Maintenance Management Performance Measures in Indonesia Calibration Laboratories Applying ISO/IEC 17025: 2017

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Abstract

The implementation of a maintenance management system is very important for organizations. The Calibration laboratory has a lot of reference equipment. Based on ISO/IEC 17025: 2017, maintenance management is essential for calibration laboratories. From the results of literature studies, the issue of maintenance management has been discussed in many studies, but maintenance management in calibration laboratories has not been studied. This paper identifies the factors that affect the maintenance management performance in the Indonesia calibration laboratory and also to analyze the correlation between maintenance management performance and ISO/IEC 17025's application through a survey of 40 calibration laboratories that for more than 10 years have implemented ISO/IEC 17025. The result shows that "human resource factors" and "information management and CMMs" significantly contribute to performance maintenance management. Maintenance management performance in Indonesia calibration laboratories does not affect the application of ISO / IEC 17025: 2017. The matrix grid shows that 47.5% of the laboratories have good maintenance practices. Calibration laboratory maintenance management practices can be categorized as "understanding" based on radar diagrams, this indicates that the implementation of maintenance is good even though the benefits have not been fully realized.

Keywords
Maintenance Management Performance, Calibration Laboratory, ISO/IEC 17025: 2017

1. Introduction

The implementation of a maintenance management system is very important for organizations or institutions (Buys and Nkado 2006). Maintenance ensures that all equipment required for production can work at all times with 100% efficiency to maintain and support efficient production (Jonsson 1997). The participation and support of all parts of the organization from all personnel (top management to production floor personnel) are indispensable in the good maintenance program (McDonnell et al. 2018). By ensuring that the organization can work in defined conditions through balancing the use of maintenance resources and organizational output, the organization can see the contribution of maintenance management performance to organizational performance (Cholasuke et al. 2004).

Calibration of measuring equipment is one of the most important processes used to maintain tool accuracy. Based on JCGM 200:2012 International- International vocabulary of metrology – Basic and general concepts and associated terms (VIM), calibration is an operation under certain conditions to compare the measurement results of a measuring instrument against national and international measurement standards for units of measure and/or certified reference materials. Each measuring instrument requires calibration after a certain time interval to provide accurate measurement results. Calibration service providers are calibration laboratories, where the calibration laboratory has a lot of reference equipment (traceability standards) that are used to carry out calibrations.

A calibration laboratory can be declared competent if it has implemented ISO/IEC 17025 and an assessment has been carried out by an accreditation body to check its suitability. One of the requirements in ISO/IEC 17025: 2017 (general requirements for the competence of testing laboratories and calibration laboratories) is that calibration laboratories must maintain their equipment by clause 6.4 (equipment) and monitor the assurance of calibration results through function check (s) of measuring equipment or intermediate checks on measuring equipment according to clause 7.7 (ensuring the validity of results). The application of ISO/IEC 17025 encourages calibration laboratories to carry out better equipment maintenance so that the validity of the calibration results is guaranteed. For this reason, maintenance management is essential for calibration laboratories.

Surveys that aim to provide an overview of maintenance management and surveys that aim to conclude the relationship between maintenance practices and other business elements and results have been carried out for example: (Jonsson 1997), (Chinese and Ghirardo 2010), (Cholasuke et al. 2004), (Buys and Nkado 2006), (Alsyouf 2009), (Fumagalli et al. 2009), (Jin et al. 2016), (Naughton et al. 2013), (Naji et al. 2019). From the results of literature studies, the issue of maintenance management has been discussed in many studies, but the measurement of maintenance management performance in accredited calibration laboratories is based on variables of top management policy, human resource management, maintenance planning, and scheduling, equipment and spare parts management, information management and computerized maintenance management systems (CMMs), and financial aspects are not yet known. Therefore, research on measuring the performance of maintenance management in a calibration laboratory that implements ISO / IEC 17025 based on these six variables is important.

