Asset Management: A Review of Contemporary & Individualised Strategies

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Abstract— **In the last number of decades, immense pressure has been put on resources to intensify productivity to sustain the world's growing needs. The evolution of asset maintenance has undergone a myriad of development since its imitation as a management strategy in the early 1940's. Many contemporary strategies have been developed during this time including Reliability Centred Maintenance (RCM) and Total Productive Maintenance (TPM), but in recent decades the growth of individualised maintenance concepts have emerged in order to individualise maintenance with the aim of utilising organisational strengths for increased economic benefit. The benefits and drawbacks of both contemporary and individualised strategies are discussed within the text. It is recognised that available resources to the maintenance sector of an organisation plays a vital role in strategy selection. It is suggested that an individualised maintenance strategy built on applicable contemporary ideas and methods would form a tailor made strategy suitable to the requirements and resources of an organisation.**

***Index Terms*—Asset Maintenance, Individualised, Contemporary, TPM, RCM**

I. Introduction

A maintenance strategy can be described as a long term plan that covers all attributes of maintenance management in addition to clear action plans and direction to attaining the desired maintenance function [1]. Maintenance is conducted in order to stop the deterioration of an asset and to hold the inherent value of the asset for the financial benefit of the enterprise. For manufacturing enterprises to increase their effectiveness in growing competitive markets the importance of asset maintenance is continuously reinforced as the need for greater product quality and lower operational costs are becoming key economic areas of focus. Maintenance has no intrinsic value to an enterprise but is used to support the strategic objectives of the plant and the fundamental objectives of the organisation [2]. Due to the numerous different applications and mechanisms of production assets, contemporary strategies such as Reliability Centred Maintenance (RCM) and Total Productive Maintenance (TPM) may be suitable for one asset, but it may not be the most appropriate strategy for another asset. In order to apply the most suitable strategy, familiarity of the assets and the obtainable resources must be recognised along with a comprehensive awareness by top management of the affecting factors surrounding asset maintenance.

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II. Evolution of Maintenance

A. First Generation

The demand for reliability and productivity has led to the creation and implementation of various maintenance management strategies. The evolution of maintenance strategies can be subdivided into three generations that have emerged since the 1940's and have developed to the present day as outlined by J.Moubray [3]. The first generation nucleated pre-World War Ⅱ. During this time, manufacturing was highly un-mechanised; which lead to little downtime. The simplicity and over-design of assets made them reliable and easy to repair. Asset maintenance was not of high importance to most managers with only the need for simple lubrication, cleaning and servicing required. Run-to-failure was the maintenance strategy most prominently employed [3].

B. Second Generation

The second generation (1950's to 1970's) witnessed immense progression in the ability and complexity of industrial equipment. Awareness of maintenance as a value added process grew in the 1950's as the cost of equipment failure escalated to a level that it was necessary for action to be taken in order to reduce production related costs. The 1950's period was post World War Ⅱ, and maintenance strategies being implemented at the time were not adequate particularly for equipment such as modernised commercial aircraft [4].

The development of Preventive Maintenance (PM) in 1951 introduced a periodic maintenance schedule based on time or asset utilisation where the asset requirements would be recognised and a time-frame would be planned for maintenance implementation [5]. Corresponding to the development of PM, predictive maintenance also evolved in the 1950's in response to asset deterioration under different circumstances.

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This strategy allowed for asset conditions to be maintained and diagnosed by measuring physical characteristics like temperature or vibration. The appropriate maintenance was planned and conducted only after a fault has been recognised [6].

In 1957, Corrective Maintenance (CM) was introduced and brought about changes in the design of assets allowing for improvements in reliability and ergonomics. For CM to be applied, a problem with the asset must first be established before any corrective action is taken. The knowledge gained during the CM could then be applied to the next generation of assets to further improve asset efficiency [5].

Additionally, the 1950's witnessed the commercial development and advance of Total Productive Maintenance (TPM). TPM involves the cooperation of the entire organisation from top management to the staff on the production floor in an effort to reduce costs and improve workplace efficiency throughout the organisation. A Japanese enterprise "Nipondenso" was the first organisation to incorporate TPM plant wide in 1960 [7].

