Relationship between Human Errors in Maintenance and Overall Equipment Effectiveness in Food Industries

Yunos Ngadiman
Dept. of Production and Operation Management
Universiti Tun Hussein Onn Malaysia
Batu Pahat, Johor, Malaysia
yunos@uthm.edu.my

Burairah Hussin
Faculty of Information and Communications Technology
Universiti Teknikal Malaysia Melaka
Durian Tunggal, Malaca, Malaysia
burairah@utem.edu.my

Nor Aziati Abd Hamid[1], Rohaizan Ramlan[2], Liew Kai Boon[3]
Department of Production and Operation Management
Universiti Tun Hussein Onn Malaysia
86400 Parit Raja, Batu Pahat, Johor
[1]aziati@uthm.edu.my, [2]rohaizan@uthm.edu.my, [3]kboonliew@gmail.com

***Abstract*—Human plays a crucial and important role in system design, production, operation, and maintenance process. Human errors could be said as inevitable in all industry. This research examined the relationship between human errors in maintenance and overall equipment effectiveness (OEE) of equipment in the food industry. This research conducted due to it was found that human errors in maintenance affected the availability rate and performance rate of equipment and also quality of the product produced while these three components were included in the evaluation of OEE of equipment. Therefore, it showed there is a correspondence between human errors in maintenance and OEE of equipment. This research conducted in food processing company located in Batu Pahat, Johor. Purposive sampling was used in this research as it purposely for maintenance personnel and a survey was done with a questionnaire distributed to the maintenance personnel in the food processing company. Total 75 maintenance personnel responded to the questionnaires distributed. Spearman correlation was used to identify the entire relationship. The outcome of this research found that human errors in maintenance have a significant positive relationship with OEE.**

***Keywords*— human errors, maintenance, availability, performance, quality, overall equipment effectiveness**

I. INTRODUCTION

Nowadays, in this turbulent and highly competitive business environment, plenty of high productivity and performance equipment have been developed. However, in order to remain on the high competitiveness, the role and contribution of human should not be ignored. [45] stated man-machine reliability is more depends on the man. Besides, the performance of equipment also depends on the maintenance activities on the entire equipment. [42] claimed that the most efficient way to improve business performance is to have an effective maintenance activity that will aid in the process of reducing cost, improving productivity, and maintaining a business profile. Conversely, fail in performing good maintenance practice could results degrade the overall performance of a company.

However, human errors are not possible to be fully eliminated, it can only be minimized through good maintenance practice [8]. The occurrence of human errors in maintenance could result in a negative impact on the equipment performance and safety [9]. Consequently, the impact will cause a significant drop in performance. Therefore, it is extremely important to study the relationship between human errors and OEE. OEE is composed of three main components which are Availability Rate, Performance Rate, and Quality Rate. The relationship between human errors in maintenance and these three components will be evaluated before proceed further.

A. Research Background

The food industry is part of the biggest industries worldwide because it is the most basic need of humans. It is one of the major contributors to the economy of Malaysia. According to Malaysian Investment Development Authority [30] remained a

net importer of food in 2013 (RM15.6 billion). The food industry in Malaysia is dominated by small and medium scale companies. The food industry in this research is widely operating in Batu Pahat, Johor. Batu Bahat was selected as food industry in this area is very competitive as there is 44 food processing industry at this area. This research carried out at the Batu Pahat area could give a positive impact and a guideline for the entire food manufacturer in order to improve their productivity.

B. Problem Statement

According to Malaysia Investment Development Authority (2015), the manufacturing sector had total approved investment of RM 71.9 billion, which was 30.5%of the total investments approved in 2014, and it surged compared to the previous year. This shown manufacturing sector will become more competitive in the future. Equipment is one of the essential elements of a production system which will affect the production rate, quality of the product and its direct cost [47]. Keen global competition caused companies' endeavor to upgrade and optimize their productivity so that they are always competitive (Huang[21] et al., 2003). [16] found that competitiveness of manufacturing companies sustained by availability and productivity of their production facilities. OEE proposed by [34] is used to measure the productivity of individual equipment in a manufacturing plant.

[35] declared that the literature related to OEE in Malaysia is very limited and this indicated OEE is still new to Malaysian Industry. Even though research regarding OEE is ongoing, but most of the research did not include human error in their studies. Le et al. (2012) urged human error in maintenance is one of the critical reasons for a quality defect in the manufacturing systems. This was proven in their study on the quality defect of engine assembly line due to human error. Besides, human errors will result in the low availability of equipment and unsatisfied machine performance. Low availability of equipment resulted from human error verified by [15]. Human error in maintenance is regarded as an improper operation which increases mean preventive maintenance time. A critical human error will cause failure of the total system while a non-critical human error leads to the non-total system or minor failure. This indicated the human error is critical in affecting the performance of a production system.

