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Determining the Efficiency of Maintenance Programs Using Performance Indicators: Case Study in Electric Cables and Wires Factory

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The performance and competitiveness of industrial organization are based on the relabelling availability and productivity of their production facility. In order to achieve the desired level of performance from these facilities, those responsible for maintenance need to adopt plans and strategies and choose the path that ensures good performance. This study aims to calculate the performance indicators of maintenance work in the electrical cables and wires factory of Ur State Company. The leading and lagging indicators were applied in order to measure the efficiency of the performance of the maintenance work in order to help the senior management choose the method or methods of maintenance that suit the nature of the company's work in general, and the community research factory in particular. These indicators were calculated for the first six months of 2019 and for all the machines that make up the production line in the lab according to the actual operating times, the breakdown times and all the other actual data needed to calculate these indicators, which were collected from the company's records as well as field visits, personal interviews conducted and direct observation.

Key words: *Preventive maintenance, corrective maintenance, predictive maintenance, leading and lagging indicators.*

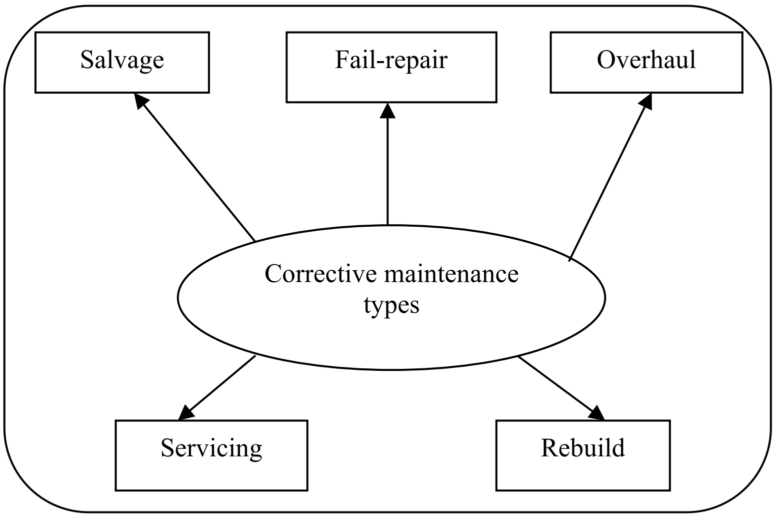
Introduction

Increasing awareness of the importance of maintenance creates added value for the work and operations performed by organizations. They are an integral part and are essential for maintaining profitability over the long term. Maintenance is an essential part of the strategic thinking of senior management (Aditya ,2006:2) as it ensures that the facilities and equipment are in good working order so that a system can perform as intended (Farnsworth & Tomiyama ,2014:1 ;Stevenson , 2018:644). Other researchers emphasize that the maintenance of any machine or system that includes three main functions are (Anyaka & Josphine , 2013:11) :-

1- Corrective maintenance that includes identification, detection, diagnosis, repair/replacement and equipment and verification of the sudden breakdown of machinery and equipment. Some researchers classify corrective maintenance into five categories :

a- Fail – repair : The failed part is restored to its operational state.
b- Salvage: This element of corrective maintenance is concerned with the disposal of nonreplicable material and the use of salvaged material from nonreplicable equipment / item in the repair , overhaul , or rebuild programs.
c- Rebuild: Restore the part or component to a level that is as close possible to the original performance, life expectancy and appearance. This is achieved through complete disassembly, inspection of all components, repair and replacement of damaged / unusable parts according to original specifications, reassembly and selection of guidelines for original production .
d- Overhaul : Restoring an item to its total serviceable state as per maintenance serviceability standards, using the "inspect and repair only as appropriate" approach.
e- Servicing: Servicing may be needed because of the corrective maintenance action, for example, engine repair can lead to crankcase refill, welding on , etc. Another example could be that the replacement of an air bottle may require system recharging (Dhillon,2002:72-73). Figure (1) illustrates this.

Figure 1. Types of corrective maintenance



Source: Dhillon , B.S.(2002) ."Engineering maintenance : a modern approach ".CRC. Press LLC . PP.73 .

2- Setting up and preparing for the implementation of scheduled preventive maintenance, replacements or necessary repairs .
3- Implementation of the reform activities in the central maintenance workshop. Organization machines and equipment that suffer from failure need to be replaced and arrive from the operating station in the organization .

Performance indicators help to identify gaps between actual performance and planned performance and are therefore one of the tools by which sufficient quantitative information can be given to management on the nature and feasibility of the maintenance work used (Arts et al., 1998 :8). The European Union of National Maintenance Societies (EFNMS) has carried out several workshops since 2004, as a result of the issuance of the draft of EN 15341. This draft included 71 indicators for measuring maintenance performance and was divided into economic indicators, technical indicators and organizational indicators. Of these, 13 were identified by EFNMS in 2002, all of which resulted in the new European standard PrEN 15341. Other researchers classify the performance indicators used in the evaluation of maintenance work into two types: leading and lagging.