Core to the progression of TPM is the training and development of the personnel with the support of training programmes to help create an expert workforce within an organisation. To allow for a true TPM strategy to progress, funding in the required areas must be made available. The cost of implementing TPM can vary depending on different organisational factors and the pace at which TPM is being applied by the organisation. Other than the cost of training, the age and condition of assets will also determine the overall cost of implementation as older assets will occasionally require additional parts [8]. Although costs may be high, the results of implementation as described by J.Venkatesh [7] will encourage essential changes within an organisation that will generate valuable financial and personal growth such as:

1) Reduction of maintenance cost
2) Multi-skilled workforce
3) Production of goods without the reduction in product quality

Although TPM can arguably to be one of the best ways of improving the total efficiency throughout an organisation, there are various areas within TPM that can cause complications during its implementation. Sinha P.K [9] has extensively reviewed barriers to TPM which include:

1) Resistance to change from the workforce
2) Fear of job loss amongst employees
3) Insufficient resources (money, time, skill level)

Due to the dramatic changes TPM can have on organisational behaviour, responsibilities, skill development and the additional use of information technology, the success rate for most organisations is less than 30% [10]. According to E.Hartmann [11], organisations that try to implement TPM a second time also typically result in failure.

Later in the second generation of development, Reliability Centred Maintenance (RCM) originated and was utilised by the U.S Department of Defence [12]. This strategy was adopted mainly by the aircraft industry and is used to determine the maintenance needed to ensure that assets fulfil their intended purpose while in operation [13]. The RCM strategy focuses on minimum safety standards and the development of maintenance plans and rules [3] and in 1978 when a report entitled "Reliability Centred Maintenance" published by Stanley Nowlan and Howard Heap became the report that all RCM approaches are now based on. It is a predictive methodology that is also used to improve asset performance as well as the reliability of the end product [14]. It is commonly used to remove inefficient PM tasks from existing maintenance plans [15]. The success of RCM lead to an increased understanding of cost effectiveness and risk levels [16].

Comparable to TPM, RCM similarly exhibits both advantages and disadvantages in its implementation. John Moubray [3] outlined in his book RCM Ⅱ, the seven basic questions to RCM. These questions are:

1) What are the functions and associated performance standards of the asset in its present operating context?
2) In what ways can it fail to fulfil its function?
3) What causes each functional failure?
4) What happens when each failure occurs?
5) In what way does each failure matter?
6) What can be done to predict or prevent the failure?
7) What should be done if a suitable proactive task cannot be found?

To have a true RCM strategy in place, RCM maintenance should comply with the JA1011 (Evaluation criteria for RCM processes) standard [17]. Numerous benefits can be gained by using RCM including [18]: The lowering of maintenance costs by removing unnecessary maintenance and overhauls, the reduction in the frequency of maintenance implementation, increased reliability of components, increased emphasis on critical components and the use of root cause analysis to assess the cause of component failure. Difficulties generally associated with RCM include: the high start-up costs associated with the training of staff and the purchasing of equipment used for predictive maintenance.

The potential savings that can be achieved using RCM are sometimes not recognised by management, therefore preventing its initiation [19].

Due to the complexity and detail required to carry out RCM successfully, the success rate of implementation is in the range of 5-10% with about 90% of applications resulting in failure [20].

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C. Third Generation

By the end of the 1970's, maintenance moved into its third generation of development transition. The progression in technology and the emphasis on health/safety and the environment emerged as catalysts for new developments.

The advances in technology lead to the development of smaller, faster computers which replaced their slower, bigger ancestors from the past [3] encouraging the growth of expert systems. The 1980's saw the advancement of atomisation and the growth of dependency on the reliability and availability of organisational assets. The focus was on having zero down time or no in-service breakdowns [21]. Advancements in maintenance support structures such as Decision Support Systems (DSS) and Failure Mode Effect Analysis (FMEA) lead to greater strategy/policy selections along with developments in predictive maintenance technologies also aiding maintenance strategy selection. A reorientation in organisational thinking towards team work and participation further enhanced maintenance management strategies throughout the definable third generation period [3].

As a result of numerous strategies and technologies being available to today's managers', strategy selection is now more effective than ever before. It must be admitted however that there is no one standard solution and many of the concepts are only practical for specific industry or assets [22]. Contemporary maintenance concepts have many advantages such as a proven procedure to follow, as with RCM, however they also incur various disadvantages as follows.

