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The Important Criterions to Select the Optimum Maintenance Strategy in Jordanian Food Industry

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Abstract

The primary purpose of this research is to study the criterions used to select the maintenance strategy in the food industry. Six criterions were identified; cost, historical data, added value, feasibility, safety, and equipment status. A survey was conducted in the Jordanaina food industry to rank them based on the importance when selecting the maintenance strategy for machines, 93.5% of the surveys were completed. Historical data was the significant (18.8%) followed by add value (18.3%), safety (17%), equipment status (16.8%), cost of maintenance (16.3%), and last is feasibility (12.8%).

Keywords
Maintenance Criterion, Food Industry, Jordan Maintenance, Machine Safety Maintenance

1. Introduction

Machine maintenance becomes a very critical part of any company, due to the need for high productivity, availability, and quality from production lines, while machines have become more complicated and expensive. Improving and achieving a maintenance program is a complex issue that suffers from many difficulties, including weak organization and lack of proper methodology. Also, while enhancing the procedure of the program connected to different parties with interests in maintenance, it becomes difficult to get satisfaction from all parties and to achieve the company's objectives. The maintenance manager has to combine all purposes to maximize productivity, availability, and quality while taking into consideration the production plan, available spares, human resources, and skills (Labib, 1998).

These days, the importance of decision-making tools increase in manufacturing industries. This has to lead to decision support systems (DSSs) to help managers to make effective decisions by controlling and processing all information and data (Tahir, 2008). Maintenance is part of the production and manufacturing system. Maintenance, in general, can be defined as the activities that can preserve or keep any machine or equipment in a system in specific operating conditions or restore that item after any failure has happened. This includes assets condition monitoring, lubrication, cleaning, planning, scheduling, and so many activities that are helping to do the maintenance or related to it (Shenoy & Bikash, 1997). Moreover, it concerns all activities required to keep a system and all of its parts in working order (Stephens, 2010).

According to the British Standard (BS), maintenance is composed of all technical and managerial actions, which includes maintenance supervision actions, aimed to retain a system or restore it to a status in which it can perform a necessary action (Kans, 2007). In terms of probability, maintenance is the process that decreases the level of failure probability for the restored system or as close to an economically viable solution as possible according to the adequate level of its design (Asp, 2008). Maintenance can be illustrated as activities necessary or incurred to keep as long, as possible the nature of an asset or resource while only repairing it for normal wear and tear. In the engineering world, the word maintenance can also be illustrated as actions required for repairing or restoring a part of the production line, machine, or system to the best status that can be achieved to maximize useful life (Azhar & Mansor, 2013).

A standard definition of maintenance is "A means to maintain and improve the quality of the parts that contribute to a production process, continuously and cost-effectively. This is achieved through detecting and controlling the changes in the status of a production process which is determined by production costs, product quality, and the working environment in order to interfere when it is possible to arrest or reduce the machine/equipment deterioration rate before the process status and product characteristics are unacceptably affected and to perform the necessary actions to restore the equipment/process or a part to its original status" (Onawoga & Olasunkanmi, 2010). A decision support system (DSS) is one of the most critical issues for an industrial organization as the process and arranges all the information and data necessary to make effective decisions (Tahir, et al., 2008).

Many researchers discuss the selection of optimum maintenance strategies using several criteria. Personnel, facilities, and environment safety have been used by researchers as a vital criterion when it comes to select a suitable maintenance strategy. Usually, weak maintenance of a machine can have an impact on the personal safety of personnel, A faulty machine can impact other machines in the system and therefore require an increase of the level of maintenance, and the environmental impact of the machine is proportional to the requested maintenance level (Jafari, et al., 2008; Wang, et al., 2007; Xie, et al., 2013; El Baz & Alaziz, 2015; Zaim, et al., 2012; Akhshabi, 2011; Momeni, et al., 2011; Stephens, 2010; Bevilacqua & Braglia, 2000; Chandrahas & Deepak, 2015).

There are individual costs associated with particular maintenance strategies such as; the hardware price of tools and sensors when using the condition-based maintenance (CBM) & predictive maintenance (PDM) strategies. Moreover, the value of software like computerized maintenance management system (CMMS) needs to follow preventive maintenance (PM) and the software which is used to analyze the sensor data in PDM; Finally, the cost of the training needs for staff to use the hardware and software (El Baz & Alaziz, 2015; Jafari, et al., 2008; Xie, et al., 2013; Wang, et al., 2007; Zaim, et al., 2012; Akhshabi, 2011; Momeni, et al., 2011; Pariazar, et al., 2008; Stephens, 2010; Chandrahas & Deepak, 2015).

