



THE RECOMMENDATION AND VALIDATION OF AN APPROPRIATE PHYSICAL ASSET MANAGEMENT POLICY FOR PRASA'S METRORAIL DIVISION

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ABSTRACT

The problematic state of public transport by rail in South Africa is common knowledge. Improved management of the physical assets of Metrorail is required. Through the development of a generic policy statement, the existing Physical Asset Management (PAM) strategies and techniques can be improved. This study tested the generic policy statement by deriving a roadmap from the statement. The roadmap was successfully applied to the wheelset maintenance procedures of Metrorail through highlighting problem areas and identifying financially sound alternatives.

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1. INTRODUCTION

The reversal of the irrefutably poor state of public transport in South Africa, specifically rail transport, has gained traction. The past two decades have seen the deterioration of the physical assets of South Africa's passenger rail industry, which has been brought on by a lack of significant investment into the physical assets since the mid-1980s and the Physical Asset Management (PAM) systems [1] [2]. Local media has covered the Rolling Stock Recapitalisation Program, but change is also occurring to the PAM systems.

In working with the Passenger Rail Agency of South Africa (PRASA) and its subsidiary Metrorail, it was discovered that their PAM strategies have not kept pace with global and local standards [3]. A variety of PAM strategies exist with varied areas of application. The choice of PAM strategies depends of the strategic intent of the organisation to which the strategy will be applied. The strategic intent of the organisation manifests itself through its particular PAM policy [4]. A PAM policy provides guidance and a framework, which allows the selection and development of specific PAM strategies that conform to the strategic intent of an organisation and align with other existing policies [5].

Upon an initial investigation it was revealed that neither Metrorail nor PRASA, have a PAM policy that guides and acts as a framework for the development of the PAM strategies that they employ [3]. In light of this a generic policy statement, called Requirement-based Asset Management (ReBAM), was developed. The aim of this article is to discuss the effectiveness of a generic PAM policy statement in a passenger rail environment.

The assessment of the suitability of a generic policy statement will allow similar types of organisations, with different PAM needs, to confidently develop and evaluate their own specific PAM policies by the use of ReBAM.

In this article relevant literature regarding the development of PAM (Physical Asset Management) policies will be discussed, along with specific literature regarding PAM strategies and relevant contextual information regarding Metrorail. Following this, the generic policy statement is explained, with the development of a policy statement-based roadmap and the application of elements of the roadmap to wheelset maintenance. The results of this application are then discussed and conclusions drawn up.

2 LITERATURE

2.1 The development of PAM policies

The Physical Asset Management (PAM) policy of any company is a written statement that articulates and explains the target or direction and the framework that that company intends to adhere to, specifically for the management of its physical assets [5] [6] [4].

There are several key requirements for the development of a PAM policy: A detailed understanding of the specific industry or organisation, for which the policy is to be developed, is required. Secondly, suitable knowledge and experience of the field and PAM and its strategies and concepts needs to have been gained. Lastly, in order to ensure relevance, a procedure for reviewing and renewing the policy and strategies needs to be put in place [6] [7]. Section 2.2 and 2.3 discuss the relevant PAM strategies and the specific organisation respectively.

