

Maintenance Management Practices and Operational Performance on Electricity Industry in Arab World – Case Study: Jordan

Abstract

Nowadays, power plants, generators, substations, and equipment are becoming technologically more sophisticated and difficult to control besides that any interruption in power supply will cause losses to the industry and economy. Therefore, the importance of maintenance with improving availability, performance efficiency, on-time deliveries, safety requirements, and overall plant productivity become more necessary.

In this context, the electricity industry in Arab countries is increasingly realizing the importance of the maintenance role. The main objective of this paper is to assess the maintenance management practices, operational performance, and issues faced by maintenance functions in Jordanian power companies as a representative case study for all Arab countries.

A comprehensive survey methodology for collecting data was designed, implemented, and presented in this research.

To achieve this goal, a questionnaire is designed to investigate maintenance needs and problems, namely, maintenance planning, automation implementation and barriers, maintenance barriers, productivity measurements, and staff training needs and assessment. We then distributed the questionnaire to a selected sample of Jordanian electricity companies where it has been filled out mainly through text surveys and personal interviews.

The results of this study clearly suggest that the top management commitment is very important in realizing the success of maintenance implementation. The key findings of this research related to maintenance practice and approaches that contribute to improving equipment availability are summarized as follows: increased utilization of proactive maintenance, aggressive maintenance, computerized maintenance management system, and maintenance troubleshooting techniques.

The result of this study would contribute greatly to the understanding of deployment strategy for the development of maintenance personnel in automated manufacturing companies incorporated within the company's maintenance strategy.

As such, a more comprehensive maintenance program should be implemented, so that the improvement of performance in the equipment availability can be achieved.

Keywords— Maintenance management, Electricity industry in Arab World, Jordan.

1. INTRODUCTION

With the huge increase in power demands and the importance of electricity in our life and its continuity, many companies become realizing the need for the use of proper maintenance of electric facilities and systems. In accordance with, “maintenance management is the activities of planning, organizing, implementing, monitoring, and controlling to sustain a certain level of availability, value, and reliability of the system and its components (assets) and its ability to operate to a certain standard level of quality”. Therefore, maintenance management is vital in ensuring the long-term success of maintenance programs with many benefits, which greatly affects the performance of the company by choosing the optimum maintenance practice and strategy. It is very important to measure the operational performance at the company; this can be done by the measure of reliability, maintainability, productivity, efficiency, availability, and production per unit cost, among others [1-3]. Normally, a company's maintenance costs are high, because of that, any reduction in cost due to applying the optimum strategy and practice of maintenance can increase the performance of the company [4-6]. Therefore, maintenance management practices implemented in Jordanian electricity industry companies are studied and evaluated, as a representative case study for other countries in the Arab world.

Arab World is a region known to be an energy reservoir—producing 30% of the world's oil, has 41% Of the world's

known reserves of gas, its most important export is hydrocarbons - they barely meet domestic demand for electricity, in part due to many political and technical reasons such as poor management and lack of maintenance.

Jordan, like many Arab countries, does not have enough electricity, which leads to reduced industrial activities and slower economic growth. This situation pushes outside investors to find other countries that have sufficient energy supplies to establish their investments and companies. Therefore, Jordan's power plants play an important role in the country's economic and industrial growth. Power plants must keep generators running, especially in compliance with specific power purchase and sale contracts. The availability target is above 85% to support the industry and its growth. However, these generators may fail from time to time, so it is difficult to reach this final set value. In addition, routine maintenance of the generator must be carried out to ensure reliable operation [7]. Therefore, the power plant maintenance practice must be strategically controlled to achieve its operational goals and commitments.

This paper provides a method to determine the impact of the implementation of maintenance management practices and the level of management support in different electric companies in Jordan on business performance [5].

In this study, seven hypotheses have been formulated based on the preliminary study and the review of the literature, which has been positively substantiated through appropriate designed research methodology.

Based on the results reported in this study, the key findings relating to the maintenance practice and approaches which contribute towards the improvement of equipment availability are summarized as follows: More utilization of proactive maintenance, aggressive maintenance, Computerized Maintenance Management System, and maintenance troubleshooting techniques.

The results also indicate that the major problem encountered by the maintenance department is related to the issue of staff maintenance personnel which is due to the lack of knowledge, competencies, and motivation. These can be overcome through the employee development approach that leads to the improvement of the plant performance. These are up-to-date

information to the body of knowledge and can provide new insight into the current situation and guidelines for the maintenance department as far as Malaysian and Irish automated manufacturing industries are concerned.

Consequently, by having good training planning and implementation, an improvement in equipment availability can be expected. On the other hand, it can be seen from the results that "on-the-job training" and "training from internal staff", are the most appropriate and efficient approaches for the maintenance personnel to increase their knowledge and competencies in performing the maintenance job.

