levels including system, sub-system, individual asset and individual failure mode level. This ability to challenge the budget predictions in such detail was something that was previously unattainable.

6 OUTCOMES

With all validation and reality checking of the model complete the reporting of budget predictions was quite simple. RCMCost enables the budget predictions to be displayed both in tabular and graphical forms. Figure 2 shows the overall budget profile over 10 yrs. Note the variation across the profile which accounts for equipment aging characteristics, major equipment replacements and overhauls. These profile plots represent the typical outputs for one vehicle.

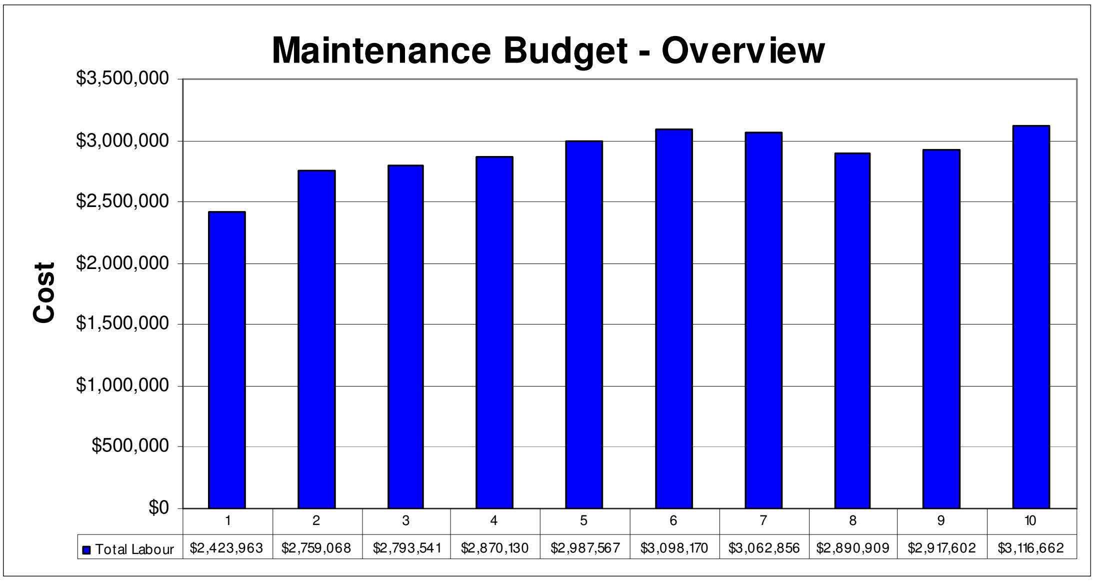


Figure 2 – Overall cost profile over 10 years

The budget profile can also be configured to show the separation of labour, equipment and spares costs as shown in figure 3

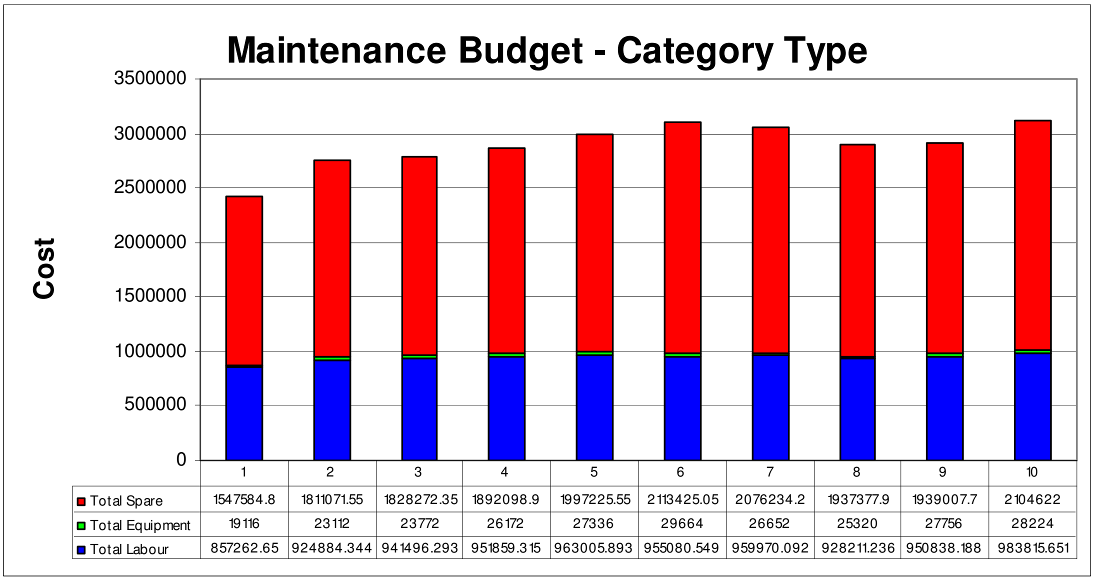
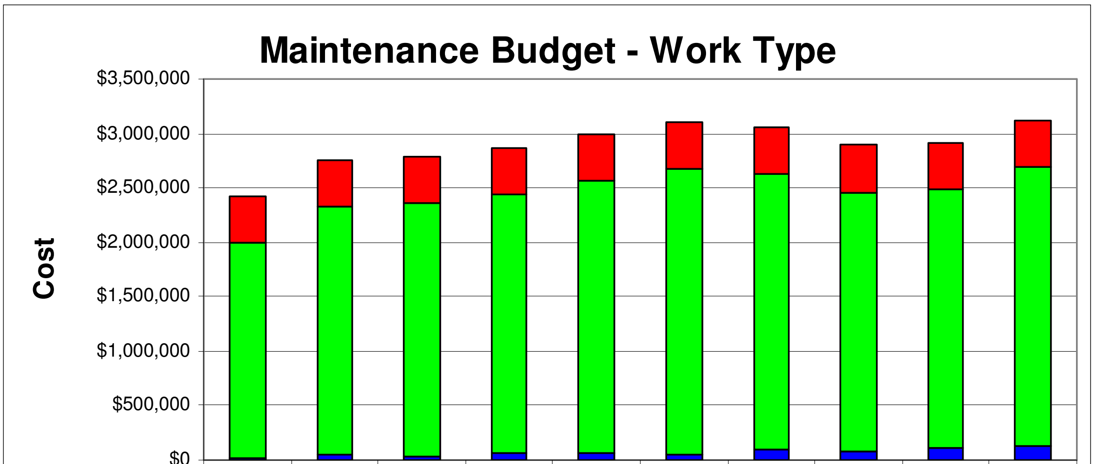