1.1 Objectives

The study aims to identify the factors that affect the maintenance management performance in Indonesia calibration laboratory and also to analyze the correlation between the performance of maintenance management and the application of ISO/IEC 17025 so will be known the status of maintenance management in Indonesia calibration laboratory applying ISO/IEC 17025: 2017.

2. Literature Review

Maintenance management is developing faster than other management disciplines, types of maintenance strategies have been developed including, preventive maintenance (PM), reactive maintenance (RM), and condition-based maintenance (CBM), this is due to the production process and the increasing complexity of the equipment (Jin et al. 2016). Based on BS EN 13306:2017 - Maintenance terminology, preventive maintenance includes physical condition assessment, analysis, and possible subsequent maintenance aimed at reducing the probability of failure of an item and condition-based maintenance and assessing and/or reducing degradation. Jin et al. (2016) stated “reactive maintenance (RM) is a corrective action applied on observable failures or unanticipated threats of failures”.

Parida and Kumar (2006) state that the measurement of maintenance management performance is a complex issue, which can facilitate the contribution of maintenance management to organizational goals. From the results of the literature study, several studies were obtained on the variables that influence the performance of maintenance management, as follows:

a. Top management policy
   Poor maintenance performance can be caused by a lack of relationship between company strategy and maintenance policies (Jonsson 1997), this suggests that the performance of maintenance management depends on top management policies in providing direction, focus, and support.
b. Human resource management
   The most important maintenance resource is personnel; because human resources function in planning, managing, supervising, and implementing maintenance management (Cholasuke et al. 2004). To optimize maintenance performance, several aspects of skill and competency personnel needed to be concerned in maintenance management (Fatoni 2018).
c. Maintenance planning and scheduling
   Lack of planning and scheduling can limit maintenance performance. Maintenance planning and scheduling helps in scheduling maintenance work and allocating resource usage (Cholasuke et al. 2004). Maintenance planning contributes positively to effective maintenance activity (Nurcahyo et al. 2018).
d. Equipment and spare parts management
   Cholasuke states that Kirby's (2000) survey shows that the cost of spare parts inventory is the second-highest maintenance cost of the 1993 US plant maintenance performance.

e. Information management and computerized maintenance management systems (CMMs)
The management information system provides a relationship between the current maintenance status functioning about maintenance objectives (Cholasuke et al. 2004). Effective and efficient maintenance information management is the output of Computerized maintenance management systems (CMMs) (Dunn 2020).
f. Financial aspect
Ingallss (2000) in Cholasuke (2004) states that maintenance financial control includes maintenance budgets, controlling contractor costs, and controlling labor and material costs.

3. Methods

In the early stages of the research, the authors conducted a survey. The questionnaires were distributed to 40 calibration laboratories that have implemented ISO/IEC 17025 for more than 10 years throughout Indonesia. The list of calibration laboratories was obtained from the database of the Indonesian accreditation body (KAN). The data obtained were analyzed using statistical significance tests and correlation studies to identify:

a. factors that significantly affect the performance of maintenance
b. correlation between maintenance performance and application of ISO/IEC 17025
c. correlation between maintenance performance factors

From the results of the study literature, questions are designed based on maintenance performance variables as shown below:

a. General information
    - activity scope (Naji et al. 2019)
    - number of personnel (Chinese and Ghirardo 2010)
b. Top management policy
    - type of maintenance policy (RM, PM, CBM) (Chinese and Ghirardo 2010)
    - maintenance position in the organization (Chinese and Ghirardo 2010)
    - responsible for the maintenance (Chinese and Ghirardo 2010)
    - maintenance orders are written (Chinese and Ghirardo 2010)
c. Human resource management
    - education level (Cholasuke et al. 2004)
    - professional experience (Naji et al. 2019)
    - number of internal maintenance operator (Chinese and Ghirardo 2010)
d. Maintenance planning and scheduling
    - maintenance work is only carried out during working hours (Chinese and Ghirardo 2010)
    - maintenance for each equipment is scheduled (Naji et al. 2019)
e. Equipment and spare parts management (Chinese and Ghirardo 2010)
    - Existence of a spare parts stock book
    - Type of work contracted out
    - Monitoring the status of production equipment
    - Cause and effect of equipment failure analyzed
    - Restoring equipment to work
    - Installing new production equipment
    - Preventive maintenance work is planned
    - Help design and repair the production process
f. Information management and computerized maintenance management systems (CMMs) (Chinese and Ghirardo 2010)
    - Presence of a CMMS
    - Work order planning and scheduling
    - Preventive maintenance planning and scheduling
    - Spare parts inventory management
    - Maintenance budgeting
    - Maintenance data filing

g. Financial aspect
   - maintenance of budget planning (Naji et al. 2019)
   - maintenance policy setting costs (Chinese and Ghirardo 2010)
   - maintenance costs are compared with the cost of losses due to equipment damage (Naji et al. 2019)

h. Maintenance performance (Chinese and Ghirardo 2010)
   - improvement of equipment availability
   - reduction of production costs
   - improvement of product quality
   - improvement of occupational safety

4. Results and Discussion

From 40 questionnaires distributed to 40 calibration laboratories, respondents can be grouped according to the type of maintenance policy carried out and the position of the maintenance organization.

- Calibration laboratory segmentation based on the type of maintenance policy
  Of the three types of maintenance policies, it was found that most of the calibration laboratories implemented preventive maintenance (PM) policy, which carried out maintenance before the damage occurred. There are 19 laboratories with a percentage of 48% using the PM policy, followed by condition-based maintenance (CBM) policy of 13 laboratories at 33% and the smallest is the application of reactive maintenance (RM) 8 laboratories with a percentage of 20%.
- Calibration laboratory segmentation based on the position of the maintenance organization
  Maintenance positions in the organization are categorized into: centralized in the technical department; not centralized, but depending on each laboratory (scope), and technical departments in coordination with each laboratory (scope). The position of the maintenance organization in which the technical department coordinates with each laboratory (scope) is carried out by 15 laboratories with a percentage of 38% and is the most applied. For centralized maintenance in technical departments, it is carried out by 12 laboratories with a percentage of 30%. Meanwhile, those that apply maintenance that depends on each laboratory (scope) consist of 13 laboratories at 33%.

4.1 Factors associated with maintenance performance

Table 1 describes the factors that affect maintenance performance. Each factor consists of several variables to explain the factors that have been determined. A simple significance test was conducted to identify the factors that most influence maintenance performance. In this study, the significance test with the Mann Whitney U test, which is a non-parametric test, is used if the data scale of the dependent variable is ordinal and is not normally distributed, to determine the median gap between the 2 independent groups (MacFarland and Yates 2016). If the p-value <0.05, it can be said that the factors have a significant effect on maintenance performance. The results of the calculation show that two factors have a significant effect on maintenance performance: human resource factors and information management and computerized maintenance management systems (CMMs). It can be said that human resources in the calibration laboratory determine how the maintenance process takes place so that higher education and work experience will improve maintenance performance. Information management has an important role whereby using CMMs, all information will simplify the maintenance process and avoid errors in receiving information.

4.2 Analysis of correlation between maintenance performance and application of ISO/IEC 17025: 2017

The correlation between maintenance performance and application of ISO/IEC 17025: 2017 can be analyzed with the Spearman’s Rank Correlation test for maintenance performance against the number of non-conformities found by the Indonesian accreditation body (KAN). The results of the Spearman’s Rank Correlation test p-value = 0.685 (p-value > 0.05) indicate that maintenance performance does not affect the ISO/IEC 17025: 2017’s application. If the accreditation body finds a large number of non-conformities, it does not mean poor performance of the calibration laboratory maintenance management. The number of non-conformities can be influenced by a larger factor than maintenance management, namely the amount of scope proposed.

