

8. Strategic asset performance methodology for MPM model, which strive to link business strategy and maintenance performance
9. Human factors in MPM approach which integrates the soft and human factors, with usefulness of the diverse aspects of the performance system being considerably reliant on the proficiency, training, and inspiration of the inclusive human aspects in control of the maintenance function.

Generally, efficacious performance measurement methods can generate a critical part in converging employees and assets on a specific facet of business mission and the subsequent are regarded as key influences, vindicating the employment of a maintenance performance measurement system:

- quantifying value generated by the maintenance function
- qualifying investments
- reviewing resources apportionments
- Health, Safety and Environmental concerns
- emphasis on information control
- adjusting to fresh developments in business and maintenance strategies, and
- enterprise structural variations (Simões, et al., 2011).

2. Maintenance Performance Indicators Selection

As a mandate to safeguard a worthy performance of the manufacturing process, maintenance practitioners require a decent outline of maintenance practices and attainments and this can be reached by pursuing a meticulously distinguished maintenance performance measurement (MPM) system and with the allied performance indicators (MPIs) (Van Horenbeek and Pintelon, 2014). Performance measurement is a vital norm of the management process and similar to other industrial disciplines, the performance measurement of the maintenance discipline is imperative (Muchiri, et al. 2011). Clearly specified performance indicators can highly contribute towards the recognition of performance deficiencies between the existing and preferred performance levels and offer signaling of headway traction towards eliminating the shortcomings (Muchiri, et al. 2011). Additionally, performance measurements afford an essential linkage between the business strategy and shop-floor operations and thus aids application and accomplishment of enhancement endeavors (Muchiri, et al. 2011). The main function of MPIs is to expose insufficiencies in performance and to drill down to identify the origin of the issue, and ideally at the same time guiding towards the resolution option (Parida, et al., 2015).

Below is a depiction of a performance measurement system designed to relate to the business strategy.

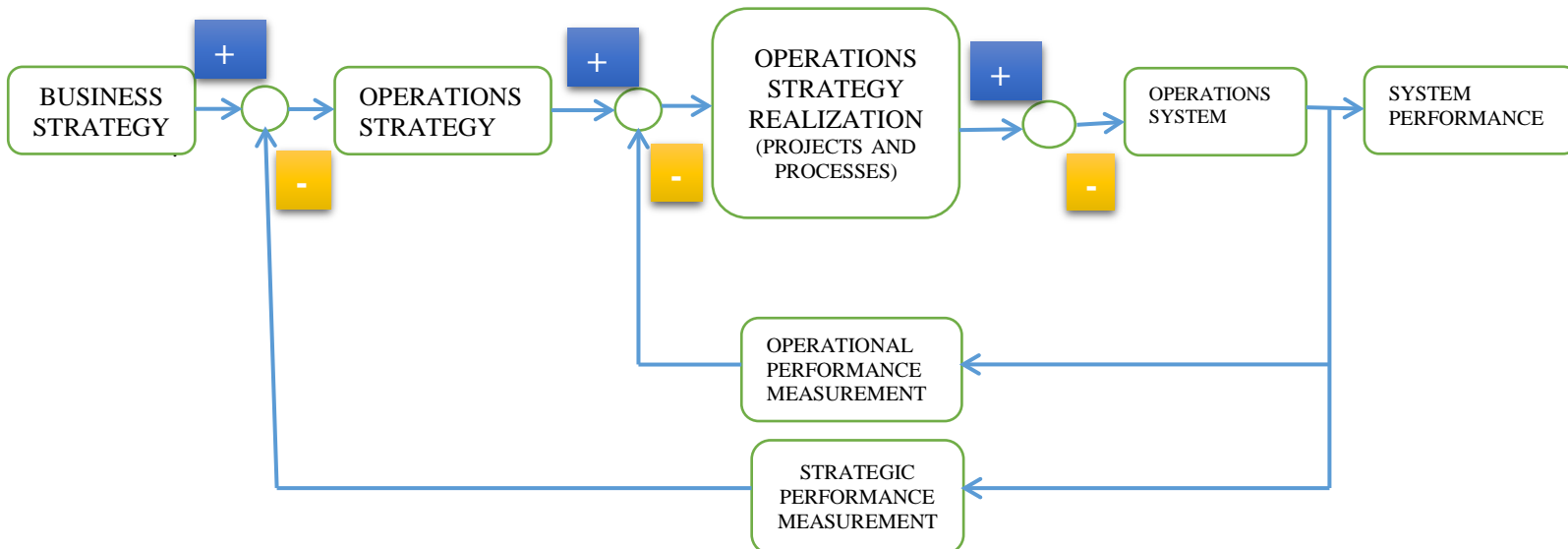


Figure 1. The strategic focused performance measurement system (Pineiro de Lima, et al., 2013).