2.2 Relevant PAM strategies and concepts

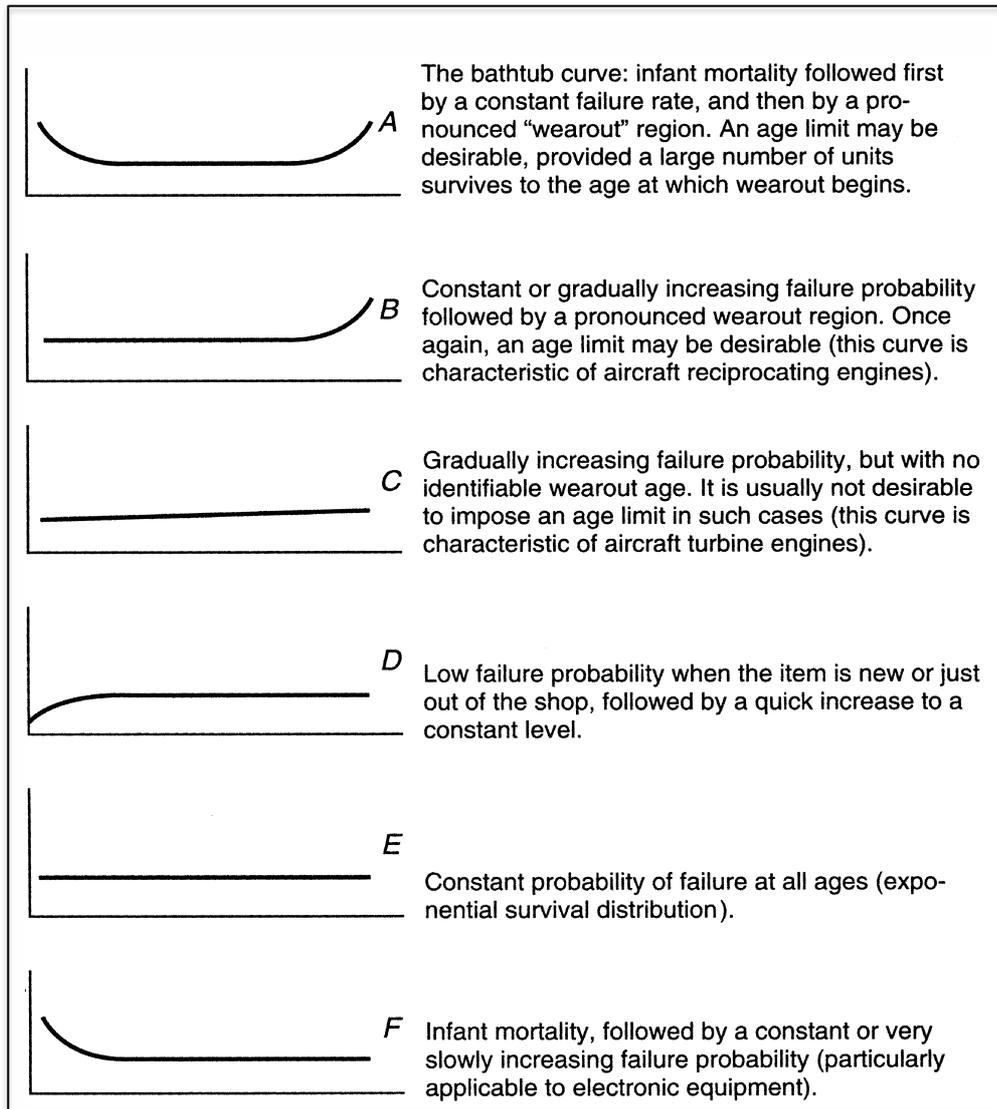


Figure 1 The six common failure mode/age-reliability profiles [8]

The largest part of PAM is maintenance, if the is known how the asset fails than it can be maintained. An understanding of how and when an asset incurs a failure allows for improved management of that asset [8]. The type of maintenance selected for an asset should be influenced by the failure mode of that asset. The failure profiles are generally grouped into six profiles as shown in figure 1.

Table 1 lists and briefly describes five different maintenance strategies, two methodologies and two standards that were investigated for this study. They can be grouped as being Corrective Maintenance/Breakdown Maintenance (CM/BM) or a subset of Preventative Maintenance (PM). PM can be split into four categories based on when and how maintenance tasks occur. They are Time Directed Maintenance (TDM), Predictive Maintenance (PdM), Run-to-failure (RTF) and Design-out Maintenance (DOM). All other forms of PM consist of a combination of two or more of these categories.