Research Methodology

Research Problem

Industry is one of the basic components of the economies of any country, and one of the main elements of this industry is machinery and equipment, which is characterized by increasing cost, resulting in the tendency of industrial organizations to work hard to maintain their operational status and also raise the level of performance in order to reach the level of production, efficiency, and quality required by their plans. This is to be achieved at the lowest cost possible through the adoption of effective management practices in maintenance work. Thus, the main problem of the research can be posed by the following question: What is the level of efficiency of current maintenance programs using performance indicators, and is it possible to implement the predictive maintenance program? The main problem arises from the following sub-problems:

- What are the maintenance programs applied in the organization under consideration?
- What is the level of efficiency of maintenance programs applied using performance indicators?
- Does the organization in question have sufficient capabilities to implement the predictive maintenance program?

Research Significance

1-The urgent need to maintain machinery and equipment in good condition in order to maintain the level of production in terms of quantity and quality.
2-The high cost of the work hour, which is added to the cost resulting from the cessation of machinery and equipment.
3-The high prices of machinery and equipment, which call for more attention to increase the benefits they afford.
4-Draw the attention of officials to increase attention to maintenance programs and thus prevent possible performance deviations from falling.
5-Assisting the industrial departments in applying the modern concepts of maintenance, including predictive maintenance by providing the necessary capabilities for this.

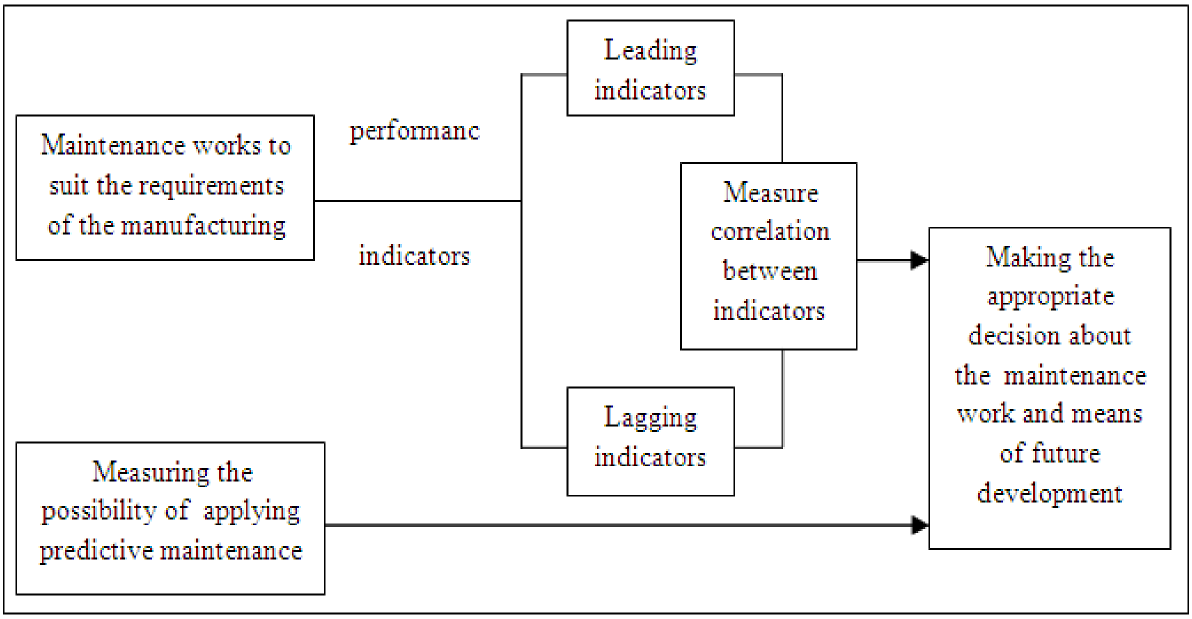
Research Objectives

1-Evaluate the maintenance programs currently in place in the organization under consideration and thus identify weaknesses, strengths, and ways to eliminate or address weaknesses and to use strengths to improve performance.
2-To create and develop a basis for decision making regarding maintenance and according to the nature of the work of the organization.
3-Increase the chances of operating machinery and equipment using the resources available for maintenance of materials, labour and capital to achieve a high level of performance.
4-To clarify the importance of the performance indicators used in selecting the best maintenance programs commensurate with the work of the organization.
5-Identify the possibilities available in the organization in question and enable them to implement the program of predictive maintenance.

Procedural Chart and Research Hypotheses

The procedural chart was designed for research and its hypotheses were formulated in accordance with the research problem, its importance, objectives. In figure (2), the procedural diagram of the research is described as follows:

Figure 2. The procedural chart of the research



Source: Done by researchers.

The hypotheses of the research were as follows:

H1: There is a significant correlation between the leading indicators and the lagging indicators for measuring the performance of maintenance work.
H2: Leading and lagging performance indicators help to determine the efficiency of completed and planned maintenance work and, after calculating the cost of maintenance, provide the necessary tools to make the appropriate decision about the maintenance work and ways of future development.
H3: It is possible that the application of predictive maintenance in the study of factory community may enable them to make the appropriate decision on maintenance work and find ways to develop it in the future.