Firstly, a contemporary strategy, such as TPM, can be resource intensive. Its implementation requires long periods of time, intensive training programmes and total commitment from all staff members [23]. These drawbacks are also confirmed by a survey conducted in the UK of 36 small and medium sized manufacturing enterprises [32]. The survey identified some of the potential barriers that can be faced by maintenance managers. Of the enterprises surveyed, 80% of management said that the lack of finances constrained the adoption of new maintenance approaches and that 84% reported that detailed and continual training programs would be needed if a new maintenance approach was introduced. However, 100% of the respondents said that no finance would be made available for training programmes.

Additional to the available resources, implementation of a contemporary strategy typically require asset data and information to be readily available in a compressed form that is accessible to all maintenance staff members [24]. However, many organisations do not have this information readily available.

Due to the above limitations, organisations are moving from contemporary solutions that may not suit their resource and staff constraints and are now leaning towards the utilisation of their internal experience, knowledge and skill to design a maintenance strategy that suits their needs by using an individualised approach.

An individualised approach to maintenance consists of "hand picking" from contemporary maintenance strategies and using their useful techniques and ideas to create a unique strategy for the enterprise [23]. It emphasises asset characteristics and allows for an appropriate maintenance strategy to be applied. It also allows for the decision making of key characteristics easier by allowing traditional concepts more available to choose from. Finally an individualised approach allows for the utilisation of appropriate resources by carefully selecting assets that require maintenance and applying a suitable maintenance solution to each asset [25].

Many individualised maintenance strategies have been developed over the last number of decades and are applied to an array of industries. An example of individualised maintenance strategy development and implementation is show by Waeyenbergh & Pintelon with the CIBOCOF framework [25, 26]. Centrum voor Industrieel Beleid Onderhouds Concept Ontwikkelings Framework (CIBOCOF) or in English (Centre for Industrial Management Maintenance Concept Development Framework) is an individualised maintenance strategy that is unique to the organisation/enterprise. The concept does not emphasis on one goal, but allows there to be emphasis on other areas such as: resource and asset examination, technical and functional inspection, maintenance policy selection, policy implementation and delivering feedback on the process, also providing procedures on how to share the information throughout the organisation. CIBOCOF uses a reiteration cycle of planning, doing, controlling, and adjusting (PDCA – approach), which when complete provides a firm maintenance plan.

It is outlined that the improvements of this strategy included: an increase in the profitability of the organisation, improvement in customer satisfaction and also workplace safety. The CIBOCOF maintenance framework was successfully applied to a light production enterprise where it was found that the modules could be used as a whole or used independently if required.

In addition to the development of CIBOCOF, an approach known as Value Driven Maintenance Policy (VDMP) was established in order to show the hidden values of maintenance and how organisations can benefit from these values [23]. In terms of VDMP, value is defined as "the delivery of maximum availability at minimum cost" [27]. The approach was developed using principles and concepts from TPM, RCM and Risk Based Inspection (RBI) and it requires an organisation to concentrate on the dynamic prospects for value creation using appropriate steps/techniques instead of using a one method fits all approach [28]. The steps used to implement VDMP include [29]:

1) Create a definition of the maintenance planning, tactical and central objectives of the production plant

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2) Categorise equipment locations into maintenance categories along with their functional necessities and requirements
3) Select appropriate maintenance strategies to implement for asset maintenance

These steps encourage the continuous improvement of cost effectiveness associated with assets maintenance.

Central to VDMP is a method called Experience Based Reliability Centred Maintenance (EBRCM) that uses feedback data and decision logic to methodically select maintenance tasks for assets [30]. This approach utilises the internal expert and operating knowledge in collaboration with FMEA's and decision logic methods to create an updated maintenance plan that is unique to the requirements of an organisation. To complement the improvements made be a VDMP, a life cycle analysis should be carried out before the purchase of any asset to estimate the total cost of an asset before installation.

As shown, the structure of individualised maintenance strategies can be as diverse as contemporary strategies with numerous steps to be taken before implementation is successful. In general, organisations are leaning towards individualised approaches to avoid costly areas that are associated with contemporary strategies and use organisational strengths such as internal experience to make a strategy customised to their available resources. However, there are some drawbacks to individualised approaches.