**Table 1 is a summary of the relevant Maintenance strategies(5), methodologies (2) and standards (2) that were investigated**

Acronym	Acronym Description
CM/BM	Corrective Maintenance/Breakdown Maintenance: fixing any un-anticipated fault/failure or breakdown [9] [8].
PM	Preventative Maintenance: all action taken to prevent or detect failures; includes TDM, PdM, RTF, DOM.
TDM	Time Directed Maintenance: replacing or reconditioning a component/system after a specific time period, based on the Original Equipment Manufacturer (OEM) or historic failure data [8].
PdM/CBM/CD	Predictive Maintenance: maintenance on components based on a concrete inspection that assesses the condition of the assets and can predict its failure [8].
DOM	Design-Out Maintenance: the action whereby the asset/asset components are redesigned and replaced, specifically to remove a fault [10] [8].
RTF	Run to Failure (operation until failure or breakdown): a maintenance technique applied to assets/asset components where any other strategy is neither viable nor feasible and the health, safety and environmental impact is unacceptable [8].
TPM	Total Productive Maintenance: focuses on the operator & maintainer relationship specifically in a production environment, with special emphasis on how to do the maintenance [9].
RCM	Reliability Centred Maintenance: a maintenance strategy that focuses on retaining system functionality. It determines the most suitable maintenance concept and inspection frequency, specifically focusing on the largest contributors to failure [8].
Lean Maintenance	An evolution and improvement of TPM, based on Lean Manufacturing principles [11].
PAS 55	Publicly Available Specification number 55 from the British Standards for optimised management of physical assets and infrastructure. It provides definitions and requirement specifications for joined-up, whole-life asset management [5] [6].
IRIS	The International Railway Standards Institute: its sole purpose is to develop standards for the Railway Industry from the supplier to the operator. It is fully compliant with the International Standards Organisation (ISO) specifications and by applying for IRIS certification ISO is included automatically [12].



2.2.1 Reliability Centred Maintenance

RCM was developed for the airline industry but has steadily been applied to all types of physical assets. RCM is defined by the following four features:

- To preserve functions.
- To identify failure modes that could defeat the functions.
- To prioritize function need (via failure modes).
- To select applicable and effective PM tasks for the high priority failure modes.

To achieve these four features, a nine-step (7+2) plan was developed [8]. This process is as important as the four features of RCM. These nine steps are listed below.

Step 1: System selection and information collection.

Step 2: System boundary definition.

Step 3: System description and functional block diagram.

Step 4: System functions and functional failures – Preserve functions.

Step 5: Failure mode and effects analysis (FMEA) – Identify failure modes that can defeat the functions.

Step 6: Logic (decision) tree analysis (LTA) – Prioritize function requirement via the failure modes.

Step 7: Task selection – Select only effective and efficient PM tasks.

These seven steps form the basis of the RCM process and contain all four features of RCM. The following two steps are specifically included for continued success of RCM implementation [8].

Step 8: Task packaging – carrying the recommended RCM tasks to the shop floor

Step 9: Living RCM program – comprising the actions necessary to sustain the beneficial results of Steps 1-8

2.2.2 Total Productive Maintenance

Similar to RCM, TPM is an expansion and add-on to a basic PM system. It is a strategy that focuses on involving operators in basic aspects of maintenance. It emphasises the need for operators to take ownership of - and responsibility for - the equipment that they operate [9].

TPM is a strategy that aims to combine conventional PM practices with the total involvement of the employee. It has five specific aims:

- To establish a company structure that will maximise production system effectiveness
- To setup a practical shop floor system that aims to prevent any losses
- To involve all departments including the support services divisions
- To involve every single employee from senior management
- To achieve zero losses through small group activities

To achieve this, TPM is based on five pillars or core principles that were developed by Seiichi Nakajima [15]. In order to implement these pillars, a three-phase plan was developed based on three cycles. Together, they form the nine-step TPM improvement plan. The combination of which pillar forms part of which cycle is shown in table below. OEE in item 1 refers to Overall Equipment Effectiveness.