In general, using a well-planned maintenance strategy will decrease the needed spare parts inventory unlike corrective maintenance (CM), may also, reduce production loss due to repetitive failures, and increase the machine availability due to helping the maintenance staff, all these are considered as adding value process to the company. Many researchers used this criterion as standard for selecting maintenance strategy, if the chosen maintenance is the best, then it will be beneficial to the production line, those benefits can be classified as; spare parts benefits, production improvement, and improvement in availability (Wang, et al., 2007; Jafari, et al., 2008; Xie, et al., 2013; El Baz & Alaziz, 2015; Zaim, et al., 2012; Momeni, et al., 2011; Pariazar, et al., 2008; Chandrahas & Deepak, 2015).

Any maintenance strategy has a complex system of implementation of new technology, will result in complicated maintenance procedure, and it will be rarely selected; this is another criterion used to select the optimal maintenance strategy. Both acceptance of labor and technique reliability is essential for decision-makers for selecting suitable maintenance strategy. The maintenance procedure of the approach chosen should be easy to understand and implement by staff and managers (El Baz & Alaziz, 2015; Jafari, et al., 2008; Xie, et al., 2013; Wang, et al., 2007).

When the maintenance manager wants to select a maintenance approach, usually they look at the downtime and number of failures the machine had previously, this history is vital to identify the suitable action for the tools (Labib, 1998; Labib, 2004; Tahir, 2008; Stephens, 2010; Bevilacqua & Braglia, 2000; Al-Najjar, 2003).

Three measures of any machines used to define the equipment statue, are (1) Reliability, which defined as the probability of any equipment to work for a period without failure. It can be enhanced by decreasing failure frequency, (2) Availability: which is the capacity of a machine to function well during an existing period; An increased failure-free time and reduced downtime can improve availability, and (3) Maintainability define as the ability that equipment

can restore to normal function in a specified period of time. It can also be represented by the downtime caused by the maintenance procedure (Bevilacqua & Braglia, 2000; Bertolini & Bevilacqua, 2006; Shahin, et al., 2012).

This research focuses on finding some crucial criterions that were collected from different literature on machine performance, and the ability for ethical maintenance decision-making to evaluate machines and the necessary maintenance activities that make the maintenance strategies selection easier. Maintenance experts in Jordanian food industries were asked to rank and grade criterion to find a relative ranking for each one. The choice of a suitable maintenance strategy is the most critical challenge that faces the maintenance decision-makers, because of two limitations: (1) Selecting a high level of maintenance that needs more cost resources, and maintenance time; (2) Selecting low maintenance levels that could affect the machine's performance, reliability and may increase the failure probability.

2. Methodology

The research methodology in selecting the optimum maintenance strategy depends on the important criterions are suggested in the literature. To find the right measures, the following steps were followed:

a) Criteria identifying:

Identifying and finding essential criteria involves reviewing the research found in the literature. Those criteria were collected and discussed to find the most important and widely used. The following criterions will be used to select the optimum maintenance strategy; (1) Cost: hardware, software, personnel training, equipment cost, (2) Safety: personnel, facilities, environment, (3) History: frequency of failure, downtime, function, and redundancy. (4) Added-value: spare parts inventories, production loss, fault identification, (5) Feasibility: acceptance by laborers, technique reliability, and (6) Equipment status: kind of product, frequency of use, surrounding atmosphere.

b) Survey building

Before evaluating, the criteria were divided into six groups. All the criteria that were of the same pedigree were grouped and each group was called a "dimension." To evaluate the criteria in the six dimensions a survey was carried out in the form of a questionnaire by asking a question for each criterion and rating its impact upon maintenance strategy selection. The participants were to evaluate from "1 = totally disagree" to "5 = totally agree". A summary of the criteria was collected and put on the survey in the form of a questionnaire to evaluate the importance and criticality of each criterion during the selection of the maintenance strategy.