Research Sample and Society

An electric cables and wires factory was selected as a research subject for its great importance in meeting the needs of the public and private sectors of its products. It is one of the factories of Ur Company in Nasiriyah, Thi Qar provice which is one of the Ministry of Industry and Minerals Iraqi companies. The company was established in 1988 by merging two adjacent factories, namely the General Establishment for Cable and Wire and the General Establishment for the Aluminum Industry, which was established in 1974-75. The company also has the international quality certificate in accordance with ISO 9001-2015 granted by Vexil BPS, New Zealand Jaz-Anz and its aim to cover approximately 45-50% of the needs of the public and private sectors of its products and is constantly working to become one of the leading self-financed industrial companies. The electric cables and wires factory was established in 1976 and started work in 1977. The factory specializes in the production of all types of low tension (1-0.6 kv) electric wires and cables for single phase or multi-phase application, made of copper, insulated and coated with P.V.C and measurements below:($1\times4mm^2..1\times500mm^2, 2\times4mm^2..2\times50mm^2, 3\times10mm^2..3\times240mm^2+120mm^2, 4\times4mm^2..4\times240mm^2$). Performance indicators were applied in the current research to the maintenance programs applied to the three machines:-

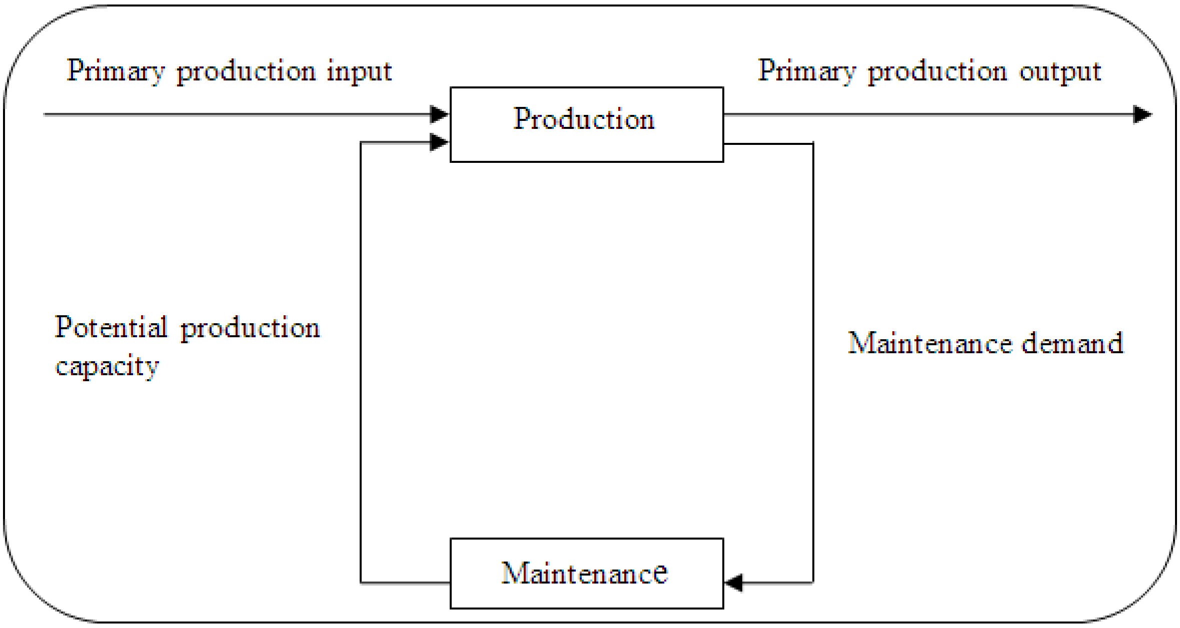
- Pull machine is used for smoothing copper or aluminium.
- Winding machine is used in the process of winding the wire from length to length to another on request.
- Twisting machine is used in the winding a set of wires together.

Theoretical Framework

Maintenance Concept

Maintenance is defined as the activities involved in keeping a system's equipment in working order (Galar *et al.,*2011:3;Heizer *et al.,*2017:662). The target of maintenance is to reduce the number of failures in machines and equipment during the process of production and elimination, as the breakdown of any of them may lead to a disruption in the processing chain. Therefore, the terms of cost, safety and the continued operation of machinery and equipment are considered during the production process (Lee et al., 2017:50). Steinsland (2018:22) added that the goal of maintenance is to keep the capability of the production system and keep the currency in good condition at minimal cost. Simon (2010:116) also pointed out that maintenance needs are considered as the "must-do's" of any business and usually comprise a top-up of knowledge and skills to support a steady-state operational environment.

Figure 3. The relationship between production & maintenance



Source: Gits,C.W (1992)."Design of maintenance concepts" . International Journal of Production Economics , 24, PP.218.

