CONDITION BASED MAINTENANCE

Maintenance strategies; a comparative analysis Africa vs Europe

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This article includes extracts of published work by the author in Journal [1]
Wakiru, J., Pintelon, L., Muchiri, P., Chemweno, P. (2021). A comparative analysis of maintenance strategies and data application in asset performance management for both developed and developing countries. International Journal of Quality & Reliability Management. Doi: 10.1108/IJQRM-02-2020-0035.

A study was conducted to empirically compare maintenance practices under asset performance management (APM), employed by firms in developed and developing countries (Belgium and Kenya, respectively). This study used survey responses from 150 professionals working within maintenance, planning and operation functions to come up with a comparative analysis of maintenance strategies between the two countries.

This article is a report of the study's findings, and it addresses condition monitoring data management practices by first delineating condition-based maintenance among other maintenance strategies as underutilized. It further explores the various types of equipment the respondents have, and the condition monitoring techniques employed. The report further looks at the two most significant improvements that the respondents' desire and the challenges or threats thereof.

Maintenance strategies

The study looked at the employment of various maintenance strategies in both countries. These are corrective maintenance, preventive maintenance, predictive condition-based maintenance, predictive condition and model-based maintenance and proactive maintenance.

> ***In both Kenya & Belgium, corrective maintenance & preventive maintenance strategies were the most utilised strategies. Additionally more Belgium firms compared to those in Kenya utilized condition based Maintenance.***

Corrective Maintenance is the type of maintenance carried out following the detection of an anomaly and is aimed at restoring normal operating conditions.

Preventive Maintenance is the type of maintenance carried out at predetermined intervals or according to prescribed criteria, aimed at reducing the failure risk or performance degradation of the equipment.

Predictive condition-based maintenance is the maintenance based on the equipment performance monitoring and the control of the corrective actions taken as a result.

Predictive condition and model-based maintenance are maintenances based on »

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monitoring and modelling deterioration then predicting the probability of failure.

Proactive maintenance is where machine failures are anticipated using root causes and eliminated before they ever develop.

In both countries as expected, the study found out that corrective maintenance and preventive maintenance strategies are predominantly employed. However, more companies in Belgium to a large extent utilize predictive condition-based maintenance, predictive condition and model-based maintenance and proactive maintenance strategies when compared to their Kenyan counterparts. This is shown in figure 1.

Despite the immense benefits of the condition-based techniques, the rate of exploitation was found to be relatively low in both countries (see Figure 1), hence the study sought to find out:

- The equipment the respondents maintained
- The condition monitoring techniques utilized.
- The challenges facing the respective condition monitoring techniques.

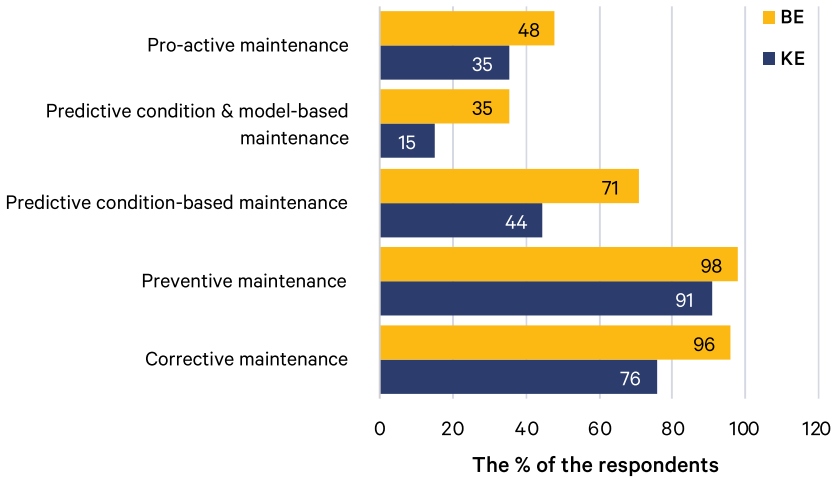

Figure 1: Maintenance policies utilized in Kenyan and Belgian firms.

Equipment & condition monitoring techniques Techniques

As shown in Table 1, it was unveiled that in both Kenya and Belgium, lubricant analysis is predominantly used on engines, compressors, gear, and hydraulic systems. This result is as expected because oil is consumed in these systems in sizeable quantities and offers insight on the equipment condition, in a more convenient and more straightforward approach. Moreover, the results show a significant usage of thermography in electrical systems and engines in both countries.

