RISK BASED MAINTENANCE – OPTIMIZE MAINTENANCE STRATEGY TO MANAGE RAMP-UP PLAN SUCCESSFULLY

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ABSTRACT

The process of re-operating a mining company must be carefully prepared. All existing company assets must be prepared and used to support production which must be achieved in stages as well. This is related to the company's financial condition, human resources, and the company's readiness to use it. The company can implement on of maintenance strategy or combine it to prepare the machines as production requirements. This paper will present the model of implementation of Risk Based Maintenance which is compared to the Reliability Centered Maintenance approach. The case studies are applied to the Off Highway Trucks (OHT) fleet with various conditions in mine copper company in Africa that will return to production. The simulation generated to get model of Risk Base Maintenance on the Off Highway Trucks has an impact on cost reduction, especially in the first year of operation by maximizing component life, maximizing all maintenance resources

(keywords: Maintenance strategy, Reliability Centered Maintenance (RCM), Risk Based Maintenance (RBM)

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1. INTRODUCTION

The decision to suspend the processing of production is common decisions on the mining that has influenced the global cost price of commodity. Processing mining ramp up decided after completed and decided the company after comprehensive mining reviewed and agreed from all stakeholder.

The intention when managing a startup production ramp-up strategy is to facilitate decisions that lead to best possible usage of time, financial means and resources when trying to meet preset ramp-up performance targets. In order to accomplish this some sort of production ramp-up management framework needs to be in place [1]

Consequently, the choice of production ramp-up strategy is to a large extent dependent on the technology complexity, logistic complexity, product variety and the ability to exploit the markets potential [1]

A complete framework for ramp up should utilize all existing company assets. The process of optimizing maintenance cost should at the best possible cost price by considering financial factors. This is due to the fact that the company has not produced 100% according to the existing capacity. The system (CMMS system), procedures, machines, tool and workshop facilities have to utilized to meet the stage of production.

The CMMS system and maintenance procedures are implemented; however, the data source must be validated first. Cost analysis used is the cost for minor and major component replacement. Costs for routine maintenance (Preventive Maintenance - PM) are not carried out because it has become a mandatory expenditure for unit maintenance

This case analysis uses actual data prepared for the plan to increase mining copper company in Africa that have stopped operations for more than two years. Large fleets for haulage trucks (Off Highway Truck - OHT) should ready to operate with a variety of conditions and the most important components are overdue or past time. During 12 quarter, the production would have mined 7-thousand-ton copper increased to 22, 5 million ton mined copper. The OHT should prepared from 9 trucks to 35 trucks.

The process preparation of the OHT cannot processes immediately. The maintenance resources and the budget of maintenance should be balanced with production. Strategy to balance the cost of maintenance and production (cost/ ton) is the main objective with acceptable reliability machines.

2. METHODOLOGY

Maintenance Strategies

There are many different approaches that can be mixed and matched, depending on company assets, industry, and the size and experience of the maintenance.
Maintenance strategy decision making involves choosing the right maintenance and repair methodology that maximizes life and equipment at the lowest cost to use. [2,3,4]. The balance of choosing a maintenance strategy is influenced by the functions of other companies such as production, finance, quality, and human resources. [5,6]

Maintenance is usually categorized into the following three types and next generation methods for adding Reliability Centered maintenance systems (RCM). [7,8]

Table 1. Maintenance strategy comparison chart

Strategy	Summary	Pros	Cons
Reactive	Fix it when it breaks	Ideal for low priority equip.	Can lead to runaway repair costs
Preventive	Maintenance on a predetermined schedule	Best strategy to implement without expertise	Without optimization, “PM creep” can occur
Predictive	Condition-based monitoring triggering work orders	Timely and informed monitoring. More insight into causes of breakdowns	Can be expensive to set up
RCM Reliability Centered Maintenance)	Investigation of failure modes to determine best maintenance strategy	If executed properly, provides the most efficient maintenance schedule	Requires time, skill and financial resources to be effective

Reliability Centered Maintenance (RCM) vs Risk Based Maintenance (RBM)

RCM consider both two factors: "equipment condition" and "importance of equipment to the system" but the above methods have a common shortage: they don't solve the problem of quantification, which would bring them big limitation when used in practice. The RCM implement the maintenance strategy that covered all failure mode of the component and will not apply external factor during implementation ie. financial condition, workshop condition, workload, etc [9,10]

RBM is the next generation of RCM. This method is used for determining the priority of maintenance using risk which integrates both safety and failure. The RBM can reduce the maintenance cost [11].