Based on the results reported in this study, the key findings related to the maintenance practice and approaches can be used as a good background for electricity industry companies in all Arab countries.

2. BASIC MAINTENANCE PHILOSOPHIES

2.1. MAINTENANCE TRIGGERS:

When a maintenance trigger occurs, maintenance must be performed at the facility level. These triggers are used to notify technicians of maintenance requirements.

1. Breakdown maintenance trigger: As its name suggests, a BM trigger occurs when a piece of equipment breaks down and can't be used anymore. The moment an asset stops working, an alert is triggered, and maintenance is scheduled to fix the problem and return the equipment to operation.

Breakdown triggers are usually put in place on non-critical assets that can be replaced or fixed quickly with little cost or effect on production with planned stock availability.

Maintenance types that used breakdown triggers: corrective, reactive, run-to-failure

2. Usage Trigger: Usage-based maintenance triggers occur when an asset requires maintenance after operating at a certain output. A belt may need to be inspected after 100 hours of production, tires could be checked after 10,000km and induction sealing equipment might require maintenance after 20 production cycles. Whatever the case, when the asset meets this usage point, a work order is triggered, and maintenance is scheduled.

Maintenance types that used usage triggers: preventive, condition-based, predictive

3. Condition Trigger: When a certain element of an asset is not working the way it's supposed to, it could mean something bad is about to happen. When a condition-based maintenance trigger is in place, it identifies the problem areas and alerts a technician that maintenance needs to be performed. For example, an engine may be overheating or a bearing on a conveyor belt may be vibrating too much, which could lead to the entire piece of equipment breaking down. When these conditions are discovered, maintenance tasks are triggered, so the engine can be cooled down or the bearing can be tightened.

Maintenance types that used condition triggers: condition-based, predictive

4. Time Trigger: Time is one of the most frequently used maintenance triggers [6]. Here's how it works: an asset is scheduled for maintenance on a predetermined schedule, such as the first of every month or every two weeks. When that time arrives, a maintenance work order is triggered, a technician is alerted, and the maintenance task is completed. Time triggers come in many different shapes and sizes, from an hourly indicator to a seasonal one. Maintenance types that used time triggers: preventive, condition-based, predictive

5. Event Trigger: This type of maintenance trigger boils down to one sentence: if this event occurs, it triggers that type of maintenance. Just add a specific scenario and corresponding maintenance tasks. When the event is added to a digital maintenance system, such as a CMMS, a series of tasks are triggered to help minimize the negative impact of the event or ensure that assets are working properly during the event. For example, if the facility basement floods, the electrical systems should be reviewed or, if an audit is scheduled, certain assets should be inspected. Maintenance types that used event triggers: preventive, condition-based, predictive

2.2. MAINTENANCE STRATEGIES:

There are different strategies that can be used in maintenance depending on different factors related to the organization, to which it is applied. All these strategies distinct or combined are mentioned and discussed below:

1. Run to failure (breakdown maintenance)

This is the basic principle that allows a machine to run without preventive maintenance until a failure occurs [8]. If the equipment fails, this maintenance will be performed. A team assigned this maintenance strategy, such as in the event of a failure (repair, overhaul, or replacement of parts), is limited until simply ordering a replacement kit becomes more practical. This strategy is acceptable. It is used for equipment with the lowest service value (characteristics of other equipment that are rarely used or reused) or equipment with the lowest cost [9].

2. Preventive (scheduled) maintenance (PM)

PM is a planned or scheduled maintenance that is carried out at the beginning of a failure, with the purpose of preventing or delaying failure and minimizing the consequences of failure. This maintenance management practice is based on the principle that prevention is better than cure. It includes maintenance work performed prior to equipment failure to maintain normal operation and minimize the possibility of failure [11-12].

Dillon (2001) mentioned the characteristics of companies that require preventive maintenance:

- Low equipment utilization due to failures.
- Large amounts of scrap and waste products due to unreliable equipment.
- Increase in equipment maintenance costs to repair and replace worn parts/components Due to negligence in routine lubrication, inspections, etc.
- Long-time operator downtime due to equipment failures.
- Reduction of fixed assets. Life expectancy due to poor maintenance.

3. Predictive maintenance (PdM):

In this strategy, maintenance is initiated in response to specific conditions or equipment degradation [13].

Check the health of the equipment for signs of wear that could cause any component of the equipment to fail. The purpose of a predictive maintenance strategy is to track component wear to ensure that imminent failure is detected. Predictive

maintenance is widely used in automotive, aerospace, manufacturing, defense, and other industries [14].