However, when it came to vibration analysis in engines, gear, fans, compressor, and pump systems, Belgium showed a higher utilization compared to Kenya. A possible explanation for this phenomenon might relate to the inherent extensive manufacturing facilities in Belgium. Moreover, large-scale facilities in Belgium can operate many motors and pumps [2].

Equipment	Engines/ generators / turbo		Gear systems		Hydraulic systems		Compressors		Pumps		Fans		Motors		Electrical and electronics		Others	
	BE	KE	BE	KE	BE	KE	BE	KE	BE	KE	BE	KE	BE	KE	BE	KE	BE	KE
Oil analysis	92	89	94	44	83	54	78	45	37	28	21	16	30	5	9	7	22	33
Vibration analysis	72	38	70	37	25	11	81	29	97	42	93	58	85	42	3	5	33	33
Thermography	52	41	27	34	25	16	44	29	33	25	29	40	42	44	97	52	67	25
Acoustic & Ultrasound	24	10	12	7	4	7	26	7	40	11	39	11	30	12	6	11	78	17
Electric discharge	16	20	-	9	8	9	15	15	7	17	11	13	18	10	22	20	22	42
No. of respondents with equipment	25	61	33	68	24	56	27	55	30	53	28	45	33	59	32	44	9	12

Table 1: Equipment and linked condition monitoring techniques in Belgium and Kenyan firms (The % of the respondents).

Challenges & desired improvements in condition monitoring techniques

While considering the challenges outlined by the respondents affecting the various techniques (See Table 2); inconsistent data collection and recording was shown as critical. Other significant challenges include misinterpretation and the inability to link the data to failure data. These challenges were found to cut across both countries.

These results underscore the importance of establishing the most desirous improvements in the organizations' maintenance data management.

The most popular desired improvement across both divides was the desire for easier integration of different data. Other improvements that the respondents wanted to be implemented include a more responsive system, ease of customization, user-friendly Graphical user interface, better decision making support and less vendor lock-in. This is summarized in Figure 2.

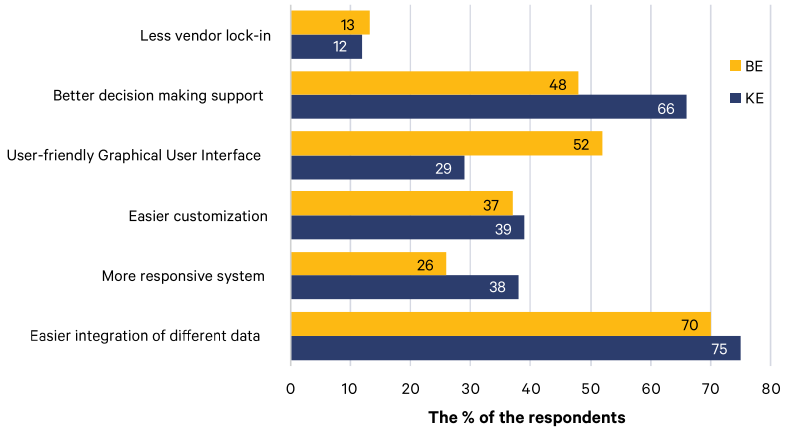

Figure 2. Desired improvements in Kenyan and Belgian firms.

Easier Integration of different data

Many maintenance organizations face challenges while trying to integrate different data towards deriving robust decision support. Currently, significant work has been done largely addressing data collection and storage between plant and equipment and the respective enterprise resource planning (ERP) platforms.

The study found out that integration of the various data such as those from various condition monitoring techniques e.g., oil and vibration analysis with a Computerized maintenance man-

	Mis interpretation	No link with failure data	Require multiple handling	Independent	Inconsistent collection and records	Too much information	Long interpretation duration	Other (e.g., insufficient info....)
Oil analysis	19%	18%	9%	5%	24%	4%	12%	9%
Thermography	14%	15%	9%	14%	22%	9%	6%	13%
Ultrasound analysis	20%	6%	11%	6%	26%	9%	9%	14%
Vibration analysis	23%	20%	10%	10%	10%	15%	7%	6%
Pressure/speed	16%	16%	6%	10%	22%	8%	10%	14%
Electric discharge	13%	13%	5%	5%	33%	8%	10%	13%

Table 2: Challenges facing condition monitoring techniques (% of respondents).