**Table 2 The relationship between the 5 pillars of TPM and the 3-cycle TPM plan adapted from [9]**

	Measurement cycle	Condition cycle	Problem prevention cycle
1. Continuous Improvement in OEE	✓	-	✓
2. Maintainer asset care	✓	✓	-
3. Operator asset care	✓	✓	✓
4. Continuous skill improvement	✓	✓	✓
5. Early Equipment Management	✓	-	✓

2.3 Relevant background information of Metrorail

Metrorail was originally part of the larger rail organisation called SATS (South African Transport Service), which became Transnet in 1990 [13]. In 1997 it was spun off to the South African Rail Commuter Corporation (SARCC), which is now known as PRASA (Passenger Rail Agency of South Africa) [14]. During the split from Transnet most of the large rail engineering services were separated from Metrorail and remained with Transnet [15].

According to the CEO of PRASA [16], when the SARCC became PRASA and ownership and operation of Metrorail was completely transferred to PRASA, PRASA found itself in a financially difficult situation. This was exasperated by the 25% and 32% increases in electricity costs in 2008 and 2009 [15]. In order to remain in operation, a cost containment exercise was implemented in July 2009, with various facets and numerous intended outcomes. One of the unanticipated results was that for 9 months payments for wheel maintenance were not made to Transnet and thus, no wheelset maintenance was done. There are three levels of wheel-set maintenance and Metrorail relies on Transnet for all of them.

After an investigation it was found that at present (2011), there exists no concrete, overarching PAM or maintenance policy within Metrorail or PRASA. Maintenance is being done based on the requirements of the Railway Safety Regulator (RSR) or according to the SARCC-Metrorail Main agreement from 1998, which does not contain a policy [17].

This manifests itself in two primary forms of maintenance, namely time directed maintenance (TDM) or run to failure (RTF), according to the senior engineers from Metrorail. However it is unclear what percentage of these RTF's are actually unplanned failures that are then resolved versus failures that are purposefully allowed to occur. Currently there is movement within Metrorail Engineering Services department to move from primarily TDM to Condition Based Maintenance/PdM. No program has been developed as yet.

3 METHODOLOGY

3.1 Explanation of Requirement-based Assets Management

In order to develop a specific PAM policy, a generic policy statement was developed based on the knowledge gained from extensive literature study and an investigation into PAM and different best practice strategies [5]. The following is the recommended policy statement:

Implement a suitable, sustainable and living national PAM policy based on the requirements of the asset component, the system and the organisation. This policy will also be known as Requirement-based Asset Management (ReBAM)



Each of the terms of the policy is briefly discussed below.

Implement: To carry out or do. The PAM system that is developed based on this policy needs to be put into action [18].

Suitable: This is one of the most important words in this policy. It means that any PAM system or strategy derived from this policy needs to be realistic enough to be achievable, yet challenging, so as to create a goal to strive for. It also needs to take the current situation of the organisation into consideration. It needs to align with the high-level requirements of the company, and all stakeholders [19] [18].

Sustainable: The PAM system needs to be sustainable from an environmental viewpoint. It also needs to be sustainable in the business sense. The derived system needs to aid the growth and improvement of the company that it is applied in, in such a way that it does not jeopardize the current or future operations. In short, the PAM system needs to be affordable and have a positive ROI. A sustainable PAM system is also both effective and efficient [18].

Living: This term has been included to highlight the need for improvement, specifically in the ever-evolving field of PAM. Thus, any system that is derived from the policy needs to be adaptable. It must evolve with the needs of the company. [8].

National: In large organisations with multiple branches the organisational structure and Regulatory Requirements do not make it feasible to have different strategies in different regions. However, the application of each strategy will lead to differing requirements in different regions. [18].

Program: Is a system or combination of methods and strategies that are applied in an organisation. Different failure modes require different preventative maintenance techniques. Thus all strategies that are considered need to form part of an organised, structured system, for manageability, effectiveness and efficiency [9] [18].

Requirements: The requirements for any asset component or system depend on the different failure modes of each component or system and the expected performance thereof. Although standardisation has its advantages, specific failure modes can only be addressed by using a specific set of concepts.

The second facet that is covered in by the term requirements are the regulations, as per national laws that are applied through the Regulator.