Table 1. Factors associated with maintenance performance

Variables	*p* value	Significance
Factor 1 Top management policy	0,8743	X
The type of maintenance policy being performed		
Maintenance laboratory position		
Maintenance responsibility		
Maintenance work orders are written and recorded		
Factor 2 Human Resource Management	0,0000	Y
Average educational level of employees in the calibration laboratory		
Average experience of employees working in a calibration laboratory		
Number of internal maintenance operators		
Factor 3 Maintenance Planning and Scheduling	0,2935	X
Maintenance work is only carried out during working hours		
Maintenance for each equipment is scheduled		
Factor 4 Equipment and spare parts management	0,9923	X
The maintenance provider is carried out internally		
Make a list for stock spare parts		
Perceptions of monitoring the status of production equipment		
Perceptions of cause and effect analysis of equipment failures		
Perception of returning equipment to storage		
Perception of preventive maintenance work planning		
Maintenance can improve the calibration process		
Factor 5 Information management and computerized maintenance management systems (CMMs)	0,0002	Y
Before the damage occurs, maintenance is carried out		
The laboratory implements a computerized maintenance system		
If implementing computerized maintenance management system, the extent to which perceptions of its use are in planning and scheduling of preventive maintenance		
If implementing computerized maintenance management system, the extent to which the perceptions of its use are in the management of spare parts inventory		
If implementing computerized maintenance management system, the extent to which the perceived use of it is in the maintenance budget		
If implementing computerized maintenance management system, the extent to which perceptions of its use are in the maintenance data archive		
Factor 6 Financial aspect	0,4548	X
Periodic maintenance budgeting is planned for each equipment		
The company sets costs in setting maintenance policies		
The costs incurred for maintenance are lower than the costs of losses due to equipment damage		

Note: X = The factors are not significantly associated with maintenance of performance; Y = the factors are significantly associated to performance maintenance

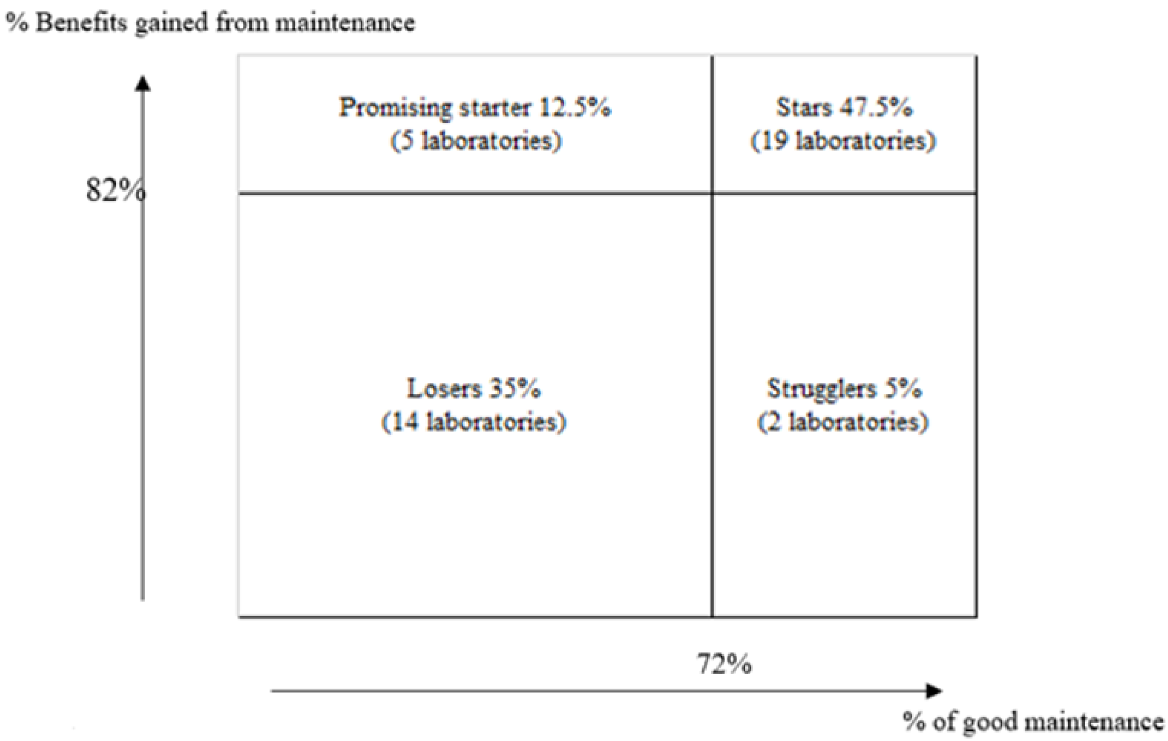
4.3 Correlation analysis among maintenance performance factors