Presently, there is a void in terms of a linkage concerning the business strategic objectives and the conforming maintenance performance indicators (MPIs), furthermore, only an insignificant number of the businesses possess a big proportion of maintenance resolutions elicited by the specified MPIs (Van Horenbeek and Pintelon, 2014). It is imperative that the MPM framework is lined up with the enterprise strategy and to achieve the business level objectives, there is need of a translation process to the shop floor or operative level of the business, with the maintenance precedence set in relevance functional criticality to overall business objectives to enable derivation and tracking of performance (Van Horenbeek and Pintelon, 2014). Figure 2 below shows the different hierarchical levels of an enterprise and the flow of performance objectives and indicators.

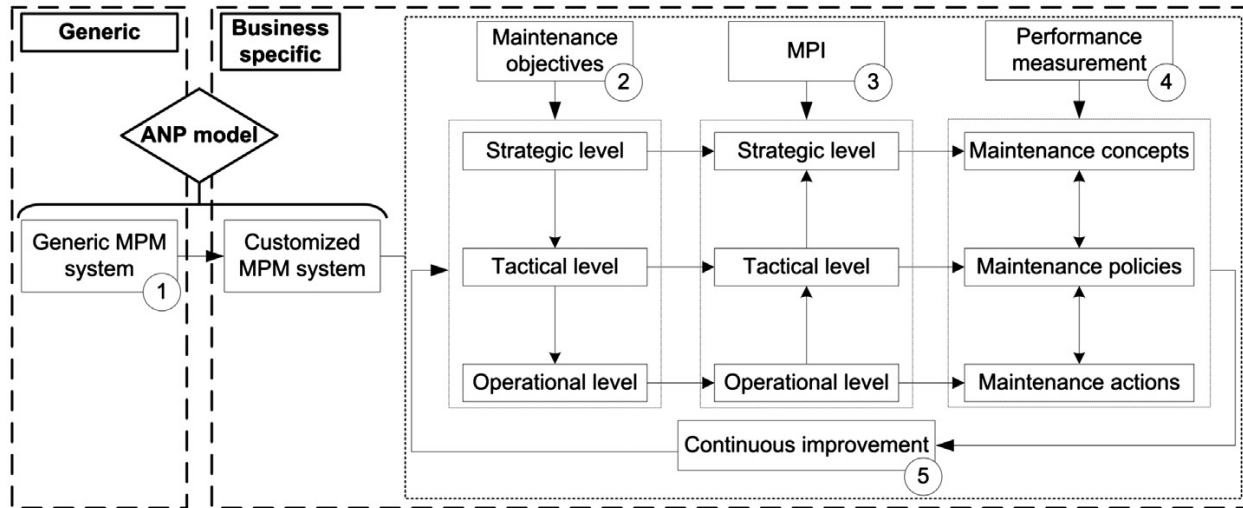


Figure 2. MPM structure linking all enterprise levels of decision making (Van Horenbeek and Pintelon, 2014).

In different organizational settings, the MPIs differ from business to business, but below is a summarized range of generic MPIs derived from the tactical level that an organization can apply in its maintenance function (Figure 3). It is essential to institute the maintenance function performance indicator set in different ranks, with the lowermost stage having indicators checking performance and maintenance regime of constituent parts (Martorell et al., 1999). Also, there should exist direct indicators, which are interrelated straight with the functioning data being reported from the operation and indirect indicators, which are consequential from direct or additional indirect indicators (Martorell et al., 1999). Parida, et al. (2015) proposed that MPIs can be generally categorized as leading or lagging indicators where leading indicators give caution about straying measures ahead of time and lagging indicators show the circumstance after the performance has occurred (Parida, et al., 2015).