An organisational policy, such as a PAM policy, is created based on two key elements, as was explained in the literature study. The first is the investigation of the specific field to which the policy should apply; the second is the accumulation of understanding and insight into the specific organisation that it will be implemented in. It is therefore very difficult to evaluate any generic policy. In order to do so, the policy needs to be applied within an organisational context, then evaluated in that context, in order to draw conclusions about the generic policy statement. Section 3.3 will discuss the policy within Metrorail's context in order to establish its validity and suitability [6] [4].



3.2 ReBAM-based roadmap

Before looking into the roadmap specifically, some general observations are required. These high-level derivatives of ReBAM are discussed in the following two paragraphs followed by the roadmap.

The first and most important observation is that there is no one strategy or procedure that is sufficient to satisfy all the requirements of a PAM system. As was discussed in the literature, every PM strategy is made up of four elements: TDM, PdM, FF, RTF and possibly DOM as a fifth. No current best practice strategy is based only on one of these. The two predominant current strategies (TPM and RCM) both include all elements mentioned. Thus the first conclusion that can be drawn is that any strategy that is implemented needs to be a hybrid strategy.

Secondly, within any proposed strategy, consideration needs to be given to taking the organisational AS-IS situation into account. Based on the current state of maintenance at Metrorail, RCM and TPM should form the basis of any PAM improvement program.

3.2.1 Basic Roadmap outline

This roadmap's development is based on ReBAM and the current state of PAM at Metrorail. A two-phase approach is suggested.

Phase 1 entails applying RCM to the Rolling Stock and Infrastructure departments of Metrorail, but subdivided within each geographical region. In parallel with this, the implementation of a TPM or TPM equivalent program at the workshops and for the infrastructure work teams, as well as operations. The initial implementation should be followed closely by an organisation wide rollout. Once TPM is firmly in place, Lean Maintenance should be applied to integrate and consolidate the RCM and TPM programs.

Phase 2 involves implementation and accreditation of either PAS 55 or IRIS or both, depending on the prerequisites of the standards and the suitability of each to the organisational and PAM situation at Metrorail at that time.

3.2.2 Why RCM and TPM?

Both RCM and TPM adopt an attitude of hybridisation towards PM strategies and procedures. Both incorporate structured implementation plans that tackle PAM in the context of the entire organisation, not only the operations and maintenance departments in isolation. RCM and TPM both also allow for further development of the PAM system [11].

Both RCM and TPM are firmly rooted in statistical foundations and, according to Smith [8], common sense. This element of common sense makes them easier to understand and easier to implement in an organisation where a PAM policy has not existed and the PAM strategies are stagnant [9] [8].

3.3 Application of ReBAM to wheelset maintenance

In order to validate the roadmap, and by implication the generic policy, an RCM analysis was performed at the Metrorail Rolling Stock Department in the Western Cape.

Step 1 of the analysis includes the selection of the system that is to be analysed. This selection is achieved by means of a Pareto analysis. Before performing a completely new Pareto analysis, the author investigated the possible existence of similar current activities. This investigation revealed that the Rolling Stock Planning Department does a similar



analysis, where operational faults and failures are documented. This analysis is known within Metrorail as the Top 7 [20].

From an investigation into the Top 7 analysis it was discovered that one of the biggest challenges that face PAM operations of the Western Cape Metrorail region is not the in service faults that constitute the Top 7, but rather wheel-related maintenance. The impact of the wheel set shortage on cancelled and shortened trains compared to the impact of the Top 7 faults is illustrated Figure 2.