4. Reliability-centered maintenance (RCM):

Reliability Centered Maintenance (RCM) is an enterprise maintenance strategy that can optimize a company or site maintenance plan. The result of the RCM program is to implement a defined maintenance strategy on the assets of each property. Formulating a maintenance strategy consists of selecting the correct combination of corrective maintenance, planned (or preventive) maintenance, and CBM to fully support system reliability in a given operating environment [11-14].

5. Risk-based maintenance

Risk-based maintenance (RBM) first allocates maintenance resources to provide maintenance for the equipment with the highest risk of failure. This strategy determines the most economical way to use of maintenance resources to minimize the risk of failure [15].

The risk-based maintenance strategy has two main stages:

1. Risk assessment.
2. Risk-based maintenance planning.

2.3. MAINTENANCE MANAGEMENT

The wellhead management system provides equipment and facilities; Once available, the production team can order and receive anything as needed, such as light, electric, air, gas, heating, cooling, or machine tools. The well-prepared Maintenance Management System helps reduce downtime and waste of time and money [16].

So far, the literature on maintenance management is very limited. The concept of maintenance varies from organization to organization. Regarding the general business framework, there is no unified solution and published literature. The main management steps identified are expropriation, approval, planning, planning, work execution, data recording, cost accounting, development management information, updating equipment history, and providing management reports.

Elements of effective maintenance management include:

1. Maintenance Policy:
2. Material Control
3. Work Order System
4. Equipment Records

5. Preventive and Corrective Maintenance
6. Task Planning and Scheduling
7. Backlog Control and Priority System
8. Performance Measurement

2.4. MAINTENANCE CHALLENGES IN ELECTRICITY INDUSTRY

The industry alone has problems and worries. However, compared with electricity producers, electricity producers may face more obstacles, because electricity is an essential and important part of our lives. If we lose electricity in a short period of time, everything will stop. The level of control in this industry is higher. As a result, system operators and maintenance teams face many major challenges, including strict standard regulations, hard working conditions, a huge grid with a variety of equipment, and complicated equipment that is hard to keep the system running. There are several challenges in achieving effective service delivery in an organization. Phogat and Gupta highlighted the main issues and obstacles that face maintenance [13-16].

Marquez and Gupta attribute the complexity of Maintenance management (MM) to the lack of an MM model, which may improve the understanding of the basic parameters of the service. Visser (1998-2015) further pointed out that there is not enough knowledge to manage maintenance. This makes it difficult to decide which service strategy to adopt [17-19]. In accordance with Marquez and Gupta, maintenance consists of a series of activities, and it is difficult to find procedures and information support systems in one place to facilitate the improvement process [13]. Hipkin and De Kock classified the obstacles to the implementation of the maintenance system. They classify the obstacles that managers, supervisors, and operators face in managing maintenance as ignorance of facilities and processes, lack of historical data, lack of time to perform the required analysis, lack of management support, and worry about production and business interruptions [20].

Marquez and Gupta also pointed out that the increase in automation and the reduction of storage buffers put pressure on the maintenance system. Electricity cannot be counted, so there is greater maintenance pressure. Utilities love generators more than manufacturing companies. In addition,

Buchanan, and Besant (1985) found that in highly automated organizations, the computational constraints of roles, the integration of teams, and the increase in knowledge requirements make it difficult to diagnose and solve hardware problems [13].

In nutshell, maintenance costs are usually high. Cost is indeed a matter of maintenance and management. Hennequin and Arango pointed out some maintenance management methods, such as total productive maintenance and total quality maintenance, require a lot of investment in manpower and information resources. Many companies may not have enough funds to make this investment. It is also worth noting that because maintenance is mistakenly regarded as a non-strategic function, the support of maintenance management practices by top managers has been rarely used in organizations [5, 21].

3. SUMMARY AND GAPS FROM LITERATURE

The maintenance must consider all factors to adjust them to the needs of the relevant company. This means that the "best" maintenance concept is unique to each company. With the rapid development of industrial systems, maintenance concepts must also be checked regularly to adapt to changing systems and environments.

Many maintenance principles are discussed in the literature. They provide promising and useful ideas, most of which require many resources in terms of personnel and management. Applying standard concepts found in the literature is not always the optimal solution. This also makes it difficult to formulate and implement maintenance concepts in practice. Part of the organization's total cost of ownership.

According to Wilson, some business processes which should be used for optimizing operational performance are: minimizing maintenance costs, adopting optimal maintenance practices, maximizing plant utilization and capability, and maximizing performance efficiency [6]. Furthermore, Ben-Daya had also identified equipment availability as a measure of a firm's operational success [22]. This is the basic principle that enables a machine to operate without preventive maintenance until a failure

occurs. If the equipment fails, this maintenance will be performed. A team assigned this maintenance strategy, such as in the event of a failure (repair, overhaul, or replacement of parts), to be limited until simply ordering a replacement kit becomes more practical. This strategy is acceptable. It is used for equipment with the lowest service value (features of other equipment rarely used or reused) or for equipment with lower cost [8-9].