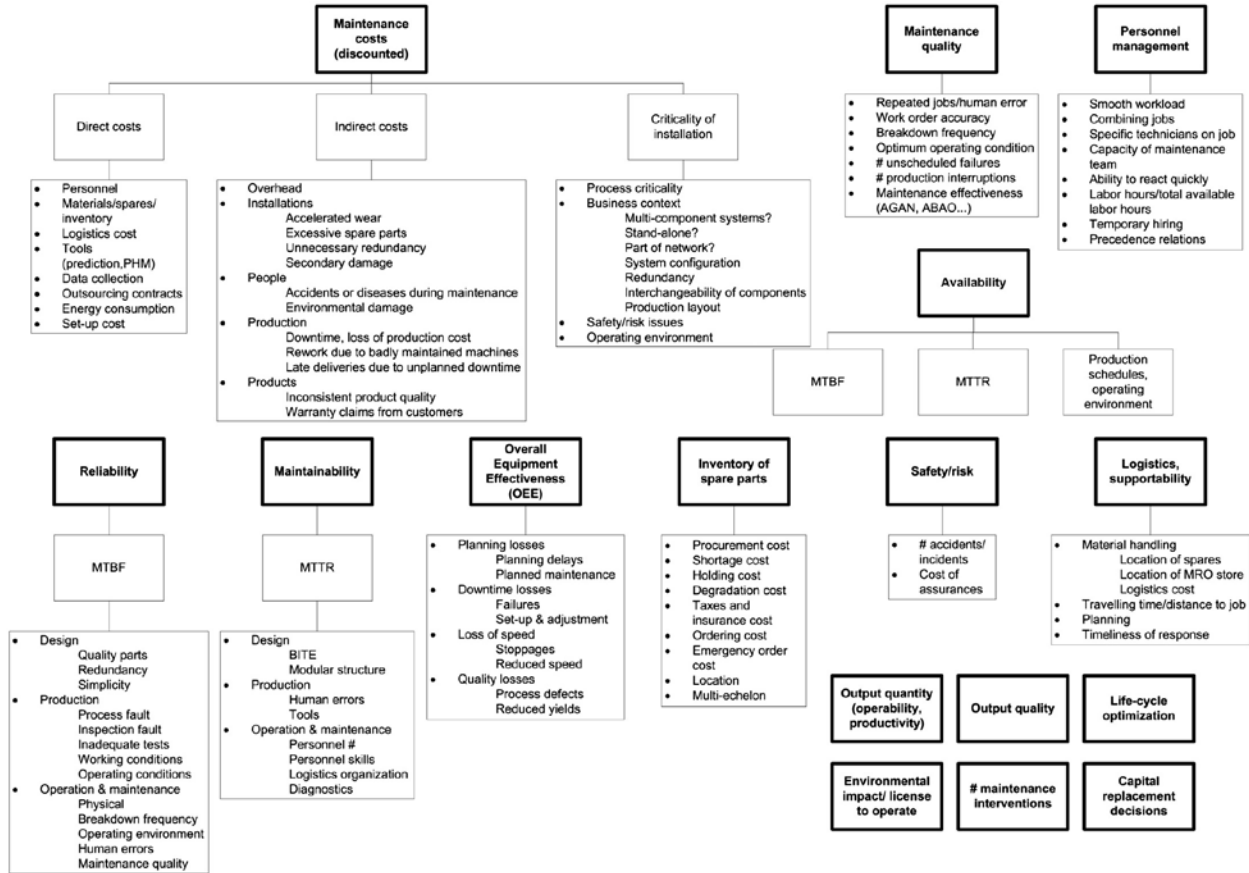


Figure 3. Operational MPIs derived from the tactical level (Van Horenbeek and Pintelon, 2014).

Three generally categorized maintenance performance measurements have been reviewed in literature centered on their emphasis areas, and comprise measurements pertaining to machinery performance, economic or costs performance and process performance, also three categories were alluded to according to EN:15341, 2007's maintenance KPIs and these are economic, technical and organizational indicators (Muchiri, et al. 2011). One critical maintenance performance indicator is the equipment reliability $R(t)$, which is well-defined as the prospect that an entity will accomplish the requisite task without undergoing failure when operating within indicated circumstances for a quantified interval/era, and from this explanation, it is manifest that preserving the reliability of an equipment is an indispensable requisite in current organizations, principally in unceasingly varying working environments of organizations (Catelani, et al., 2015). For most equipment, reliability guides that encompass Mean Time Between Failure (MTBF), Failure Rate (FR) and Mean Time To Repair (MTTR) are deployed by several organizations to measure the maintenance performance (Catelani, et al., 2015). MPIs can be ordered into seven segments and they are interconnected together for attaining overall maintenance performance and these segments contain the following linked indicators: consumer fulfillment, economic/cost, machinery, maintenance activity, education and development, Health Safety and Environment and staff contentment (Parida and Kumar, 2006). Before operationalizing the MPIs, they have to be verified for reliability, confirming their capability to deliver the precise measurements dependably over a period, and for validity, checking the capacity to quantify what they are designed to measure (Parida and Kumar, 2006).