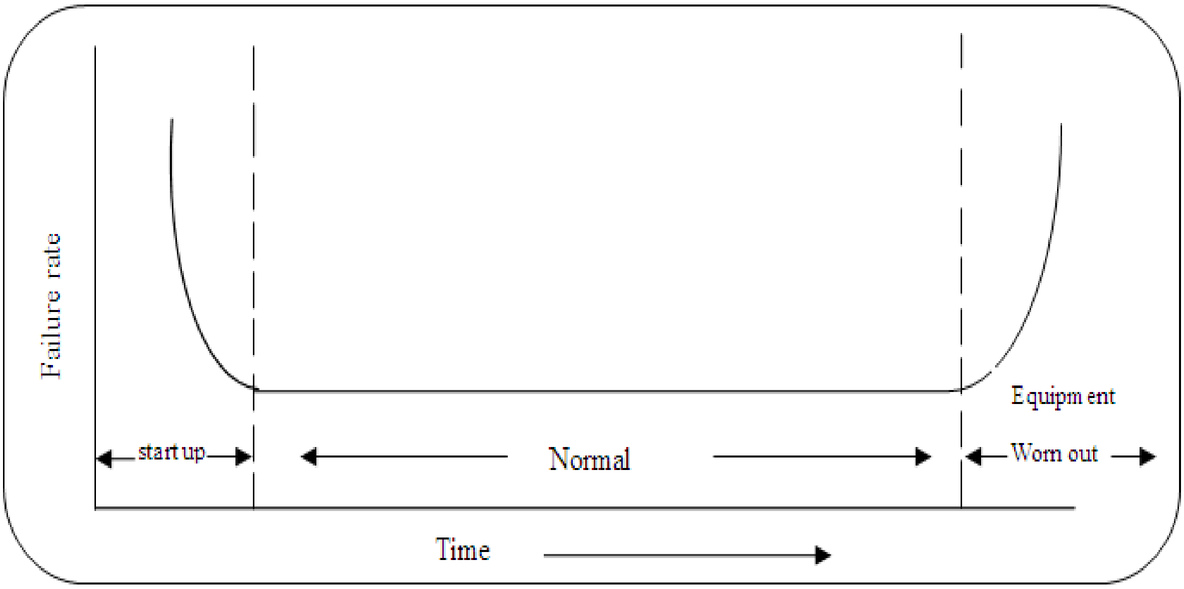
Maintenance Management Methods

There are two traditional maintenance management methods: Run-to-Failure and Preventive maintenance.

1- Run-to-Failure management: This method is based on a major philosophy that "The machine or system is not repaired unless it is broken." The money is spent on maintenance only when the machine or system fails. This method is a reactive management technique that waits for the failure of the machine or system before carrying out the necessary maintenance. This is expensive because it needs large quantities of spare parts in the inventory (Monchy,2000:32 ; Exner,2018:8).

2- Preventive Maintenance: This is a scheduled maintenance carried out by the organization to ensure that the machine or system continues to operate according to the mean-time-to-failure (MTTF) or bathtub curve indicating that the machine or system failure is relatively low during the first few weeks of machine work but increases sharply over time (slack & Jones,2018:512) .