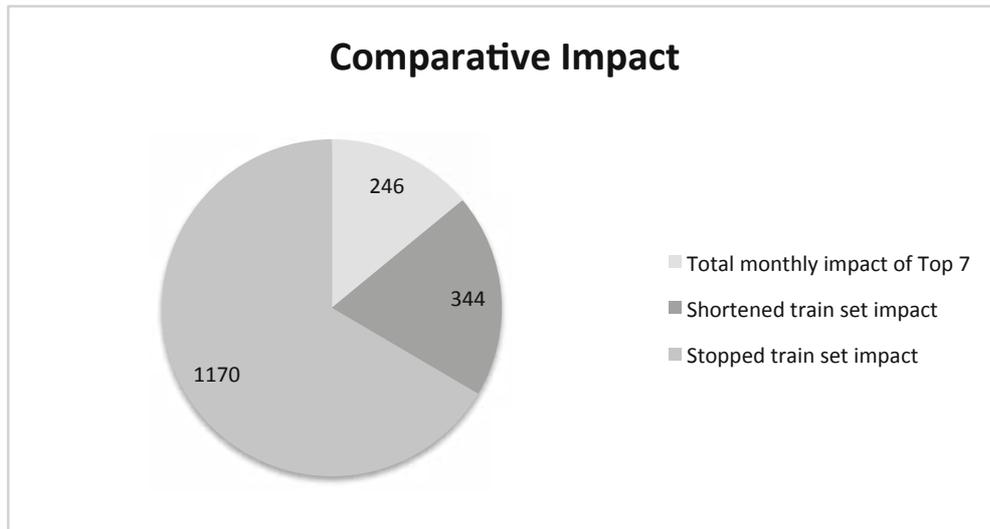


Figure 2 Comparative impact of unavailable train sets compared to the combined total of the Top 7

The findings from the investigation into the Top 7 resulted in wheelsets being selected as the system for the RCM analysis and in so doing completed the first step of the analysis. Steps 2-7 were then completed and led to the following findings.

- The current strategy of buying unused wheels from across the country is only a short term solution.
- There are currently no bearing related PM tasks being performed
- The wheelset shortage and backlog is primarily due to insufficient supply from Transnet

A secondary aspect of RCM is the items of interest (IOI). An IOI is any idea, thought or solution that has been developed as a result of the RCM analysis, but does not necessarily form part of deciding what the best strategy is [8]. The current backlog of reprofiling work and the lack of viable alternative supplier options are having a greater impact on the system functionality than the current PAM procedures of the wheel sets. The pursuit of retaining and maximising system functionality forms one of the core aspects of RCM, thus an investigation into an alternative to Metrorail-Transnet relationship was warranted.

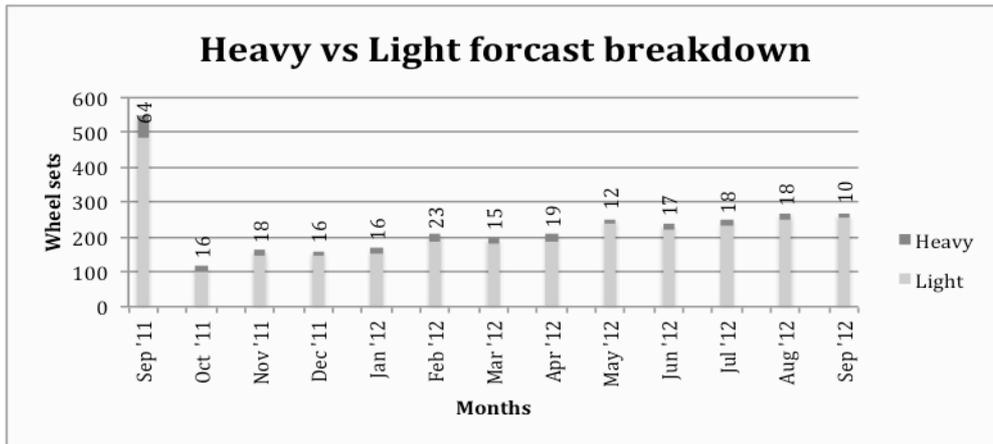


Figure 3 The forecast demand of light- and heavy wheelset reconditioning

The investigation into an alternative supplier to Transnet revealed that there is currently no viable alternative supplier for long-term wheel maintenance [21]. Thus, the viability of setting up a wheel workshop within Metrorail needs to be investigated. There are three alternatives that Metrorail could pursue. The first is to acquire a full wheel set workshop to perform all the required tasks. The second is to acquire both the under-coach system and wheel set workshop. The final option is to acquire only the under-coach system. However an under-coach system is limited to perform the light reconditioning. Thus Metrorail would rely further on Transnet for the medium and heavy work. A full workshop installation requires large amounts of capital, highly skilled and trained employees, and significant construction time. However, the greatest factor in considering any alternative is demand. Figure 3 shows the forecast demand, which has been split between light reconditioning and heavy reconditioning.