3. Requirements for Effective Maintenance Performance Measurement System

Van Horenbeek and Pintelon (2014) presented an analytic network process (ANP) model and approach to create an enterprise customized MPM scheme which comprised of 5 major phases that are: 1. Translation of a standard MPM scheme to a business specific MPM scheme encompassing all structural stages (i.e. strategic, tactical and

operational). 2. Prioritizing maintenance intentions on all structural levels (top-down methodology) to develop business centered goals 3. Translation of the business derived maintenance intentions into applicable MPIs on each structural level (bottom-up slant). 4. Measure, track and regulate maintenance performance centered on specified MPIs. 5. Unceasing perfection by reviewing maintenance objectives relative to the business atmosphere. Muchiri, et al. (2011) developed a MPM conceptual framework that classified basic essentials and practices that drive the maintenance function towards accomplishment of performance required by manufacturing goals, with the context supporting for linkage of maintenance intentions with the manufacturing and business goals and therefore guiding the maintenance actions towards accomplishing the requisite performance and constant enhancement of the manufacturing machinery performance. Three key segments were identified and these are: maintenance configuration linkage with production, maintenance activities/practices assessment and maintenance outcomes performance assessment.

Complications are encountered when computing and evaluating the effort and outcome of the maintenance practices, and this is accredited to the multifaceted connection between the maintenance and manufacturing functions (Muchiri, et al. 2011). To overcome this difficulty and establishing a regulated methodology of quantifying performance of the maintenance activities, it is vital to ensure a detailed maintenance strategy is derived from the business and manufacturing strategies, and techniques like cognitive mapping and analytical network process can be utilized to formulate and align the strategies (Muchiri, et al. 2011).

For fruitful employment of MPM, employee involvement is necessary and all pertinent human resources concerns have to be addressed. Moreover, the customary OEE used by businesses is insufficient, as it merely measures the interior efficiency and for measuring the overall maintenance efficacy both interior and exterior efficacy should be measured (Parida and Kumar, 2006). Much focus should be on the economic and machinery performance indicators as they are valuable in exploiting performance exploration of the maintenance discipline and detecting the performance shortcomings that would activate management response, and they thus lead to knowledge acquisition and development of the maintenance system (Muchiri, et al. 2011). There has to be a shift from perceiving MPM as a sheer budget reportage standpoint, to taking it as an organized, business perception (Simões, et al., 2011). As has been witnessed over the past 20 years, the arena of MPM has progressed from measurement to management, and MPM now incorporates the cultural and behavioural facets of MPM (Bititci, et al., 2015).

In application of MPIs, there must be multi-level indicators, showing the hierarchical link of the MPIs as they strive to increase performance in relation to business strategic objectives and they have to be implemented with a complete involvement of the whole business (Parida, et al., 2015).

Parida, et al. (2015) stated that even though MPM systems have proved to escalate the performance and efficacy of companies by applying more secure metrics, execution concerns are always encountered and some of them are:

- poor leadership and opposition to changes
- inability to operationalize business strategy due to incompatibility with actual drivers of maintenance.
- Use of negotiated goals rather than those derived from stakeholder needs
- endeavoring for flawlessness can destabilize attainment
- strategy may not be related to function, team and distinct objectives
- numerous measures can dilute the total impression
- metrics may be weakly specified
- not using an effective information management system which is easily accessible
- reparations of measurements and
- limited time and expenses unbearable

Generally, MPM schemes must be proactive and flexible to accommodate new developments like the ensuing:

- alteration in enterprise aims, strategies and policies
- changes in technology and information management systems
- structural variations;
- new regulatory guidelines for HSE
- migration of stakeholder needs and
- economic cycles (Parida, et al., 2015).

4. Maintenance Performance Measurement Gaps in a Case Study Company

A South African manufacturing company was assessed for their maintenance performance measurement system and it was established that they have a system for measuring maintenance performance in three major categories, and these are: Safety, Technical Performance and Costs. Table 1 below shows the dashboard for the performance measures as they monitored and tracked.