4. RESEARCH METHODOLOGY

The purpose of the research methodology is to address the objectives of the research. Preliminary research and literature research will help identify areas that require consideration when designing the implementation framework. The next is the most important stage in the paper research methodology of gathering information to clarify the research results. Therefore, it is important to have a good understanding of the problems related to the research method before starting the fieldwork.

Therefore, a comprehensive survey methodology for collecting data (Figure 1) was designed, used, and presented in this paper. In accordance with the standard practice of professional survey bodies, this study has followed with utmost care all the well-established principles and guidelines, especially on the procedure of the survey design and process, as well as the data processing analysis techniques employed.



Figure 1: Research Methodology

5. POPULATION OF SURVEY AND PROFESSIONAL QUESTIONNAIRE LIST

The population of the research includes all maintenance departments in electric companies located in Jordan. A total of 257 questionnaires were sent out and only 55 questionnaires with the required answers were returned, with a response rate of 25%.

This low level of feedback stems from the fact that a large number of employees were off work during the preparation of this research work and questionnaire due to COVID 19 circumstances in Jordan and around the world. Table I shows the names of the main companies that participated in this research work.

Table I: Electricity companies participating in the research work and questionnaire.
Central Electricity Generating Company (CEGCO)
Samra Electric Power Company (SEPCO)
Amman East Power Plant (IPP1)
Korean company KEPCO Qatraneh (IPP2)
Amman Asia Company (IPP3)
Amman East Power Plant (IPP4)
Zarqa'a Electricity Generating Company
National Electric Power Company (NEPCO)
Irbid District Electricity Company (IDECO)
Jordan Electric Power Company (JEPCO)
Electricity Distribution Company (EDCO)

6. RESULTS, DATA PROCESSING AND ANALYSIS

After receiving the response from the participants, the results were edited and electronically saved. The data processing stage mainly comprises 4 steps:

1. Establish a database
2. Data entry

3. Data analysis
4. Generate a report and documentation.

Windows version 12 with the Statistical Software Package for Social Sciences (SPSS) is used for data entry and processing. Based upon the results obtained, Figure 2 shows the distribution of the electricity categories of the companies questioned. The results show that the companies belong to three functional groups: power generation (35.5%), power transmission (21.8%) and power distribution (43.6%).