This method is the best solution to prepare fleet machines considering the production stages. There are five points for RBM [11] :

- Quantitative, financially based analysis technique which establishes the relative worth of various maintenance task and serves as continuous improvement tools
- RBM defines opportunities and benefits of incremental improvement by eliminating low-value task and introducing task that address high commercial risk areas
- This is not any specific maintenance strategy but is a combination of various other strategies which is devoted to the risk to the risk factor of the plant/equipment
- The risk-based maintenance methodology is designed to study failure modes determining the risk associated with those failure modes, developing a maintenance strategy that minimize the occurrence of the high-risk failure modes
- Such type strategy plays a vital role in managing risk at sites like mines.

Proactive maintenance tactics do not only apply to one method. The type of parameter must be considered to get maximum results. [12]. The combination of RBM and RCM methods will be used to create a simulation table to determine the cost/ ton. (budget maintenance/ budget mined)

The process of re-operation of mining operations will be discussed more precisely using the RBM system. The purposed is to optimize existing assets and optimal costs in line with the production target by the company.

The valid data and complete inspection analyzed as asset condition indicator. The table shows the actual condition of the asset refer to failure mode that analyze (equipment health) and several of machines status.

A comprehensive framework must cover the operational requirements with the maintenance capability to provide machinery.

A comprehensive framework must cover the operational requirements with the maintenance capability to provide machinery. Scenarios to provide operational needs should consider:

1. Condition of the unit
2. Costs for repairs (Plan component replacement)
3. Human resources (mechanics), tools and workshop facilities
4. Availability of parts and components

RCM information and analysis is continued and developed with RBM. Simulation tables are created to combine with external factors that can influence the final result. These factors are part of the RBM.

3. RESULT AND DISCUSSION

The RCM process considers all failure modes that can cause a component to fail. Actual

condition and component life will be the main considerations to determine the priority of the maintenance process.

The first step for this method is RCM. Comprehensive failure mode on the system generated the actual condition with specific maintenance task. It's the guidelines to prevent the component failure and the next step will have improved of the reliability machines. [13]

Table 2. Fleet Condition report (CMMS Data)

Equip ID/#	STATUS	CONDITION
TRUCK 01 - TRUCK 07	PARKED UP	ASSET TRANSFER. HISTORY UNCKOWN. MACH. PERFORMANCE TEST (TA1/TA2), FRAME CRACKED. MAJOR COMPONENT OVERDUE
TRUCK 08	PARKED UP	REPLACE MAJOR COMPONENT
TRUCK 09 - TRUCK 11, TRUCK 16	PARKED UP	MACH. PERFORMANCE TEST (TA1/TA2), MAJOR COMPONENT OVERDUE
TRUCK 12	PARKED UP	REPLACE TRAN. MINOR REPAIR
TRUCK 13	PARKED UP	MACHINE WILL PARKED UP . MAJOR COMPONENT OVERDUE
TRUCK 14 - TRUCK 29	RUNNING	MACHINE WORKING. MAJOR COMPONENT OVERDUE
TRUCK 30		ASSEMBLE MACHINE
TRUCK 31		ASSEMBLE MACHINE
TRUCK 32		ASSEMBLE MACHINE
TRUCK 33		ASSEMBLE MACHINE
TRUCK 34		ASSEMBLE MACHINE
TRUCK 35		ASSEMBLE MACHINE

The simulation table generated refer to the main mine plan of the company. The gradual production and the requirement of the machines allow to generate any scenario with the better option to get cost / ton.

Table 3. Mine production budget vs Truck (OHT) requirement

Year	Periode	Est. Production	OHT req (unit)
Year I	Q1	7,000,000	11
	Q2	10,000,000	13
	Q3	14,000,000	16
	Q4	14,000,000	19
Year II	Q1	15,000,000	19
	Q2	18,000,000	22
	Q3	20,000,000	27
	Q4	22,000,000	34
Year III	Q1	22,500,000	34
	Q2	22,500,000	35
	Q3	22,500,000	35
	Q4	22,500,000	35

Table 2 data generated from actual condition that recorderd on the CMMS system. History of the maintenance, actual condition and al the failure mode of the system factor generated the maintenance task and certain priority. All maintenance activity and would applied on this case will determine higher cost/ton on the Q1 and continue decreased for the next quarter. (Table 4)
It's contradictive with mine production budget. The ideal condition, when the production increase, cost maintenance budget should be increased it