Table 1. Maintenance performance measures for a South African manufacturing company

Objective Tracking 2017																
Number	Category Designation		Target	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	
1	SAFETY	Lost Time Accident TF1 Category	0	0	0	0	0	0								
		Incident TF2 Category	0	0	0	0	0									
2	PERFORMANCE	Engineering Reliability %	99.00%	99.39%	99.30%	99.16%	99.83%	99.30%								
		Number of Technical Stops per month	10	11.00	13.00	16.00	5.00	16.00								
		MTBF for Plant (hours)	300	346.16	263.40	249.12	392.91	401.93								
		MTTR for Plant (hours)	1.5	1.49	0.90	1.13	0.35	0.73								
		On time completion of planned works orders (%)	95	97%	96%	97%	96%	95%								
		Number of AA machines to Step 3	1	0	0	0	0	0								
		Number of A machines to Step 3	1	0	0	0	0	0								
3	Costs	Maintenance spend kR	R521K	R205K	R539K	R261										

In terms of the technical performance the MPIs tracked are equipment reliability, technical stops, MTBF, MTTR, and planned maintenance compliance. Below are the graphical representations of reliability and MTBF performances.

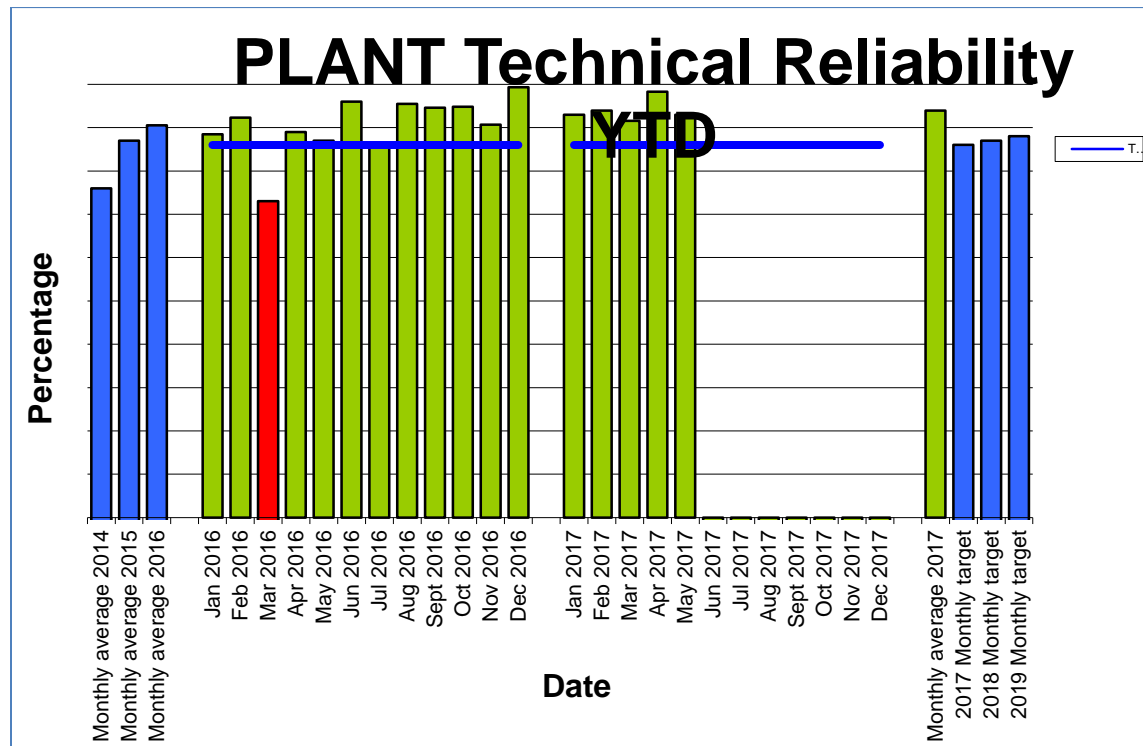


Figure 4. Technical Reliability graph for a South African manufacturing company

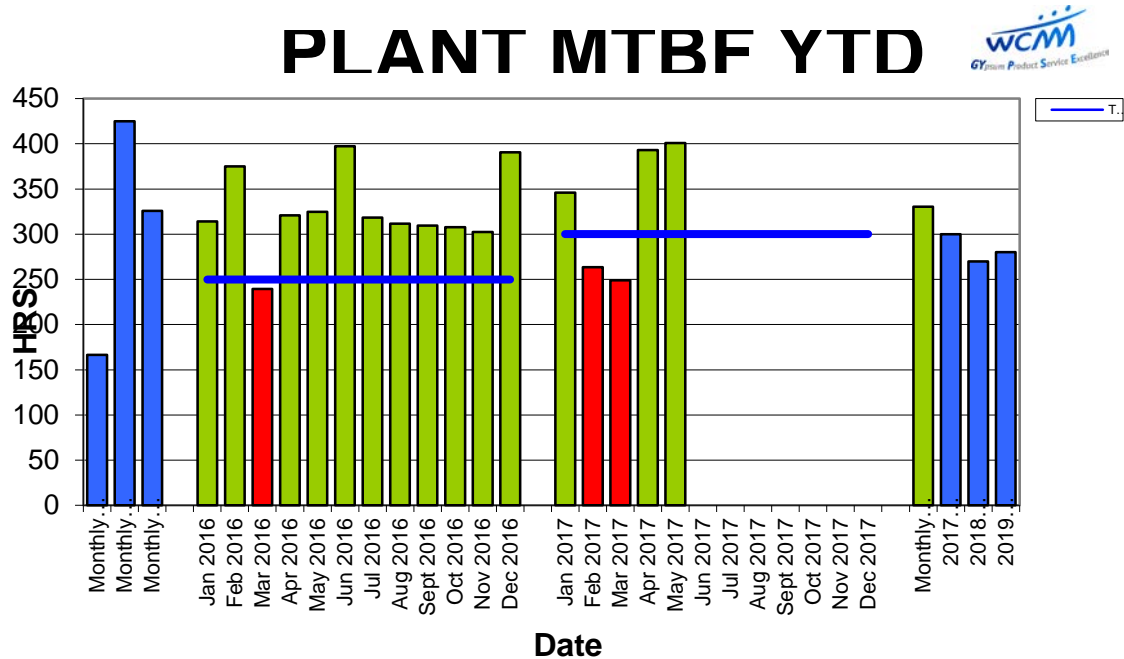


Figure 5. Plant MTBF graph for a South African Manufacturing Company

The key observations that were identified concerning the MPM for the South African manufacturing company were as follows:

1. there was no strategic link between the MPIs with manufacturing and business strategies
2. there were no resultant action planning documented on MPIs that were trending below targets, this was noticed on the number of technical stops which were not within the targeted range
3. on a positive note, the MPIs like MTTR were cascading down to individual equipment levels and that means not only the overall plant measure was being tracked
4. Their main focus was on a few key MPIs as depicted on table 1 above and that is where most of the maintenance resources were channeled towards
5. There was no categorization of the hierarchical allotment of MPIs
6. A SAP CMMS system was utilized for managing maintenance information but the data integrity was a major concern as a lot of critical information fields were not completed, thus discrediting the credence of the data