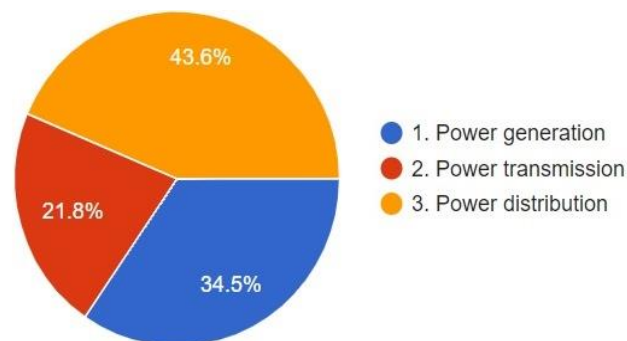


Figure 2: Type of electricity Industry

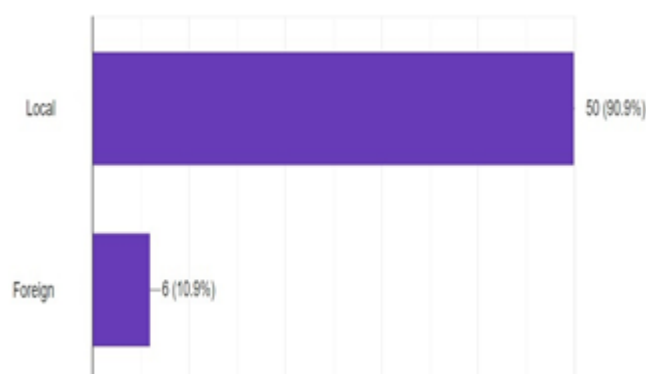


Figure 3: Firm's ownership status

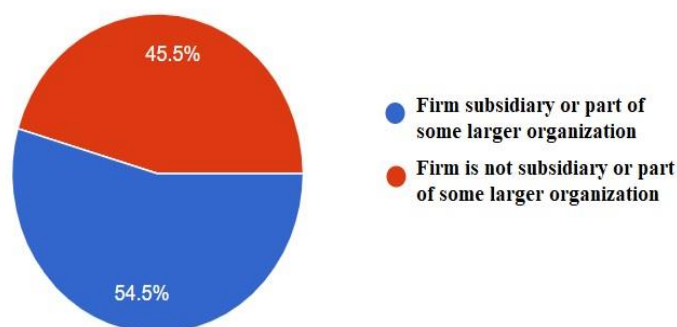


Figure 4: Firm's subsidiary status

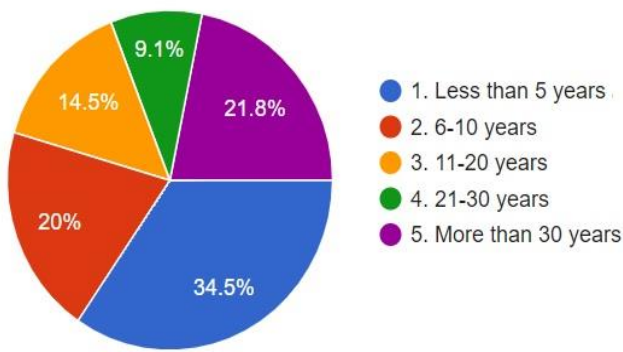


Figure 5: Number of years in operation

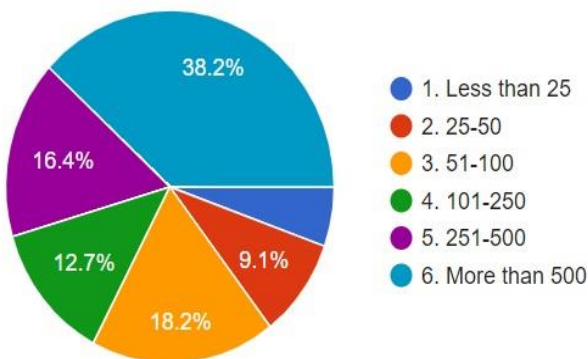


Figure 6: Number of workers

As Figures 3 and 4 show, most businesses and companies involved in this research are “local” businesses and subsidiaries of large organizations.

In terms of years of work and number of employees, Figure 5 shows that most of the Jordanian companies that shared this questionnaire have been in business for less than 10 years and Figure 6 shows the number of employees where most of these companies have at least 100 employees.

7. AUTOMATION AND INTEGRATION LEVELS

Jordanian electricity production companies can be classified, based on the method used in their operation, as manual, semi-automatic, or fully automatic. From this perspective and as shown in Figure 7, most of the companies involved in this research are fully automated. Hence, this is followed by the fact that most of the production is automated.

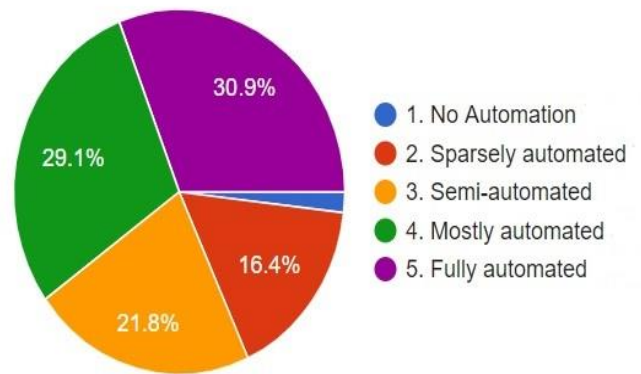


Figure 7: Automation and integration degree

Furthermore, the necessary operations in electric power generation companies and stations that require starting and stopping electrical machines when required by the system need an adequate and automatic protection for these machines. The design and development of PLC controllers and automatic relays with a high degree of accuracy, sensitivity and reliability made such automation possible.

Table II shows that the type of controllers used depends on the degree of automation. This table also shows that the most used control unit for fully automated electrical systems is the PLC controller.

	Sparsely automated	Semi-automated	Mostly automated	Fully automated
Rely	Moderate	Extensive	Minimal	Minimal
PLC	Extensive	Extensive	Extensive	Extensive
DCS	N/A	N/A	Moderate	Extensive
Microprocessor	Moderate	Moderate	Moderate	Extensive
SCADA	N/A	N/A	Moderate	Extensive

Automatic relays are also found to be implemented in semi-automatic electrical systems. The latest generation of control systems, DCS and SCADA systems are widely used in fully automated systems. Meanwhile, the correlation analysis (CA) between the degree of automation and the type of control in a production show that the higher the degree of automation, the

more complex the type of control used, such as DCS and SCADA systems.

8. MAINTENANCE TYPES USED

Table III shows the types of maintenance implemented and their scope of application. The results show that "preventive maintenance" has the highest average value and is often classified as "extensive or quite extensive", followed by "BM" and then "corrective maintenance".

The results in Figures 8a and 8b also illustrate that many respondents have implemented "Total Productive Maintenance" (TPM) compared to "Reliability Centered Maintenance" (RCM).