Table 4. Est. Cost per Ton – RCM Analysis

Year	Periode	Est. Production	Est. Cost	Est. Cost per Ton
Year I	Q1	7,000,000	$1,015,297	0.15
	Q2	10,000,000	$1,228,895	0.12
	Q3	14,000,000	$1,107,426	0.08
	Q4	14,000,000	$1,511,658	0.11
Year II	Q1	15,000,000	$1,331,631	0.09
	Q2	18,000,000	$1,293,796	0.07
	Q3	20,000,000	$806,309	0.04
	Q4	22,000,000	$900,855	0.04
Year III	Q1	22,500,000	$991,554	0.04
	Q2	22,500,000	$997,338	0.04
	Q3	22,500,000	$890,715	0.04
	Q4	22,500,000	$607,955	0.03
		Total	$12,683,429	

The RBM process considering the optimal cost management. The table below shows the real differences. This is due to the fact that some components which is the conditions are still good and reliable will continue to extend the life of the components. Furthermore,

maintenance activities will increase it along with increased costs and along with increased production

The financial aspect and the requirement and production requirement created technical analysis the condition of the asset with various maintenance task and priority of the repairs. These not any specific maintenance strategy but it's a combination of various other strategies which is devoted to the risk factor of the equipment. Maintenance Strategy applied to minimize high risk failure and showed it on the maintenance task. These maintenance strategies have to determine and covered all the failure mode

Another important consideration is all of the resources to carry out maintenance tasks as mechanics, tools, workshop capacity, and other resources. Maintenance activities that increase gradually also provide sufficient time for the recruitment process and also approve the components or spare parts needed

The RBM Process implemented in the ramp-up should be followed, processed as follows:

- Accurate historical data and OEM guidelines
- Physical conditions including equipment rating
- Operational characteristics
- Risk estimate for each unit/ equipment refers to the health of the unit / equipment analysis and statistical data
- Process accurate recording of health units (defects) and valid maintenance tasks

All the aspect of the system can have combined it with external aspect to get more option of the maintenance activities. RBM process applied with simulation table to determine the best scenario.

The simulation table process by considering internal and external factors can be obtained cost/ ton which is close to ideal. This is indicated by the cost/ ton that tends to be linear for all quarters. This shows a favorable condition between the increase in the maintenance cost budget and the budget of production. (Table. 5).

Table 5 Est. Cost per Ton – RBM Analysis

Year	Periode	Est. Production	Est. Cost	Est. Cost per Ton
Year I	Q1	7,000,000	$551,006.56	0.08
	Q2	10,000,000	$929,022.43	0.09
	Q3	14,000,000	$1,046,282.74	0.07
	Q4	14,000,000	$1,012,402.72	0.07
Year II	Q1	15,000,000	$1,096,229.09	0.07
	Q2	18,000,000	$1,167,552.93	0.06
	Q3	20,000,000	$1,138,212.40	0.06
	Q4	22,000,000	$1,278,242.03	0.06
Year III	Q1	22,500,000	$1,231,588.07	0.05
	Q2	22,500,000	$1,034,581.69	0.05
	Q3	22,500,000	$1,206,020.50	0.05
	Q4	22,500,000	$941,009.21	0.04
		Total	$12,632,150.38	

4. CONCLUSION

The Risk Based Maintenance, one of the maintenance strategy methods to prepare for the ramp up process was successfully applied in a mining company with cost control and health of heavy equipment become priority treatment using risk by integrating safety and failure. It's indicate the gradual mine production and gradual budget maintenance got the cost/ton tend to linier.

The Risk Based Maintenance method has various advantages when compared to other methods. In general, the benefits of Risk Based Maintenance, as follow:

- Save maintenance costs especially on the first year operation.
- Increase equipment reliability and availability
- Accurate estimation of remaining life
- Priority for maintenance urgency

On the ramp up process, the RBM have other benefits if it compared it with RCM system. The benefit are:

- Flexibility Manage maintenance costs incrementally
- Maximize the life of equipment / asset components
- Maximize all maintenance resources - workshops, equipment, mechanics, and etc

RBM process also have the following weaknesses:

- The maximized component life potential will lose the opportunity to recondition of the component due to catastrophic failure due to component fatigue

- Turnover parts / components will decrease because existing warehouse stock will be used when the component is damaged. The component replacement every unit will not have the same frequency.