The Spearman Rank Correlation test was conducted to analyze the correlation between maintenance performance factors. Spearman's Rank Correlation was introduced by Spearman in 1904. Spearman's Rank Correlation is used to find a relationship or to test the significance of the associative hypothesis if each of the variables linked is ordinal, and the data sources between variables are not necessarily the same (StatisticsSolutions 2020). The results of the Spearman's Rank Test in Table 2 show that there is a relationship between factors, which is positively correlated. Interpretation of results (r) is as follows: $0 < r < 0.5$ indicates a weak positive correlation between factors, $0.5 < r < 0.9$ indicates a moderate positive correlation and $0.9 < r < 1$ indicates a strong positive correlation. **(**Statstutor 2020).

Table 2. Correlation between maintenance factors

	X1	X2	X3	X4	X5	X6
X1	1	0.136	0.569	0.690	0.428	0.511
X2	0.136	1	0.266	0.007	0.370	0.035
X3	0.569	0.266	1	0.437	0.375	0.421
X4	0.690	0.007	0.437	1	0.500	0.664
X5	0.428	0.370	0.375	0.500	1	0.590
X6	0.511	0.035	0.421	0.664	0.590	1

Note: X1 = Top management policy; X2 = Human resource management; X3 = Task planning and scheduling; X4 = Maintenance management equipment; X5 = Management information; X6 = Financial aspect.



Notes:
Stars – laboratory who employ most of good maintenance practices and realise benefits from them
Promosing starters - laboratory who employ some of good maintenance practices and realise the good results
Strugglers - laboratory who employ most of good maintenance practice buat achieving little benefits from them
Losers – laboratory who have poor maintenance practice and do not emplot any good practice in maintenance management

Figure 1. Maintenance maturity grid

4.4 Status of maintenance management in Indonesia calibration laboratory applying ISO/IEC 17025: 2017

In determining the maintenance management performance status of the calibration laboratory, figure 1 shows the maintenance maturity grid. Where respondents are classified into 4 quadrants consisting of losers, struggles, promising stars, and stars. The benefits of maintaining and implementing good maintenance practices were used as criteria for classifying respondents. The percentage of benefits derived from maintenance (maintenance management performance) plotted on the vertical axis and the percentage of good maintenance practices plotted on the horizontal axis. The benefits of maintenance practice are counted from the level of maintenance performance and the percentage of good maintenance is calculated from each of the factors that build maintenance performance as mentioned in Table 1. From the results of the analysis, it shows good results where most of the respondents are in the stars category of 47.5% which consists of 19 laboratories, where these laboratories have realized the importance of implemented good maintenance performance and fully aware that the benefits of maintenance are part of improving strategies in the laboratory. However, there are still some laboratories with a percentage of 35% consisting of 14 laboratories that have not implemented good maintenance performance and are still not aware of the benefits of maintenance itself.