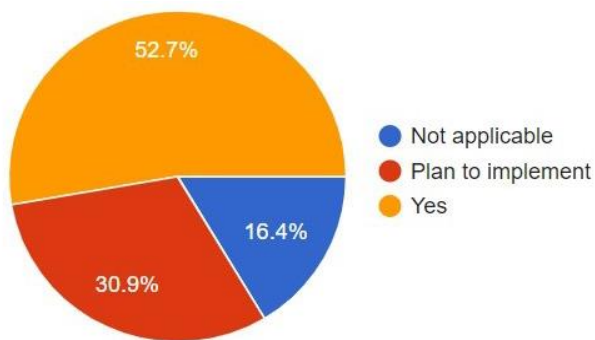


Figure 8a: Practice of Total Productive Maintenance (TPM) program

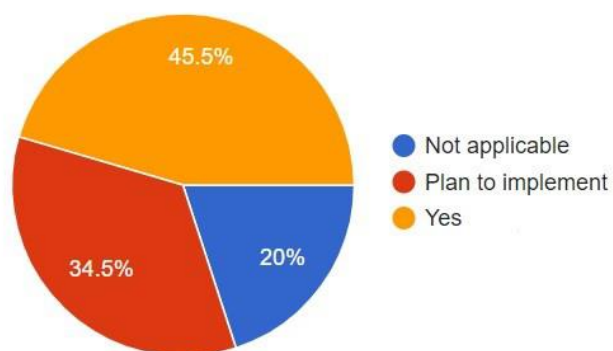


Figure 8b: Practice of Reliability Centered Maintenance (RCM) program.

Table IV shows the main obstacles that face the maintenance of the automation system. The results in Table IV indicate that there are two elements: "lack of motivation" and "lack of supervisory skills" that represent the highest average. Most of the problems identified as obstacles fall into the soft skills

category. On the other hand, "hard skills" categories such as "insufficient manpower" and "insufficient training" are classified as secondary obstacles.

Table III: Maintenance strategies implemented in this research.

Maintenance Strategy	0: Do not have	1: Used minimally	2: Used quite	3: Used moderately	4: Used quite	5: Used extensively	Mean value
F - RCM	16.36%	9.09%	5.45%	14.55%	34.55%	20.00%	3.02
E - TPM	18.18%	3.64%	7.27%	20.00%	29.09%	21.82%	3.04
D - Predictive	12.73%	12.73%	10.91%	18.18%	9.09%	36.36%	2.91
C - Preventive	7.27%	14.55%	9.09%	14.55%	16.36%	38.18%	3.29
B - Corrective	9.09%	5.45%	7.27%	29.09%	18.18%	18.18%	3.18
A - Breakdown	9.09%	5.45%	7.27%	16.36%	12.73%	49.09%	3.27

8.1. PLANNING AND IMPLEMENTATION OF TRAINING

Figure 9 shows the results of using Training Needs Analysis (TNA) to determine the company's maintenance training needs. Based on these results, we can find that most respondents conducted TNA once a year. Meanwhile, the survey results also showed that (16.4%) of respondents did not conduct TNA exercises in their company.

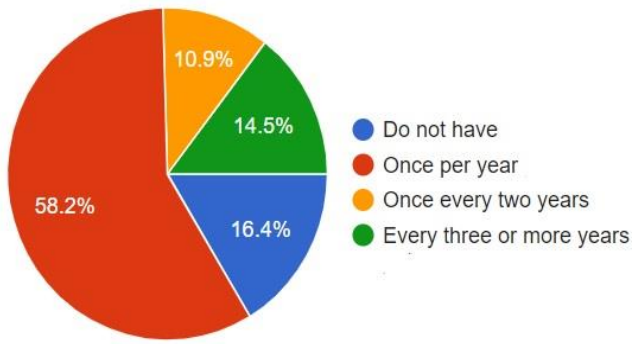


Figure 9: Analysis of training need.

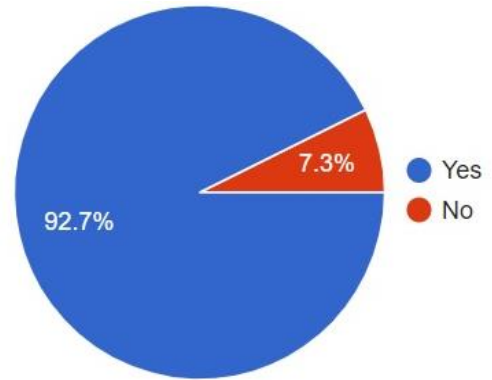


Figure 10: Maintenance role required to review.

8.2. USAGE OF OUTSOURCING MAINTENANCE

Table V shows the ratio of “in-housed maintenance” to outsourcing in maintenance. The average result shows that most respondents use suppliers and manufacturers to outsource maintenance services and qualify as “full participation”.