5. REFERENCES

[[1] Manus Berg, Kristina Safsten (1999), Managing Production Ramp-up – Requirement on strategy content, Department of Industrial Engineering and Management, Jonkoping University, Sweden

[2] Mike Sondalini, (2019), Correct Equipment Maintenance Management Strategy Selection makes All the Difference,
https: //lifetimereliability.com

[3] Matsuda Reiko, Tsuji Toshiyuki (2006), Asset Management Solution for Improving Business Operational Efficiencies, NEC Technical Journal vol 1 No,2

[4] Angelo I. Reyes, (2015), Implementation of an Asset Management and Maintenance System for the College of Information and Communication Technology, International Journal of Innovation and Applies Studies

[5] Asraf W. Labib (2014), World-class maintenance using a comprised maintenance management system, University of Manchester Institute of Science and Technology (UMIST), Manchester, UK

[6] A. V. Kizim (2013), Establishing the maintenance and repair body of knowledge: comprehensive approach to ensuring equipment maintenance and repair organization efficiency, Volgograd State Technical University, Lenin Avenue 28, Russia, 400005

[7] C.B.H Nel & J.L. Jooste (2016), A Technologically-Driven Asset Management Approach to Managing Physical Asset – A Literature Review and Research for 'SMART" Asset Management, South African Journal of Engineering December 2-16 Vol 27(4)

[8] Greg Arbour (2019), Maintenance Strategies: 4 approaches to Asset Management

[9] Rizkya, I., Siregar, I., Siregar, K., Matondang, R., Henri, E.W., (2019), Reliability Centered Maintenance to Determine Priority of Machine Damage Mode, E3S Web of Conferences 125,22005

[10] M. Rusydu Alwi, (2016), Reliability Centered Maintenance dalam Perawatan F.O. Service Pump Sistem Bahan Bakar Kapal Ikan

[11] Aashis Khaira (2016) , Risk Based Maintenance – A Unique Approach of Maintenance Management, AMMJ - AMMJ – Asset Management and Maintenance Journal

[12] Shahin A , Aminsabouri, N, Kianfar, K, (2018) Developing a Decision Making Grid for determining proactive maintenance tactics: A case study in the steel industry, Journal of Manufacturing Technology Management Volume 29, Issue 8, 10 December 2018, Pages 1296-1315

[13] Zhang, Y, (2012) Study on the employment of RCM system by railway coal trucks in Hohhot, TEIN 2012 - 2012 3rd International Conference on Telecommunication and Information2012, Pages 296-300

[14] Xu, Y.a, Han, X., Yang, M.a, Wang, M.a, Zhu, X.a, Zhang, Y.b (2020), Condition-based midterm maintenance scheduling with rescheduling strategy, International Journal of Electrical Power and Energy Systems

[15] Wu, T., Yang, L., Ma, X., Zhang, Z., Zhao, Y. (2020), Dynamic maintenance strategy with iteratively updated group information, Reliability Engineering and System Safety
197,106820

[16] Bareiß, J.M., Jovanovic, A.S., Balos, D. , (2007) New concepts of RBI/RBM as applied in power plant practice, VTT Symposium (Valtion Teknillinen Tutkimuskeskus)
2(247), pp. 35-49

[17] Snider, B., (2007) , New concepts in asset reliability management, 2007 NPRA Reliability and Maintenance Conference and Exhibition - Technical Papers

[18] Ma, Z., Ren, Y., Xiang, X., Turk, Z., (2020), Data-driven decision-making for equipment maintenance, Automation in Construction 112,103103

[19] Zarei, M. (2018), Correct Modeling for Maintenance Scheduling, 26th Iranian Conference on Electrical Engineering, ICEE 2018 8472548, pp. 1356-1361

[20] Ramagaga, T., Telukdarie, A., Medoh, C., (2018), Critical success factors for the implemntation of reliability centred maintenance, 39th International Annual Conference of the American Society for Engineering Management, ASEM 2018: Bridging the Gap Between Engineering and Business pp. 282-290

[21] Deepak Prabhakar, P., Dharmaraj, A. (2019), Implementation of reliability centered maintenance in process industry – issues and difficulties, Journal of Advanced Research in Dynamical and Control Systems
11(7 Special Issue), pp. 538-547