The survey was extracted from the following Ph.D. research (El-Tohamy & Al Raoush, 2015) "The impact of applying Total Quality Management principles on the overall hospital effectiveness: An empirical study on the accredited governmental hospitals in Jordan" for A. T. Al Raoush. Faculty of Commerce and business administration; Helwan University, Egypt.

c) Survey testing:

The validity and consistency of the research measurement tool were tested by calculating Cronbach's alpha coefficient. Acceptable values for alpha coefficient are 0.6 and above. To check the validity, a pilot study was conducted to identify the degree of clarity and understanding of the questionnaire paragraphs from the respondent's viewpoint and also to determine possible problems with the design and instrument used in this study.

In order to test the validity and consistency of the research measurement tool in order to determine to what extent the researcher can rely on it in testing research hypotheses and achieving research objectives, validity was tested by calculating Cronbach's alpha coefficient. This is one method for measuring the internal consistency of summated scale measurements such as the Likert scale. Cronbach's alpha measures the extent of the internal consistency of the questionnaire in terms of its ability to obtain consistent results from the respondent. Alpha interpreted as a confidence acceptable values for alpha coefficient are 0.6 and above (George & Mallery, 2003).

The researcher has conducted a pilot study to identify the degree of clarity and understanding of the questionnaire paragraphs from the respondent's viewpoint and also to determine possible problems with the design and instrument used in this study. A convenience sample of 20 participants was obtained using identical selected criteria as planned for the main study. Cronbach's Alpha of the pilot study calculated it was 0.665 which was accepted (Alpha interpreted as confidence acceptable values for alpha coefficient are 0.6 and above) (George & Mallery, 2003).

Table 1. Testing Tool Validity

Item	Cronbach's Alpha if Item Deleted
Selection of the suitable maintenance is determined by the cost of the needed tools	0.647
Cost of the needed software plays a role in the selection of the right maintenance strategy	0.624
Maintenance staff training in using the tools and techniques plays a role in the maintenance strategy selection	0.638
Equipment or machine prices affect the selection of suitable maintenance	0.638
Affecting of the machines in the personal safety contribute in the requested maintenance determination	0.634
Affecting the machines on other machines contributes to the selection of the appropriate maintenance	0.620
The environmental impact for the machine is a factor to select the suitable maintenance	0.688
Faults repetition is one of the factors that lead to review of the maintenance program	0.668
The average duration of the downtime affects to maintenance strategy should be applied	0.648
The machine function and uniqueness which is caused a stop of production play a role in the selection of the needed maintenance	0.655
The applying of the best maintenance strategy contributes to reducing the spare part inventory	0.633
Decreasing of the waste in production is one of the advantages caused by applying the suitable maintenance	0.662
Selection of suitable maintenance contributes to increasing the machine availability	0.617
The maintenance program acceptance restricts us in the selection of the maintenance strategy	0.646
The selection of suitable maintenance is difficult for a modern machine	0.715
Kind of the machine product leads to select the suitable maintenance	0.692
Utilization of the machinery contributes to determining the appropriate maintenance	0.641
The surrounded ambient temperature plays a role in the selection of suitable maintenance	0.649

d) Survey publishing:

After survey validation, the surveys were carried out by many maintenance experts in the Jordanian food industry via e-mail, hand, or phone. Two hundred questionnaires were sent, and 187 reviews were completed.

e) Survey result analyzing:

The collected data was analyzed to determine the ranking of each criterion using Statistical Package for the Social Sciences (SPSS). The dimensions will be ranked by analyzing the mean values of each criterion. Historical data was found to be the most critical dimension with small variance and of the lowest importance was feasibility.

3. Results and Discussion

After collecting the survey results from many maintenance experts (187) in the Jordanian food industry, the six dimensions (cost, safety, historical data, add value, feasibility, and equipment status) were distributed from 1 to 5 (Figure.1) and evaluated as follows:

a. Cost

The cost dimension includes four criteria which were evaluated (see Table.2). The highest one is the training cost the mean of the evaluation was 4.45, the second one in this dimension was software cost with mean of the evaluation of 3.74, the third one in this dimension was equipment cost the mean of the evaluation was 3.72. and the lowest one in this dimension was hardware cost the mean of the evaluation was 3.41.