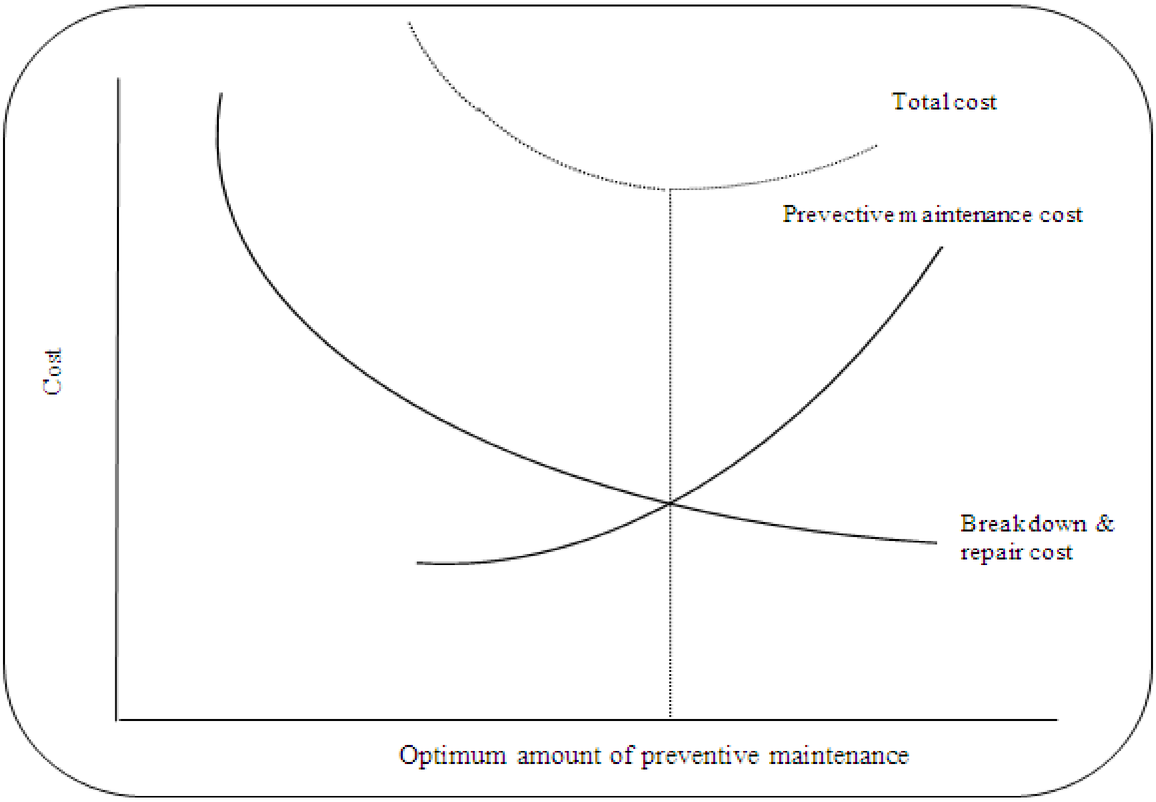
Figure 4. Classical Bathtub Curve



Source: Foster, S. Thomas(2013)."Managing quality : integrating the supply chain". 5th.ed, Pearson Education, Inc., publishing as prentice Hall .PP.325.

The mean-time-between-failures (MTBF) is the period between one failure and another and is used in order to document the relationship between maintenance and faults and to prevent or minimize these failures. Some researchers have known preventive maintenance as a plan that involves monitoring routine inspections, servicing and keeping facilities in good repair (Heizer et al., 2017: 662 ; Idoniboyeobu et al., 2018). Figure (5) explain total maintenance cost as a function of preventive maintenance effort (Stevenson , 2018:645).

Figure 5. Total maintenance cost as a function of preventive maintenance effort



Source: Stevenson , William J.(2018) ."Operations management". 13th.ed , McGraw Hill education .PP.645.

4- Predictive maintenance : This is a philosophy that simply uses the actual operation of factory machinery and equipment through a total program that is highly effective and that focuses on the regular monitoring of machine condition, vibration monitoring, thermograph tribology, etc. It aims to reduce the number and cost of unscheduled failures , improve productivity , product quality as well as the overall efficiency of manufacturing and production, as it schedules all maintenance activities as needed to ensure the optimum operation of machinery and equipment. Recent advances in predictive maintenance technologies have led many manufacturers to abandon traditional periodic maintenance policies and replace them with predictive maintenance policies (Mckone & Weiss,2002:109). Improving the productivity of machines and equipment:

5- Improving the economic efficiency of machines and equipment.
6- Improve system reliability.
7- Improving the level of availability.
8- Improve safety
9- Minimize expected maintenance costs per unit time.

The European Union of National Maintenance Societies (EFNMS) has carried out several workshops since 2004, as a result of the issuance of the draft of EN 15341. This draft included 71 indicators for measuring maintenance performance and was divided into economic indicators, technical indicators and organizational indicators. Of these, 13 were identified by EFNMS in 2002, all of which resulted in the new European standard PrEN 15341. These indicators were called key performance indicators (EFNMS, 2006). Other researchers classify the performance indicators used in evaluation of maintenance work into two types:

1- Leading indicators : These indicators are called maintenance indicators and give a clear idea to users not to arrive at the goals before there is a problem. It is one in a statistical series that acts as a performance guide if the activities and maintenance functions are performed well and draw the attention of the maintenance official to verify the current situation compared to the reference situation. It also monitors the activities and tasks that lead to the achievement of the required results (Kumar et al., 2013 : 235) . These are the following indicators :

a. preventive maintenance works(%) = $\frac{\textit{total working hours for preventive maintenance}}{\textit{total maintenance costs}}$**.....(1)**

The benchmark is between (75-80%) by standard EN 15341.

b. corrective maintenance works(%) = $\frac{\textit{total working hours for corrective maintenance}}{\textit{total maintenance costs}}$**........(2)**

The benchmark is between (10-15%) by standard EN 15341 .

c. planned works density(%) = $\frac{\textit{total required works}}{\textit{total planned works}}$**...........(3)**

The benchmark is between (95%) by standard EN 15341 .

d. Mean time to repair (MTTR): It is also called the Maintainability indicator because there is breakdown . It includes (the time of diagnosing the faults, dismantling the machine, the replacement that may be partial or total, in addition re-installing the machine, as well as the time of inspection and making sure that the machine returned to work) . It can be expressed by following equation (Kattan & Hassan , 2010 :356) :

MTTR = $\frac{\textit{total stop times}}{\textit{number of breakdowns}}$....................(4)

e. Mean time between failures(MTBF): MTBF is an important indicator for measuring the quality of maintenance performance. It measures the average time between vacations occurring in the machine or one of its repairable parts . When this indicator is increased, the efficiency of the machines and equipment will increase in the production of products of the required quantity and quality, so it is an essential indicator for measuring maintenance performance (Heizer et al., 2017 :703). It is also called the reliability indicator and it is possible that the machine will work well for a certain period of time under specific conditions of use. Reliability refers to the time required by the machine to work before any breakdown occurs or, in other words, the rate of time of use of the machine that is trapped between breakdown (Stevenson , 2012 :171). It is expressed in the following equation:

$$\text{MTBF} = \frac{\boldsymbol{total\ operational\ time}}{\boldsymbol{total\ number\ of\ failures}} \ldots\ldots\ldots\ldots(5)$$

f. Failure rate (λ) : It is average time inverted between breakdowns, symbolized by the symbol (λ) . The probability of the occurrence of failure is one of the most important indicators necessary to analyze the reliability of the machine, as it determines the possibility of the failure of equipment and machines that have been running for a certain period at any moment to come. It is expressed in the following equation:

$$\lambda = \mathbf{1}/\boldsymbol{MTTR} \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

g. Availability: This indicator measures the degree of efficiency of the machine to perform its function under the interdependent factors of reliability and maintainability under specific operating conditions, within a certain period of time (Nilsson & Bertling , 2007 :225). The value of this indicator should be as high as possible, depending on preventive maintenance performed during the planned operating time (Katukoori , 2011 :25). The increase in this indicator depends on two options (Muchiri et al., 2011: 25):

10- Increase mean time between failures (MTBF)
11- Reduce mean time to repair (MTTR)

$$\text{Availability} = \frac{\boldsymbol{MTBF}}{\boldsymbol{MTBF+MTTR}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Or

$$\boldsymbol{Availability} = \frac{\boldsymbol{Required\ availability - Downtime}}{\boldsymbol{Required\ availability}} \times \mathbf{100} \ldots\ldots\ldots(7)$$

h. Time loss: It means the lost time, which is not used by the machine because it suffers from a breakdown, and depends on the duration of the breakdown. The longer the time of the breakdowns the greater the time loss. It is calculated with the following equation:

Time loss = planned operating time - actual operating time…………(8)

i. Overall equipment effectiveness (OEE)

OEE = Availability × Performance rate ×Quality rate .

*performance rate : It is a measure of the level of performance, compared to the ideal or design performance. This measure shows the actual production speed compared to the ideal speed or design, although this speed may different from product to product. It is expressed in the following equation :

$$-\boldsymbol{Performance\ rate} = \frac{\boldsymbol{Number\ of\ produced\ units \times ideal\ Operating\ time}}{\boldsymbol{available\ load\ time - breakdowns\ time}} \ldots\ldots(9)$$

* Quality rate : Is a measure of the proportion of usable units (the units are free of defects) to the total number that has been produced, this measure shows to some extent the lost time in the production of defective units

$$-\boldsymbol{Quality\ rate} = \frac{\boldsymbol{total\ number\ of\ produced\ units - number\ of\ defective\ units}}{\boldsymbol{total\ number\ of\ produced\ units}} \ldots\ldots\ldots(10)$$

2- Lagging indicators: Also called maintenance results indicators, it is determined whether the outputs or results have been achieved .

a. Total maintenance costs = Preventive maintenance costs + Corrective maintenance costs…(11)

Total maintenance costs indicator = $\frac{\boldsymbol{total\ maintenance\ costs}}{\boldsymbol{total\ production\ costs}}$……………………(12)

b. Cost of maintenance personnel = $\frac{\boldsymbol{total\ maintenance\ personnel\ costs}}{\boldsymbol{total\ maintenance\ costs}}$…………………(13)

It is important to determine the relationship between preventive maintenance time and average repair time using correlation coefficient , it is expressed in the following equation (Al-Rawi , 1979 :443)

$$r = \frac{\Sigma(x - x^{-})(y - y^{-})}{\sqrt{\Sigma(x - x^{-})^{2}\Sigma(y - y^{-})^{2}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

Therefore

$-1 \leq r \leq 1$

This means that the direct correlation indicates that any increase in the values of one of the two variables leads to an increase in the values of the other variable, whereas the indirect correlation indicates that any increase in the values of one of the two variables leads to a decrease in the values of the other variable . It should be emphasized here that the correlation coefficient between two variables is a descriptive measure of the linear correlation between them and that when (r = 0) it means that there is no linear correlation between them and not the absence of a relationship between them (Al-Rawi , 1979 :443) .

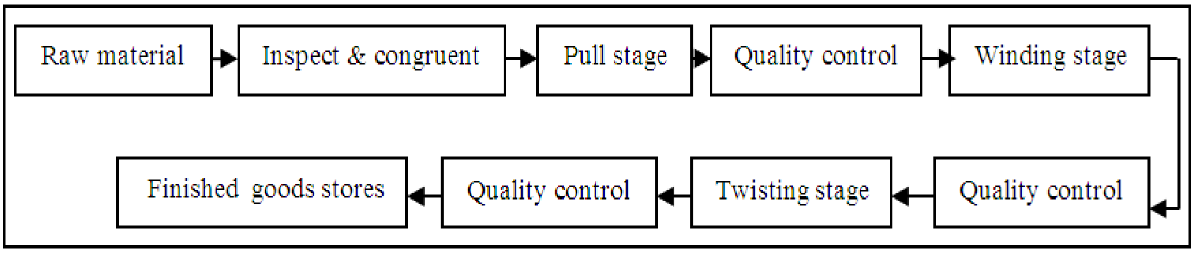
Practical Framework

In the practical framework, we will focus on the following paragraphs:

1- The technological track for the production of electric cables and wires in the factory research society.