Although the individualised approach requires organisations to utilise internal knowledge and experience, Naughton & Tiernan [24] indicate that there is a lack of self-belief in the practitioners own abilities and a lack of regard towards experience based knowledge amongst personnel. With that, their research has highlighted further difficulties such as;

1) Experience based protectionism
2) Fear of change amongst employees
3) Lack of management support
4) The overall cost of the change initiative
5) The lack of plant/process knowledge
6) Scepticism and/or low morale for the change initiative

A positive change in management support is necessary for maintenance strategies to deliver their economic benefits. A change in organisational culture is also essential to allow for a smooth transition of both individualised and contemporary strategies into an organisation. For individualised strategies to continue their effectiveness, it is suggested that key areas within the implemented strategy should be reviewed periodically to ensure consistency and quality of the concept and to account for changes within the surrounding environment. This aspect may cause drawbacks in the individualised strategy due to its time consumption [23].

III. Conclusion

Contemporary maintenance strategies such as RCM and TPM have been successfully implemented to an array of industries with numerous accounts of their benefits being acknowledged by diverse organisations. They typically have well-structured steps that allow for detailed implementation of maintenance to be carried out on industrial assets. However, contemporary maintenance strategies do have drawbacks that include: the length of time needed for implementation, the cost of implementation (training and purchasing of predictive equipment) and the amount of detail/information about the process required for the strategy to work at its full potential.

Due to the various requirements needed for successful implementation; a lot of organisations opt to go for an individualised strategy that will work with the resources available to their maintenance sector. Many organisations can find that contemporary strategies are not suitable to their requirements. It is known that the budget allocated to the maintenance sector of an organisation plays a huge role in strategy selection and may determine the strategy to be used. Although the type of industry may also dictate the selection process, an individualised strategy could exploit the resources available to the maintenance sector. The workforce knowledge, skill and experience could also be utilised to create a strategy suited to the requirements of the organisation, especially if there is a lack of resources needed for particular aspects required for a true contemporary maintenance strategy.

Although individualised strategies have many benefits, they also incur some disadvantages including the lack of regard towards the experience based knowledge amongst personnel. This can hinder the development of the strategy and will require full management support in order for the strategy to be effective. An organisation needs a flexible strategy that applies ideas and methods from contemporary concepts in order to tailor the requirements and resources of the organisation into the implemented strategy.

IV. Acknowledgements

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V. References

[1] Knackstedt, Torsten. What is a maintenance strategy? *Kwaliteg.* [Online] 2011. [Cited: 26 January 2011.] http://www.kwaliteg.co.za/.
[2] Keeney, R. A path to creative decision making. *Value-focosed thinking.* Cambridge MA : Harvard University Press, 1996.
[3] Moubray, John. *Reliability-Centered Maintenance.* 2. s.l. : Industrial Press Inc, 1997. p. 320.
[4] Kennedy, Ross. Examining the processes of RCM and TPM. *Plant Maintenance.* [Online] January 2006. [Cited: 19th January 2011.] http://www.plant-maintenance.com/articles/RCMVsTPM.pdf.