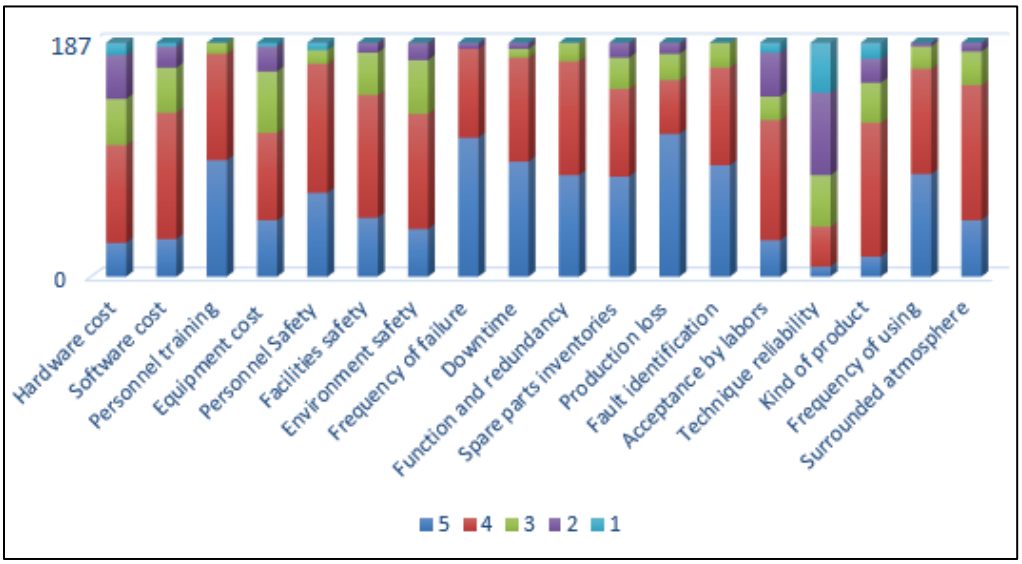

Figure 1. Survey Result

Table 2. Cost criteria effects on maintenance strategy selection

	Variable	Mean	SD	Rank
1	Selection of the suitable maintenance is determined by the cost of the needed tools	3.41	1.11	4
2	Cost of the needed software plays a role in the selection of the right maintenance strategy.	3.74	0.89	2
3	Maintenance staff training in using the tools and techniques plays a role in the maintenance strategy selection	4.45	0.59	1
4	Equipment or machine prices affects the selection of suitable maintenance	3.72	1.00	3
Mean		3.83	0.90	

b. Safety

The safety dimension includes three criterions (Table 3), the expert chooses personal safety as the highest criterion among them with mean of evaluation of 4.20, then the facility safety with mean of 3.98, the lowest evaluation was for the environmental safety with evaluation of 3.82.

Table 1. Safety criteria effects on maintenance strategy selection

	Variable	Mean	SD	Rank
1	Affecting of the machines in the personal safety contribute in the requested maintenance determination	4.20	0.82	1
2	Affecting the machines on other machines contributes to the selection of the appropriate maintenance	3.98	0.78	2

3	The environmental impact for the machine is a factor to select the suitable maintenance	3.82	0.84	3
Mean		4.00	0.81	

c. Historical data

The historical data dimension includes (Table 4); Frequancy of failure with average evaluation of 4.54 the highest among the other criterions, then downtime with average evaluation of 4,40, and the last one is function and redundancy with mean of 4.35.

Table 2. Historical data criteria effects on maintenance strategy selection

	Variable	Mean	SD	Rank
1	Faults repetition is one of the factors that lead to review of the maintenance program.	4.54	0.64	1
2	The average duration of the downtime affects to maintenance strategy should be applied.	4.40	0.69	2
3	The machine function and uniqueness which is caused by a stop of production play a role in the selection of the needed maintenance.	4.35	0.63	3
Mean		4.43	0.65	

d. Added value

The add value dimension includes three criteria which were evaluated as following (Table 5); The highest one is the production loss where the mean of the evaluation was 4.40, the second one in this dimension was fault identification with mean of the evaluation was 4.37, the lowest one in this dimension was spare parts inventories, the mean of the evaluation was 4.17.

Table 3. Added-value criteria effects on maintenance strategy selection

	Variable	Mean	SD	Rank
1	The applying of the best maintenance strategy contributes to reducing the spare part inventory	4.17	0.89	3
2	Decreasing of the waste in production is one of the advantages caused by applying the suitable maintenance	4.40	0.87	1
3	Selection of suitable maintenance contributes to increasing the machine availability	4.37	0.67	2
Mean		4.31	0.81	

e. Feasibility

The feasibility dimension includes two criteria which were evaluated as following (Table 6), acceptance by labor with mean of 3.55 and technique reliability with mean of 2.48.