The technological track of the electric cables and wires production line consists of three main stages: pull stage, Winding stage, twisting stage. There is also a stage of quality control that comes after each manufacturing stage.

Figure 6. The technological track for the production of electric cables and wires



2- Collecting and analyzing the actual data of the operation and suspension of machines with the evaluation of the performance of maintenance work in the factory research society.

The data was collected for the actual times when the machines work in the electric cables and wires factory. The factory operates for 8 hours and over two morning and evening shifts for a period of 5 days per week, which is equivalent to 320 hours per month, or 19200 minutes. The design capacity of the factory is 35 tons per month, which is equivalent to 48611.11 meters per month. Table (1):

Table 1: Types of breakdowns that are exposed factory machines

The electric board breakdown	Feeder holder breakdown
Hydraulic system breakdown	Breakdown of machine break
The control circuit of the main motor is breakdown	Feeder rollers breakdown
The cooling fan breakdown	Change the receiving stand for the machine
Heathers repair	Break a number of templates and replace them with another
Cut the timing belt of the pull motor	Switching the system to break the machine
Cut the main timing belt of the cylinder	Replacing the main roller press on timing belt

The results of the implementation of indicators of measuring the performance of maintenance work (Leading and lagging indicators) for each machine for a period of 6 months were treated for a sample of the research. 18 observers observed. Table (2) shows the average number of indicators used for each stage and the production line in general .

Table 2: The average indicators for measuring the performance of the maintenance work of the stages (machines), which consists of the electric cables and wires factory and the production line in general

Stage (machine)	cmw	pmw	pwd	mtt	mtb	fr	av	tl	oee	tmc	cmp
pull	0.63	0.37	0.45	1.79	30.85	0.56	0.94	58.15	0.54	2773691.833	0.84
winding	0.64	0.36	0.45	1.9	35.65	0.52	0.94	57.03	0.55	3056315.167	0.74
twisting	0.47	0.53	0.45	1.72	20.08	0.61	0.92	65.60	0.54	3018152.500	0.72
production line	0.58	0.42	0.45	1.80	28.86	0.56	0.93	60.26	0.54	2949386.500	0.77

Table (2) shows the following:

a. Regarding the percentage of corrective maintenance work, we find that the winding phase (machine) has achieved the highest average (0.64) and note the need to pay attention to the machine's breakdowns, as well as to give the subject of maintenance attention at this stage. The value of this indicator at the level of production line was (0.58), which is acceptable.
b. The twisting machine has the highest average for the percentage of privative maintenance (0.53). We note that the attention of the maintenance team located in the factory at this stage and the necessary corrective maintenance ensure the continuation of the work of this machine during the production phase and reduce the number of breakdowns. The value of this indicator at the level of the production line has recorded (0.42) .
c. The ratio of planned work density was a fixed ratio for all stages and in the production line in general. It recorded an average (0.45).
d. The average of the repair time was the largest winding phase compared to the other stages. It recorded (1.9), while the production line in general has recorded (1.8), indicating that the ability of maintenance operations on the winding machine in particular and the production line in general.
e. Regarding the average time between the two breakdowns, the highest average on the winding machine (35.65) has helped to achieve this average of regular maintenance of the preventive maintenance of this machine, and therefore the time of operation of this machine.

f. The indicator of the availability of machines (winding and pull) has the highest percentage compared to the twisting machine, which was (0.94), indicating low breakdowns and maintenance. These results are consistent with the views of many researchers such as Slack et al. (2018).

g. The overall equipment effectiveness (OEE) recorded the highest percentage of the winding machine compared with the rest of the machines (0.55). Most studies in this field indicate the need to eliminate the six big losses (Breakdown setup / adjustment, idling / minor stoppages, speed, Defects in process and rework , Start up losses) in order to raise the proportion of this indicator. The value of the production line in general was (0.54) .

h. The total cost of maintenance was 2773691.833 Iraqi Dinar . The total cost of maintenance for the production line in general is 2949386.5 Iraqi Dinar.

i. The percentage of maintenance workers' costs was lower on the twisting machine compared with other machines as the ratio (0.72) of the total maintenance costs. The average cost of the production line in general was recorded as (0.77) of the total maintenance costs .

Table (3) shows the average cost of preventive and corrective maintenance and performance and quality rates for each stage and the production line in general:

Table 3: Average cost of preventive and corrective maintenance and performance and quality rates for each stage and production line

Stage	Statement						
	pmc	cmc	actual production	defective percentage	defects (meter)	performance rate	quality rate
Pull	1303600	1623091.83	22120	0.051	1128.12	0.61	0.95
winding	1485568	1532584.5	22120	0.057	1260.874	0.63	0.94
twisting	1354315.833	1701999.33	22120	0.048	1060.7	0.61	0.95
production line	1381161.28	1619225.22	22120	0.052	1149.90	0.616	0.946

$$utilization\ rate\ of\ the\ production\ line = \frac{Actual\ production}{Design\ capacity}$$

$$utilization\ rate\ of\ the\ production\ line = \frac{22120}{48611.11} = 0.455 \approx 46\%$$

The results of the analysis presented in Tables (2) and (3) show the validity of Hypothesis (2) which states that the leading and lagging performance indicators help to determine the efficiency of completed and planned maintenance work and, after calculating the cost of maintenance, provide the necessary tools to make the appropriate decision about the maintenance work and ways of future development.