The survey result radar diagram is shown in Figure 2 which consists of 7 measurement areas (6 maintenance factors and 1 maintenance performance). There are three distribution groups for each area, namely Innocence, Understanding, and Excellence. The laboratory that does not adopt maintenance practices and does not understand the benefits of maintenance are categorized under the "innocence" (inner level). The “Understanding” refers to a laboratory that adopts maintenance practices and understands the benefits of maintenance, but not the maximum. Meanwhile, a laboratory that fully or almost completely adopts maintenance practices and has superior maintenance performance is categorized in the “Excellence” (outer level). Table 3 shows the criteria for each level in each sector.

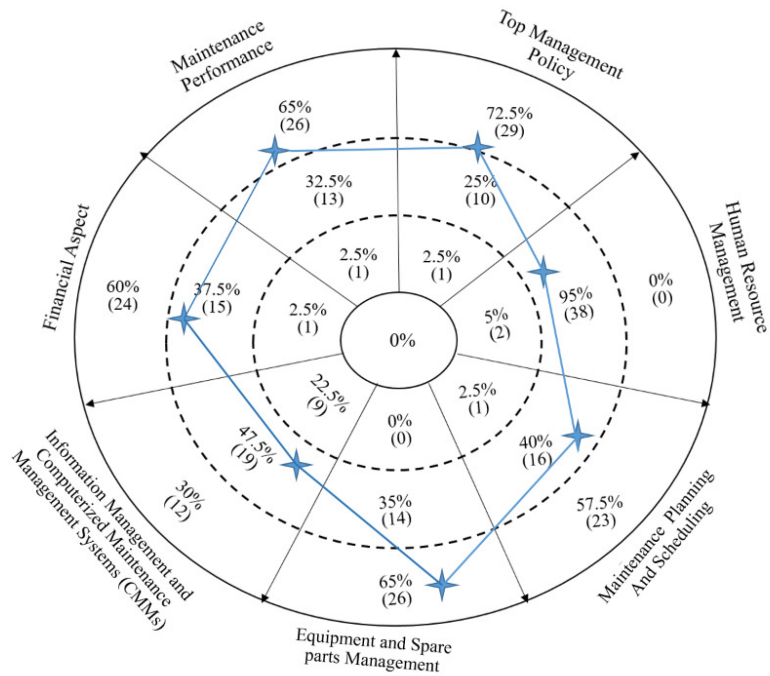


Figure 2. Radar diagram of the maintenance status of Indonesia calibration laboratory

The number of respondents who fall into the category of innocence, understanding, and excellence can be seen from the percentage displayed in each area. The radar diagram shows that the status of maintenance management needs improvement. On average, the maintenance management practices of calibration laboratories can be categorized as “understanding” which means, although the benefits of implementing maintenance management have not been fully realized, maintenance management practices have been implemented properly.