[5] Ben-Daya, Mohamed, O. Duffuaa, Salih and Raou, Abdul. *Handbook of Maintenance Management and Engineering* . s.l. : Springer, 2009. p. 420.
[6] Girdhar, Paresh and Scheffer, Cornelius. Practical machinery vibration analysis and predictive maintenance. s.l. : Elsevier, 2004.
[7] Venkatesh, J. An Introduction to Total Productive Maintenance. *Plant Maintenance Resource Center.* [Online] 03 August 2009. http://www.plant-maintenance.com/articles/tpm_intro.shtml .
[8] Gupta, Sorabh, Tewari, P C and Sharma, Avadhesh Kumar. TPM Concept an Implementation Approach. *Maintenance World.* [Online] [Cited: 02 February 2011.] http://www.maintenanceworld.com/articles/sorabh/research_paper.pdf.
[9] Sinha, Dr.Pradip Kumar. *Manufacturing and Operations Management.* 1. s.l. : Prakashan, December 2008.
[10] Choy DS , Siam Yoke . TPM Implementation Experiences . *Maintenance Resources.* [Online] [Cited: 02 February 2011.] http://www.maintenanceresources.com/referencelibrary/ezine/tpmimplementation.htm.
[11] Hartmann, Ed. Prescription for Total TPM Success. *Maintenance Technology* . [Online] 01 April 2000. [Cited: 02 February 2011.] http://www.mt-online.com/component/content/article/178-april2000/573-prescription-for-total-tpm-success.html?directory=90.
[12] August, Jim . Applied reliability-centered maintenance. s.l. : PennWell, 1999.
[13] Dunn, Sandy. Maintenance Terminology - Some Key Terms. *Maintenancere Sources.* [Online] 2010. [Cited: 10 November 2010.] http://www.maintenanceresources.com/referencelibrary/maintenancemanagement/keyterms.htm#RCM.
[14] Telang, A D and Telang, Amit. *Comprehensive Maintenance Management: Policies Strategies and Options.* s.l. : PHI, 2010.
[15] *Reliability Centered Maintenance.* Rausand, Marvin. 1998, Reliability Engineering and Safety Systems.
[16] Cadick, John, Capelli-Schellpfeffer, Mary and Neitzel, Dennis. *Electrical safety handbook.* 3. s.l. : The McGraw-Hill Company, 2006. pp. 5-5.
[17] Moore, Ron. *Selecting the right manufacturing improvement tools: what tool? when?* s.l. : Butterworth-Heinemann, 2007.
[18] Technology, Reliability and PdM. Reliability Centered Maintenance Advantage and Disadvantages . *PM-PdM Technology for Manufacturing Industries.* [Online] 06 January 2010. [Cited: 16 December 2010.] http://preventive-predictive-maintenance.blogspot.com/2010/01/reliability-centered-maintenance.html.
[19] Lingham, Leo. Management Consulting/Maintainance Management. *AllExperts.* [Online] 09 March 2010. [Cited: 03 February 2011.] http://en.allexperts.com/q/Management-Consulting-2802/2010/9/MAintainance-Management.htm.
[20] Bloom, Neil B. 3 Day In-house RCM Training Seminars. *RCM Training Seminars.* [Online] 2005. [Cited: 02 February 2011.] http://www.rcmtrainingseminars.com/index.html.
[21] Jabar, Hisham Bin and Bhd, Segi Perkasa Sdn. Plant Maintenance Strategy: Key for enhanceing Profitability. *Maintenance Resources.* [Online] 2003. [Cited: 10 November 2010.] http://www.plant-maintenance.com/tzd.shtml.
[22] *A framework for maintenance concept development.* Waeyenbergh, Geert and Pintelon , Liliane. 2000, International journal of production economics, pp. 299-13.
[23] Murthy , D N.P and Kobbacy, K A.H. Complex System Maintenance Handbook. s.l. : Springer, 2008, pp. 34-35.
[24] *Individualised Maintenance Management: A Proposed Framework & Case Study*. Naughton , Michael Daragh and Tiernan, Peter, In Print.
[25] *CIBOCOF: A framework for industrial maintenance concept developement.* Waeyenbergh, Geert and Pintelon, Liliane. 2006, International journal of production economics, pp. 633-640.
[26] *CIBOCOF: A framework for industrial maintenance.* Waeyenbergh, G and Pintelon, L. 2006, International Journal of Production Economics, pp. 633–640.
[27] *Value Driven Maintenance-creating shareholder value with maitnenance.* Haarman, M. 2004, Journal of Maintenance and Asset Management, pp. 29-32.
[28] Gharachorlou, Kamran and Jonker, Remco . Getting lean through value-driven maintenance. *The Engineer.* [Online] 6 May 2008. [Cited: 18 November 2010.] http://www.theengineer.co.uk/channels/process-engineering/getting-lean-through-value-driven-maintenance/306009.article.
[29] *Value-driven maintenance planning for a production plant.* Rosqvist, T, Laakso, K and Reunanen, M. 1, 2007, Relibility Engineering and System Safety, Vol. 94, pp. 97-110.
[30] *Experience based reliability centred maintenance—a case study of the improvement of the maintenance programme for valve drives.* Laakso , K, Hänninen, S and Simola , K. 1995, The international journal for all those concerned with the management of physical assets, pp. 333-350.
[31] *Maintenance Strategy Development within SME's: The Development of an Integrated Approach.* Baglee, David. Sunderland : International Maintenance Conference , 2008. International Maintenance Conference .

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