3- Analysis of relations between indicators

After examining and analyzing indicators measuring the performance of leading and lagging maintenance work, an important issue concerning correlation between these indicators and Table (4) shows the correlation between the leading indicators and the lagging indicators combined. The correlation coefficient between these indicators is (0.938) at a significant level (0.01) and a confidence level (0.99), indicating the correlation strength between these indicators.

Table 4: Matrix of correlation between the leading and lagging indicators combined

	cmw	**pmw**	**pwd**	**mtt**	**mtb**	**fr**	**av**	**tl**	**oee**	Ld	La
cmw	1 18										
pmw	.977** .000 18	1 18									
pwd	.909** .000 18	.923** .000 18	1 18								
mtt	.953** .000 18	.968** .000 18	.966** .000 18	1 18							
mtb	.987** .000 18	.990** .000 18	.957** .000 18	.981** .000 18	1 18						
fr	.583** .000 18	.935** .000 18	.883** .000 18	.946** .000 18	.939** .000 18	1 18					
av	.910** .000 18	.864** .000 18	.953** .000 18	.941** .000 18	.950** .000 18	.519** .000 18	1 18				
tl	.942** .000 18	.935** .000 18	.928** .000 18	.937** .000 18	.974** .000 18	.875** .000 18	.919** .000 18	1 18			

oee	.783** .000 18	.587** .000 18	.833** .000 18	.685** .000 18	.938** .000 18	.922** .000 18	.951** .000 18	.588** .000 18	1 18		
Ld	.941** .000 18	.787** .000 18	.861** .000 18	.633** .000 18	.638** .000 18	.522** .000 18	.987** .000 18	.816** .000 18	.529** .000 18	1 18	
La	.907** .000 18	.913** .000 18	.838** .000 18	.881** .000 18	.559** .000 18	.914** .000 18	.934** .000 18	.903** .000 18	.893** .000 18	.889** .000 18	1 18

**. Correlation is significant at the 0.01 level (2- tailed)

Table (5) shows the (t) test of the correlation between the advanced and late indicators for measuring maintenance.

Table 5: (t) test of the correlation between the advanced and late indicators for measuring maintenance

Correlation	degree of freedom	Calculated (t) value	tabular (t) value
0.889	17	7.339	2.567

** at a significant level 0.01

Table (5) shows that the calculated (t) value is greater than its tabular (t) value at a level of confidence (0.01). This confirms (0.99) the strength of the relationship between the leading and lagging indicators at the current research level. It accepts hypothesis (1), which states that there is a significant correlation between the leading indicators and the lagging indicators for measuring the performance of maintenance work.

4- Measuring the possibility of applying predictive maintenance in the research community factory

Predictive maintenance depends on the principle condition monitoring of the machine in order to predict the type and time of the occurrence of the fault before it is delivered. This entails the provision of adequate funds. To determine the possibility of applying this type of maintenance in the factory, the factory manager and the personnel working in maintenance were interviewed. A set of open and direct questions were also asked to clarify the advantages of using predictive maintenance in terms of increasing the life of the machine, reducing downtime and increasing reliability

Conclusions and Recommendations

Conclusions

1- The increase in the number of breakdowns and stop hours led to a decrease in the percentage of machines' availability from the ideal condition required (100%). The availability indicator of the production line was (0.93). In other words, the decrease in the availability indicator was due to the decrease in the average time period between the breakdown and the increase in the time loss.
2- The increase in the number of breakdowns affected the decrease in the percentage of utilization of the production capacity of a number of machines, which negatively affected the decrease in the utilization rate of the production line as it recorded (0.46).
3- Tested the validity of the first hypothesis, which indicates a significant correlation between the leading and lagging indicators to evaluate the performance of maintenance work in the factory .
4- The results of field visits and interviews with members of the board of directors and the director of the factory electrical cables and wires in particular proved unavailable to apply the predictive maintenance method..
5- The results showed a decrease in corrective maintenance compared with preventive maintenance.

Recommendations

1- Greater attention to maintenance operations in accordance with new foundations and programs aimed at reducing the size of breakdowns and increasing the hours of actual operation of the machines to lead to increased availability and little time loss.
2- The need to rely on the quantitative indicators that measure the quality of the performance of maintenance work in the factory of electric cables and wires, in addition to the need to analyze the real relations the number of failures and times of stops and work.
3- Improving the operational efficiency of existing machines through total or partial maintenance, and updating outdated machinery after relying on indicators of assessment of replacement and development processes.
4- Allocate sufficient funds for the completion of programs and training courses and the development of employees in the company and the factory community in particular to provide them with the methods and techniques that can raise the level of performance of maintenance work, including the possibility of applying predictive maintenance because of its great benefit to the company in general.

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