From Figure 3 it is evident that less than 10% of the wheel sets require heavy reconditioning, with a monthly average of 17 wheel sets. The primary and most expensive piece of equipment required for a wheel set workshop is a lathe. The capacity of the Hegenscheidt-MFD 165-CNC machine that is installed at Transnet is 36 wheel sets per 8-hour shift [22]. Converting this to a monthly production capability results in a monthly capacity of 756 wheel sets per month with one 8-hour shift per day and 21 working days per month. The estimated cost, as per Hegenscheidt-MFD, of equipment for a wheel set workshop is R 30 million, compared to the under-coach option, with an installation cost of R15,74 million [22]. The R15 million difference for the capability to recondition an extra 10% of wheel sets is not viable. Due to these findings, only under-coach options are considered further.

The conclusion of the application of the Pareto principle shows the same recommendation.

4 RESULTS AND DISCUSSION

4.1 Financial investigation of the ‘insource’ alternatives

Until recently, the under-coach maintenance systems were limited to under-floor lathe systems. The recent alternative to this system is a track based mobile lathe. The coach is lifted and suspended, whereupon the mobile lathe moves along the track under the coach and reprofiles the wheel set [23].

For the purpose of investigating the viability of either type of under-coach systems the two competing products produced by Hegenscheidt-MFD are investigated. Based on the requirements and specifications of Metrorail Rolling Stock, the following two products were deemed suitable and therefore investigated. The under-floor machine is a U2000-400, which is the same machine that is used at Transnet’s Saldanha workshop, the second is the



MOBITRUN^{®2}. The system acquisition price was quoted in Euros and converted to Rands at an exchange rate of 1:12. The production capacity figures are taken for one 8-hour shift per day, with 21 working days per month and 12 months per year. The U2000-400 requires a shunting vehicle to move the coach or train set and the MOBITURN^{®2} requires a row of lifting jacks [24].

Table 3 A breakdown of the capital required to acquire each system

	U2000-400	MOBITURN ^{®2}
Production capacity/year	3096	2748
Purchase cost	R11 640 000	R13 920 000
Installation costs	R1 500 000	R0
Shunting unit/ lifting jacks	R2 600 000	R22 220 478
Total	R15 740 000	R36 140 478

In order to calculate the Return On Investment (ROI), the operating costs need to be known. There is currently no MOBITURN^{®2} system in operation in South Africa. The operating costs of the U2000-400 could not be made available for this investigation. According to Hegenscheidt-MFD the operating costs for both the U2000-400 and the MOBITURN^{®2} are very similar. In order to proceed with the ROI analysis, the operating costs of both machines were taken to be the cost that Transnet charges Metrorail for each wheel set that is reprofiled by their U2000-400 at Saldanha. The cost per wheel set is R 2 604 per wheel set. The ROI is calculated by using the potential cost saving of both of the potential machines compared to the continued use of Transnet in Salt River as the income.

The following assumptions are made with regard to the ROI analysis.

- The comparative cost used for TRE Salt River is the average cheapest light repair cost according to the ratio between motor coach and plain trailer light repairs as per the forecast.
- The forecast for the number of wheel sets requiring a light repair is currently 90% of the total. For this comparison it will be taken as 80% of the total, to be conservative.
- The current practice (at Transnet Salt River) is to replace the bearings with each repair on any wheel set. With any under-coach wheel reprofiling, the bearings are not replaced. The maximum number of times that a tired wheel can be reprofiled is 5. Thus the longest frequency is 1:5 where the wheel set requires a new tyre in every fifth year and thus will also receive new bearings.
- The lifting jack price is supplied by Yale Engineering Products, with the cost calculated for the installation of an entire row of jacks to service a 14-coach train set.
- Depreciation is 20% per annum and is used as such on the total investment, including all peripherals. However the useful life of these products, normally exceeds 20 years. Thus the annualised ROI is calculated over 5, 10, 15 and 20 years with only the 20 year calculation table displayed here.
- The calculations do not include the tax benefit of depreciation.