Figure 3 – Cost profile over 10 years showing the separation of labour, equipment and spares.

The chart in figure 4 shows the budget profile separated into the proportion of breakdown, preventative and inspection cost. Both breakdown maintenance costs and secondary action costs as a result of inspections have been included in the budget prediction to reflect a true zero based budget.



	1	2	3	4	5	6	7	8	9	10
Total_inspection	$421,704	$428,896	$428,949	$429,005	$428,927	$428,864	$428,967	$428,930	$428,862	$429,046
Total_preventive	$1,985,074	$2,285,514	$2,330,603	$2,374,532	$2,494,152	$2,616,408	$2,542,147	$2,389,933	$2,379,349	$2,554,930
Total_corrective	$17,186	$44,658	$33,989	$66,592	$64,488	$52,898	$91,742	$72,046	$109,392	$132,686

Figure 4 – Cost profile over 10 years showing the proportion of breakdown, preventative and inspection work.

To model the full mobile fleet, multiple vehicles can be quickly created by click and drag type functionality to duplicate items. Initial ages can then be entered against each item such that the fleet profile can be generated taking into account the varying ages of each vehicle.

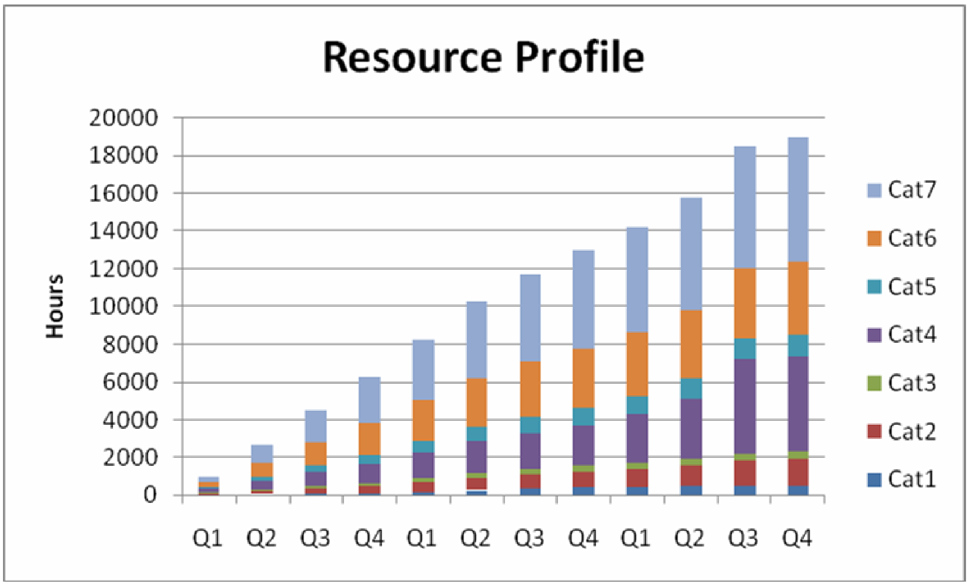


Figure 2 – Resource profile

Figure 2 shows the profile of required resources matched to vehicle ageing and growing fleet size over the first 3 years.