A Decision support system (DSS) should facilitate the decision process support rather than automate decision making, and should also be able to respond to changing needs of decision-makers.

agement system (CMMS) may lead to an e-maintenance platform that may not adequately deliver appropriate integrated data for end-users.

Firstly, the data available may not be well formatted. In many cases, the data may be unstructured and lacking a common base, thereby necessitating significant preprocessing before integration can be done.

Another reason could mean that the data required to be integrated may not be on the platform you need it to be. For instance, data stored in HTML files may require significant transposition before integrating into the excel platform.

Poor data quality, duplicated data, and lack of a clear common understanding of the data may also be a hurdle towards data integration.

Lastly, the various data sets of interest may be significantly heterogeneous (high variability in types and formats).

According to the survey, there was high utilization of manual techniques compared to model-driven and data management tools to integrate various data sets (e.g., condition monitoring, operational and event data).

Data standardization challenge was highlighted as a critical threat to maintenance data management. This challenge, therefore, highlights the necessity for a framework that would pre-process, standardize, and integrate heterogeneous data to the analysis-ready state, and ultimately derive and integrated decision support.

Such a framework would enable managers to employ data mining techniques to pre-process often unstructured data and merge heterogeneous data sets. Moreover, a data management software embedded with machine learning algorithms(e.g., classification models) could be developed, to derive decision support.

Better decision-making support

Decision making in complex systems such as manufacturing systems, hospitals and supply chains is a demanding task. Expert driven decisions based on intuition and experience present limitations, such as bias, personal affinities and prejudice influencing the decision, among others.

The study recommends the development of a decision support system (DSS) and its application as a solution to improve condition monitoring strategies in both countries.

A DSS should facilitate the decision process support rather than automate decision making, and be able to respond to changing needs of decision-makers. There are two types of DSS Systems: model-driven DSS and knowledge-driven DSS.

Model-driven DSS utilizes data and parameters to aid in understanding a situation and potentially deliver the required representation to the decision-makers. Model-driven DSS incorporates various modelling categories like forecasting, financial and accounting, decision analysis, optimization, and simulation modelling.

Knowledge-driven DSS recommends actions for the maintenance manager by utilizing computer systems with specialized problem-solving expertise such as Machine learning and statistical modelling. Machine learning is an application of artificial intelligence that provides systems to automatically analyze data and build analytical models, whereas statistical model derives inferences from the data. A related concept is **data mining,** which involves both machine learning and statistical modelling, sifting through data, and discovering hidden patterns.

Further, the study identified maintenance knowledge loss as a critical aspect that affects robust decision-making support in maintenance data management. Maintenance knowledge loss occurs when individuals with valuable knowledge leave the organization due to workforce mobility or ageing issues. To mitigate this, the report recommends that organisations conduct knowledge mapping and auditing to identify hurdles in knowledge proliferation and point out improvements. A significant antidote to knowledge loss is inculcating the knowledge sharing process because the knowledge gained over a significant period will assist in improving operations and the organizations' performance.

Conclusion

Condition monitoring techniques under condition-based maintenance such as oil analysis, vibration analysis and thermography retain significant benefits in the reliability optimization of assets when implemented. Despite the expected benefits, countries in both developed and developing divide have not embraced the techniques as would be expected.

The use of data generated during operation and from measuring various conditions of the assets is a significant resource that is exploited to trigger interventions. The industries from the surveyed population desire to generate robust decision-making support while integrating the various data sets in the maintenance data management process.

However, aspects like lack of standardization, presence of unstructured data, maintenance knowledge loss were picked as significant threats to this process. Therefore, plants require to re-evaluate their maintenance data management practices and adopt more structured and deliberate practices such as structuring and standardizing their data collection and recording, incorporating knowledge retention techniques and employing decision support systems or tools that resonate with first their expected requirements, secondly the age and condition of their assets and lastly, their forecasted needs and investments. ■

References:

[1] Wakiru, J., Pintelon, L., Muchiri, P., Chemweno, P. (2021). A comparative analysis of maintenance strategies and data application in asset performance management for both developed and developing countries. International Journal of Quality & Reliability Management. Doi: 10.1108/IJQRM-02-2020-0035.

[2] Muchiri, P.N., Pintelon, L., Martin, H. and De Meyer, A.M. (2010), "Empirical analysis of maintenance performance measurement in Belgian industries", International Journal of Production Research, Vol. 48 No. 20, pp. 5905-5924