Table 4 ROI comparison of the U 2000-400 and the MOBITURN®2 over the first 20 years

Average Annual ROI over first 20 years	U2000-400	MOBITURN®2
Operating cost/wheel set	R2 604,00	R2 604,00
TRE (Salt River) avg. cost	R5 509,89	R5 509,89
Saving/wheel set	R2 905,89	R2 905,89
Annual light demand (number of wheel sets)	1710	1710
Annual light demand with 1 in 2 bearing replacement	855	855
Annual light demand with 1 in 3 bearing replacement	1140	1140
Annual light demand with 1 in 4 bearing replacement	1282,5	1282,5
Annual light demand with 1 in 5 bearing replacement	1368	1368
Annual cost saving (1 in 2)	R2 484 531,97	R2 484 531,97
Annual cost saving (1 in 3)	R3 312 709,30	R3 312 709,30
Annual cost saving (1 in 4)	R3 726 797,96	R3 726 797,96
Annual cost saving (1 in 5)	R3 975 251,16	R3 975 251,16
Depreciation (5%)	R787 000	R1 807 024
Investment cost	R15 740 000	R36 140 478
ROI (1 in 2)	10,78%	1,87%
ROI (1 in 3)	16,05%	4,17%
ROI (1 in 4)	18,68%	5,31%
ROI (1 in 5)	20,26%	6,00%

From the table 4, it is apparent that the frequency with which the bearings need to be changed has a significant impact on the RIO. It is also apparent that both the U2000-400 and the MOBITURN®2 have significant spare capacity. The current forecast only takes the Metrorail demand into consideration. The Shoshaloza Meyl requirements would also have an impact and improve the ROI.

5 CONCLUSION

The need for PAM strategies and plans to be guided and bound by a framework, in order to align with the requirements of an organisation and its employees, physical assets and customers, has been highlighted throughout this discussion. To achieve this alignment and guidance, organisations need a PAM policy that facilitates the selection and development of PAM strategies and plans.

From literature it became evident that there can be no entire generic PAM policy that can be directly adopted by different organisations. A PAM policy needs to be specific for the situation and context of an organisation. Therefore, to address this need, a generic PAM policy statement was developed called ReBAM, or Requirement-based Asset Management, with the specific focus on facilitating the alignment of the PAM policy, with the needs, both present and future, of an organisation.



In order to discover the applicability of ReBAM, a proposed strategic roadmap was developed. The roadmap consists of two phases. The purpose of the first would be to lay the foundations of a “world-class” PAM system by getting the fundamental principles of PAM right. Phase 2 would then build on this foundation by looking at future best practices such as IRIS and PAS 55. Phase two was only developed as a concept, as it would be shaped by phase 1 and its outcomes.

Phase 1 was validated through application at PRASA’s Metrorail, specifically in wheelset maintenance in the Western Cape. The initial RCM analysis required a Pareto style analysis and resulted in the discovery of the Top 7. The investigation into the Top 7 brought forth the full application of RCM into the case of wheel set maintenance. The results and findings of the RCM analysis demonstrate the applicability of the policy-derived roadmap and by direct implication the benefit of ReBAM.

The development of the generic policy and the successful application of its derivatives have contributed to the field of asset management by providing a basis for the development of a PAM policy for an organisation. Due to its generic nature, the policy statement is not limited to any specific industry and can be applied to any organisation with PAM needs.

The diverse portfolio that PRASA manages highlights the significance of its plans to use ReBAM and further shows the breadth of the applicability of ReBAM.

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