	A-In housed	B - Consultant	C-Vendor & Manufacturer
0: No involvement	12.73%	16.36%	12.73%
1: Minimal involvement	25.45%	29.09%	36.36%
2: Quite moderate involvement	20.00%	10.91%	9.09%
3: Moderate involvement	10.91%	21.82%	10.91%
4: Quite fully involvement	9.09%	5.45%	18.18%
5: Fully involvement	21.82%	16.36%	12.73%
Mean value	2.63	2.67	3.33

Figure 10 indicates that the majority of respondents see that the role of the company in maintenance needs to be reviewed. Table VI indicates that for those companies whose management does not regard maintenance functions as investments and important support functions, the company's role in maintenance should be reviewed.

	A-Overhead	B-Investment	C-Supporting funct
1: Strongly disagree	7.27%	5.45%	5.45%
2: Disagree	10.91%	12.73%	5.45%
3: Moderate	38.18%	45.45%	34.55%
4: Agree	25.45%	16.36%	21.82%
5: Strongly agree	18.18%	20.00%	32.73%
Mean value	3.40	3.13	3.60

	A-Product Quality	B-Equip Availability	C-Reduce Prod Cost
Less than 20%	12.73%	14.55%	21.82%

About 35%	27.27%	18.18%	14.55%
About 50%	12.73%	21.82%	16.36%
About 65%	9.09%	12.73%	16.36%
More than 80%	38.18%	32.73%	30.91%
Mean value	2.50	2.82	3.06

Table VII indicates maintenance work contributes to productivity. The average results show that maintenance expenditures contribute the most to "improving production cost reduction", followed by "improvement of equipment availability" and "the improvement of product quality".

8.3. USAGE OF CMMS

Regarding the use of a computerized maintenance management system (CMMS), as shown in Figure 11, 41.8% of the respondents used CMMS.

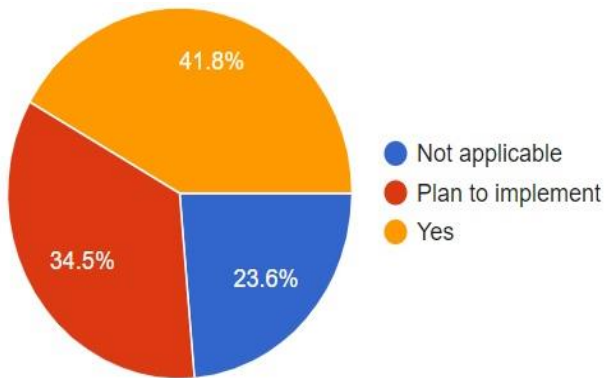


Figure 11: Usage of CMMS.

From the perspective of the level of CMMS used, as shown in Figure 12, most companies use the system extensively. The Pareto analysis technique is used to determine the level of CMMS and most extensive modules used. Modules are classified according to frequency distribution data and average value from the most frequently used module to the least frequently used module.

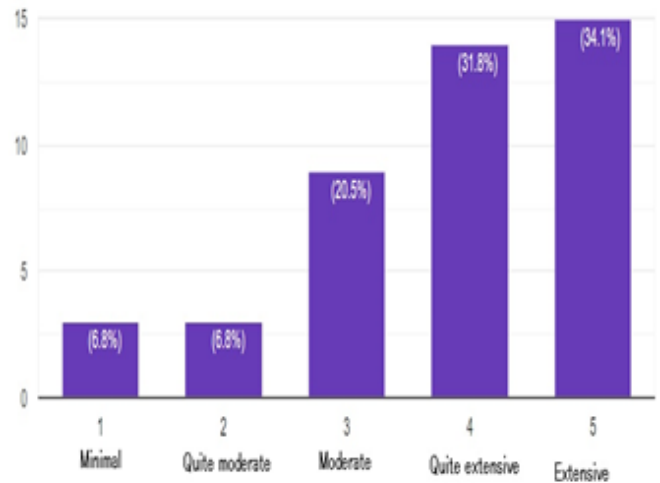


Figure 12: Level of CMMS usage

8.4. MAINTENANCE MANAGEMENT MODEL

Figure 13 shows the proposed Maintenance Management Model, including corrective and preventive maintenance management.