Table 3. Factors vs the status of maintenance performance at various levels

	Level 3 Excellence	Level 2 Understanding	Level 3 Innocence
Maintenance performance	Maintenance management greatly contributes to increasing the availability of equipment, reducing production costs, improving product quality and improving work safety.	Maintenance management contributes in part to improving equipment availability, reducing production costs, improving product quality and improving work safety.	Maintenance management does not contribute to increasing equipment availability, reducing production costs, improving product quality and improving work safety.
Top management policy	Maintenance work orders are carried out in writing. Top managers are in charge of maintenance. Maintenance activities are carried out by technical departments in coordination with each laboratory (scope). The maintenance policy applied is to carry out maintenance before damage occurs.	Partial maintenance work orders are carried out in writing. The technical manager is responsible for maintenance. Maintenance activities are carried out not centrally, but depending on each laboratory (scope). The maintenance policy is based on the condition of the equipment.	Unwritten maintenance work order. Skilled personnel are responsible for maintenance. Maintenance activities are carried out centrally in the technical department. The maintenance policy applied is to carry out maintenance when a breakdown occurs.
Human resource management	Internal maintenance activities are carried out by more than 10 people with more than 10 years of work experience and a minimum education of S2.	Internal maintenance activities are carried out between 3-10 people with work experience between 1-10 years and education between D3-S1.	Internal maintenance activities are carried out by less than 2 people with less than 1 year of work experience and high school education.
Task planning and scheduling	Maintenance activities are always scheduled, and only performed during working hours.	Maintenance activities are scheduled, but implementation is erratic. Maintenance work is sometimes carried out outside of working hours.	Maintenance activities are not scheduled, and are only carried out outside working hours.
Equipment and spare parts management	Maintenance work is entirely carried out by internal parties. List of spare parts is made. The importance of monitoring the status of production equipment, analyzing the cause and effect of equipment failure, returning the equipment to storage, planning preventive maintenance work, improving the calibration process due to maintenance.	Maintenance work is carried out by internal and external parties. Making a spare parts stock list is partially implemented. Part of it is monitoring the status of production equipment, analyzing the cause and effect of equipment failure, returning the equipment to storage, planning preventive maintenance work, improving the calibration process due to maintenance.	Maintenance work is entirely carried out by external parties. There is no list of spare parts stock. Considered insignificant related to monitoring the status of production equipment, analysis of the cause and effect of equipment failure, returning the equipment to storage, planning preventive maintenance work, improving the calibration process due to maintenance.
Information management and computerized maintenance management systems (CMMs)	Maintenance in the laboratory is completely computerized, and maintenance activities are preventive.	Maintenance in the laboratory is carried out manually and computerized, and partly by preventive maintenance activities.	Maintenance in the laboratory is completely manual, and maintenance activities are carried out when a breakdown occurs.
Financial aspect	Periodic maintenance budgeting is planned for each piece of equipment. The company takes into account the costs in setting maintenance policies. Costs incurred for maintenance < cost of losses due to equipment damage.	Partial periodic maintenance budgeting is planned for each equipment. Companies sometimes factor costs into setting maintenance policies. Costs incurred for maintenance = costs of losses due to equipment damage.	Periodic maintenance budgeting is not planned. The company does not take into account costs in setting maintenance policies. Costs incurred for maintenance> cost of losses due to equipment damage.

5. Conclusion

Maintenance management has an important role for an organization, including the calibration laboratory. This paper presents the results of the identified factors that affect the maintenance management performance in the Indonesia calibration laboratory and also to analyze the correlation between the performance of maintenance management and the application of ISO/IEC 17025. The questionnaire consists of 32 variables derived from six maintenance factors. The results of the analysis show that "human resource factors" and "information management and computerized maintenance management systems (CMMs)" significantly contribute to maintenance management's performance. From the survey results, maintenance performance in Indonesia calibration laboratories does not affect the ISO/IEC 17025: 2017's application. If the accreditation body finds a large number of non-conformities, it does not mean poor performance of the calibration laboratory maintenance management. The matrix grid shows good results where 47.5% of these laboratories have realized the importance of implemented good maintenance performance and fully aware that the benefits of maintenance are part of improving strategies in the laboratory. Calibration laboratory maintenance management practices can be categorized as “understanding” based on radar diagrams, this indicates that the implementation of maintenance is good even though the benefits have not been fully realized.

From the results of this study, it is possible to take strategic actions related to ensuring the maintenance management of calibration laboratories that apply ISO/IEC 17025 by optimizing the variables "human resource factors" and "information management and computerized maintenance management systems (CMMs)", so that the number of calibration laboratories have realized the importance of implemented good maintenance performance and are fully aware that the benefits of maintenance can increase. Future research can be carried out by developing variables that affect the performance of maintenance management in calibration laboratories, the object of research can also be expanded to calibration laboratories that have not implemented ISO/IEC 17025 so that the maintenance performance of calibration laboratories that have implemented ISO/IEC 17025 can be seen and calibration laboratories that have not implemented ISO/IEC 17025.

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