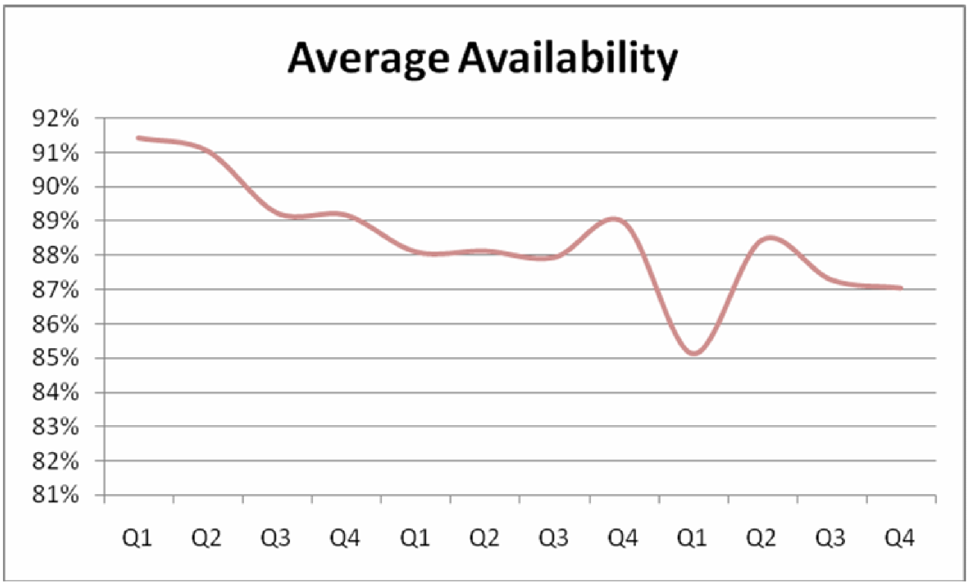


Figure 3 – Availability Profile

Figure 3 shows the fleet availability profile as produced by combining the RCM data with the RBD in AvSim+ software. As the vehicles age the availability drops as equipment items age and require more major maintenance. The profiles are typically generated by both calendar time and operating hours. The modeling can be extended to predict throughput of the mine given the full fleet and cycle times.

7 UPLOADING CMMS

For existing fleets or for new mines or expansions that proceed, naturally the maintenance plans developed as part of the modeling process can be uploaded via a portal into the CMMS.

Both Master Data such as Asset hierarchy, spare parts and BOMS can be uploaded, along with maintenance plans, strategies and work instruction documentation.

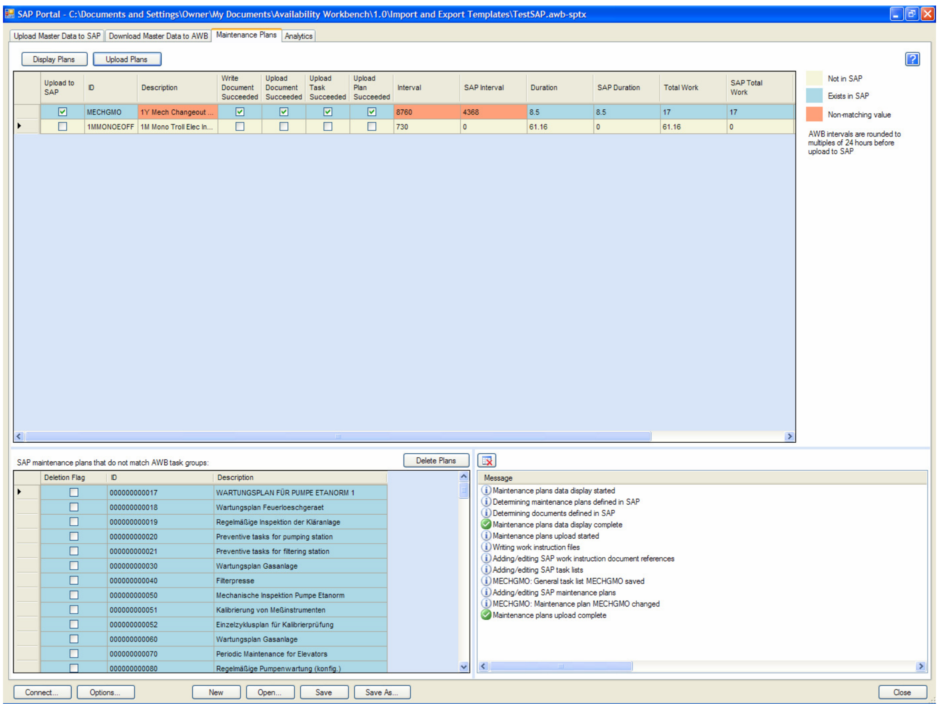


Figure 4 – SAP* portal, showing maintenance plan upload screen

8 CONCLUSION

The paper has presented a Reliability Centered Maintenance and Reliability Block Modeling approach to evaluating optimal service regimes and fleet sizes which can be applied to new, expanding or existing mines. Once complete the models can be used to predict budgets, maintenance labour and resource requirements and spares usage.

The paper shows through the breadth of results available, the benefit in applying an RCM and RBD approach to fleet modeling. The outcomes can help ensure that the mines throughput goals are achieved at least cost and most efficient maintenance regimes for the fleet.

Acknowledgements
* RCMCost, AvSim+ and SAP Portal are software modules of Availability Workbench which is owned by Isograph and distributed by ARMS Reliability Engineers