Table 4. Feasibility criteria effects on maintenance strategy selection

	Variable	Mean	SD	Rank
1	The maintenance program acceptance restricts us in the selection of the maintenance strategy	3.55	1.09	1

2	The selection of suitable maintenance is difficult for a modern machine	2.48	1.13	2
Mean		3.01	1.11	

f. Equipment status

The equipment status dimension includes three criteria which were evaluated as following (Table 7), the highest one is the frequency of using where the mean of the evaluation was 4.31, the second one in this dimension was the surrounding atmosphere with mean of the evaluation was 4.02, and the lowest one in this dimension was the kind of product, the mean of the evaluation was 3.50.

Table 5. Equipment status criteria effects on maintenance strategy selection

	Variable	Mean	SD	Rank
1	Kind of the machine product leads to select the suitable maintenance	3.50	1.02	3
2	Utilization of the machinery contributes to determining the appropriate maintenance	4.31	0.71	1
3	The surrounded ambient temperature plays a role in the selection of suitable maintenance	4.02	0.73	2
Mean		3.94	0.82	

The proposed criteria can be ranked as follows:

1- Historical data (with rank 4.43)

According to the survey, the Maintenance experts in the Jordanian food industry believe that the historical data is the most important criteria that should be taken into account when selecting the optimum maintenance strategy.
The percentage of this criterion = 4.43/ (4.43+4.3+4.0+3.94+3.83+3.01) = 18.8%
The sub-criteria were also ranked as following:

a) Frequency of failure 4.54
b) Downtime 4.40
c) Function and redundancy 4.35

2- Add value (with rank 4.3)

This was the second most important criterion according to the survey as it scored 18.3%
The sub-criteria were also ranked as following:

a) Production loss 4.40 (34.0%)
b) Fault identification 4.37 (33.8%)
c) Spare parts inventories 4.17 (32.2%)

3- Safety (with rank 4.00)

This was the third most crucial criterion according to the maintenance experts in the Jordanian food industry with a percentage of 17%
The sub-criteria were also ranked as following:

a) Personal safety 4.20 (35.0%)
b) Facilities safety 3.98 (33.2%)
c) Environmental safety 3.82 (31.8%)

4- Equipment status (with rank 3.94)

This was the fourth most important criterion as the maintenance experts in the Jordanian food industry rated this criterion at 16.8%
The sub-criteria were also ranked as following:

a) Frequency of use 4.31 (36.4%)

b) Surrounding atmosphere 4.02 (34.0%)
c) The kind of product 3.50 (29.6%)

5- Cost (with rank 3.83)
This was the fifth most important criterion according to the maintenance experts in the Jordanian food industry with a percentage of 16.3%
The sub-criteria were also ranked as following:
a) Training cost 4.45 (29.0%)
b) Software cost 3.74 (24.4%)
c) Equipment cost 3.72 (24.3%)
d) Hardware cost 3.41 (22.4%)

6- Feasibility (with rank 3.01)
This was ranked sixth by the maintenance experts in the Jordanian food industry with a percentage of 12.8%
The sub-criteria were also ranked as following:
a) Acceptance 3.55 (58.9%)
b) Technique reliability 2.48 (41.1%)

4. Conclusion

The demand for high production and high quality has increased. This has raised the importance of manufacturing and high expectations regarding reliability and availability. This has led manufacturers to look for new ways to decrease or eliminate production line failure and shutdown, and therefore effective maintenance of machinery has become a big concern. There is a need to find maintenance strategies to achieve increased production and decrease the number of failures and downtime. For this reason, maintenance is now considered as an investment, which helps to increase the institution's profit.
There is a need to understand the criteria that should be used to determine the optimum and suitable maintenance strategies and programs to preserve machines and equipment in the production lines. After much research, it was found that most focused on six dimensions, which are:
1- Cost
2- Safety
3- Add value
4- Historical data
5- Feasibility
6- Equipment status.
After studying the importance of these criteria by evaluating them from the perspective of maintenance expert's opinion in the Jordanian food industry, it appears that the historical data criterion should be the most important criterion. Most of them believed that the past trends of the machine could help to determine or predict future expected failures. This means that preventive action can be completed and this is the cheapest and easiest way. The least essential criterion was considered to be feasibility which is divided into two criteria: acceptance by laborers and technique reliability. This may be because the food industry in Jordan has traditional production lines and new technology has not been tried and tested.

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