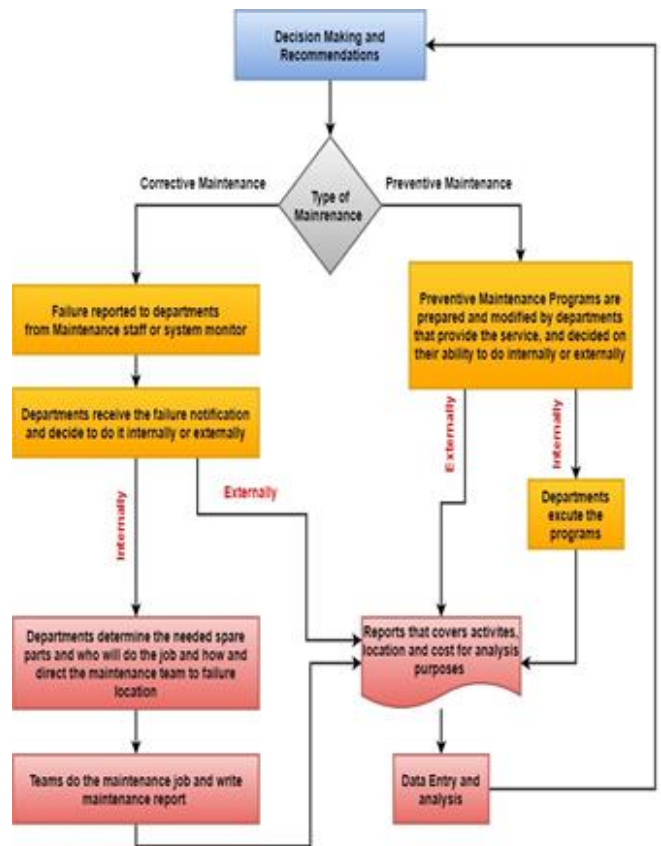


Figure 13: Proposed maintenance management model

In addition, the model takes into consideration the possibility of outsourcing maintenance services and explains the role of different management levels in executing it. The relationship between the various departments of the public utility, such as procurement, branch offices, and information technology departments. The maintenance management model takes into account the need to record the location and cost of maintenance work for analysis and decision-making. Although the model can be adopted by any electric utility company, regardless of its level, the researcher recommends starting with the implementation of the MMM in power distribution because it is more feasible.

9. CONCLUSIONS

This research paper conducts a study on the application of maintenance practices in electrical power companies in Jordan. From the perspective of the technologies used, it can be found that the higher the degree of automation in power plants, the more maintenance practices are implemented.

In this study, a comprehensive data collection method is developed, applied, and introduced. In compliance with the practice of professional investigation agencies, this study strictly follows all established principles and guidelines, especially in the design and investigation process and the data processing and analysis methods used.

Moreover, to achieve the main objectives of this research, a questionnaire was conducted to study how necessary the maintenance is for the companies participating in the research and other things related to the maintenance such as planning, spare parts, equipment calibration, and training of maintenance personnel.

The survey results reveal that most of the respondents had never attended the maintenance conference, seminar, or workshop. This result shows low participation, although the existence of such a maintenance conference is supposed to be a platform for the maintenance personnel to discuss the maintenance issues and share information with other maintenance personnel in different organizations.

The results of this research clearly show that management commitment is critical to successful maintenance performance. Furthermore, according to the stated purpose of this research, the maintenance strategy formulation process leads to the formulation of the development strategy of the maintenance personnel of the utility company and incorporates it into the company maintenance strategy.

Relied on the results provided in this paper, the main findings of maintenance practices and methods that help improve plant availability are summarized as follows: Increasing use of proactive maintenance, computerized maintenance management, and troubleshooting during maintenance. This practice and approaches can be summarized as follow:

- Higher degree of utilization of proactive maintenance approaches such as preventive and predictive maintenance.
- Higher degree of utilization of aggressive maintenance approaches such as TPM.
- Lesser degree of utilization of reactive maintenance approach such as breakdown maintenance.
- Higher degree of utilization of Computerized Maintenance Management System (CMMS).
- Higher degree of utilization of maintenance troubleshooting techniques such as Failure Modes Effects & (Criticality) Analysis, System Analysis Design Techniques, Fault Tree Analysis, and Pareto Analysis.

The results show that the maintenance effort contributes the highest percentage in the improvement of equipment availability, followed by the reduction of production cost and product quality. In addition, the correlation analysis indicates that the higher the improvement of equipment availability, the better the improvement on the product quality and the reduction of production cost. In other correlation analysis results, it indicates that the higher the improvement of the performance, the higher the level of satisfaction on the maintenance achievement.

The research work highlighted in this paper suggests that the maintenance staff should be composed of multi-purpose and multi-task personnel. According to the application field and

technology of the power plant, they can solve any problem that can meet such requirements with the help of maintenance personnel training. From the point of view of personnel development, proper analysis of training needs, planning, and implementation of training courses are expected to improve equipment availability.

10.LIMITATIONS OF THE STUDY

Time is the main determinant of this study. The COVID 19 pandemic affected the way of work and preparation of this research that was mainly dependent on the online network pattern and use of different technology platforms like ZOOM, Microsoft team, etc.

In addition, another significant limitation of this study is the accessibility of participating companies. Due to COVID 19 pandemic, there were many cases of prolonged closures in Jordan and sometimes, 50% of the employees of participating companies were out of work, which greatly affected the response rate to the survey.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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