7. The information on the charts was upto date, but some shop floor maintenance team members professed ignorance on the value of the MPIs

5. Discussion and Conclusion

In essence, the crucial aspect unveiled is that maintenance performance should never be established in isolation from the business strategic thrust. Equipment reliability, and therefore maintenance function performance can derail the overall business performance if not managed properly through effective performance measurement. Customization of performance indicators at various levels of the enterprise will ensure a synchronized business performance with all levels contributing their worth.

Human factors also need to be considered as employee buy-in is essential for the success of the MPM scheme. Employee learning and understanding is crucial and many good systems fall through the hands of implementers because of lack of understanding of the value derived or benefits attained by embarking on such business processes. Leadership commitment is always essential to envision the organization towards the right performance attributes and the business leadership need to drive the MPM program. Adequate resources need to be allocated to ensure the requisite infrastructure for data collection and analysis is availed at all levels, e.g. CMMS and computers hardware.

Most importantly, the maintenance-performance-measurement system should be migrated to a maintenance-performance-management system as great value is derived if the system is systematically managed. A deviation reporting system should be available to capture any shortcomings in performance and an action closure loop has to be devised to ensure control of all actions necessary for the business to attain its strategic objectives.

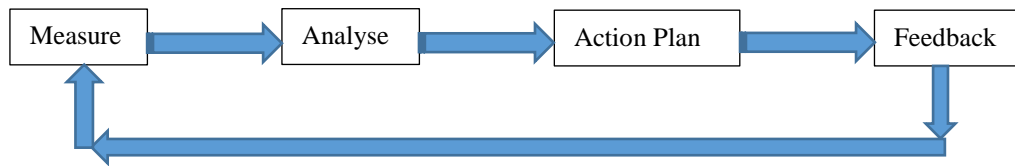


Figure 6. Proposed Feedback loop for maintenance performance management

The feedback loop will ensure that timely actions are taken to address the maintenance performance issues that can prevent the business from attaining its business objectives.

Lastly, future research activities should be focused more on the management aspects of the maintenance performance system and ways to ensure that models are developed for maintenance practitioners to adopt in the field.

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