C. Objective

The objectives of this study were:

1) To identify the relationship between human errors in maintenance and machine availability towards OEE.
2) To identify the relationship between human errors in maintenance and machine performance towards OEE.
3) To identify the relationship between human errors in maintenance and product quality towards OEE.
4) To identify the relationship between human errors in maintenance and OEE.

II. LITERATURE REVIEW

A. Maintenance

Maintenance is defined as activities essential to keeping a facility in "as built" or newly condition and, therefore, continuing to have its original productive capacity [38]. [22] have stated the role of maintenance in modern manufacturing systems is turning out to be extremely vital to companies embracing the maintenance as a profit generating business element. [11] was classified maintenance into three categories:

1) preventive maintenance: all actions performed on a planned, periodic and specific schedule to maintain equipment in started working condition through the process of checking and reconditioning.
2) corrective maintenance: it is an unscheduled maintenance or repair to return the item to its initial state due to maintenance persons or users identified deficiencies or failure, and
3) predictive maintenance: diagnose equipment condition during operation accurately by using innovative measurement and signal processing method.

B. Human Errors

The human error described as unsuccessful to perform a given task (of the performance of a prohibited action) that could result in disturbance of planned operations or damage to equipment and property ([28, 29]; [20]; [9]. Human error can be ranked either as critical or non-critical. A critical human error is an error which can be resulted in the failure of the total system, whereas non-critical human errors will cause only non-total system or another minor failure [10]). According to [13], human error has occurred since the dawning of mankind but it only being subject to scientific inquiry in the last 50 years. They have identified few causes for the occurrence of human errors, which included inadequate lighting in the work area, inadequate training or skill of the manpower involved, poor equipment design, high noise levels, an inadequate work layout, improper tools, poorly written equipment maintenance and operating system.

Besides, [13] have also categorized the human error into six categories: operating errors, assembly errors, design errors, inspection errors, installation errors and maintenance errors. [3] defined human error as any action or inaction of human factors that possibly or, in fact, resulted in negative system effects or affect the actual function of the entire system.

1) ***Human Errors in Maintenance***

Human error in maintenance can have an effect on equipment performance and safety in various ways. For an instant, substandard repairs can result in rising of the number of equipment breakdowns, which consequently will increase the risk associated with equipment failures and the occurrence of personal accidents ([27]; [9]).

2) ***Maintenance Environment and Causes for the Occurrence of Human Error in Maintenance***

Due to the maintenance personnel work directly on equipment, the location of equipment and its design features directly dictate many of the parameters of their work environment. Maintenance environments are affected by the factors such as noise, poor illumination and temperature variation [41].

Few causes of human error have been identified and are illustrated in Figure 2.1 [9].

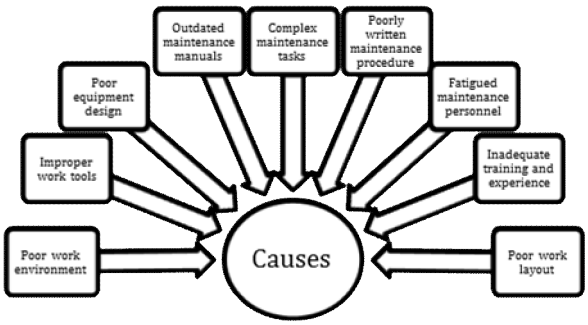

Figure 2.1 Causes for the occurrence of maintenance errors [9]

3) ***Types of Maintenance Errors and Typical Maintenance Errors***

[14] identified six types of maintenance errors that are recognition failures, memory failures, skill-based slips, knowledge-based errors, rule-based errors and violation errors. Recognition failure is a kind of failure which the maintenance personnel has the difficult to recognize or identify something. On the other hand, the example of memory failures included input failure, storage failure, premature exit and omission following interruptions. Skill-based slips are normally related with "automatic" routines, which included branching errors and overshoot errors. Knowledge-based errors happened due to the maintenance personnel lack of the knowledge and usually, happen when the maintenance personnel performs an unusual task for the first time. Rule-based slips occurred due to misapply a good rule and applying a bad rule. Misapplying a good rule is the means by applying a rule to a situation where it is not suitable while applying a bad rule is to the rule applied might get done under certain circumstances, but it can have numerous impacts. Lastly, violation errors are intentional acts, which contravene procedures. These included thrill-seeking violations, routine violations, and situational violations.

C. Overview of OEE

[34] introduces OEE in Total Productive Maintenance.TPM [17] is an approach to equipment maintenance that looks for no breakdown and no defects [36]. K.Y Jeong and D.T Phillips (2001) stated OEE is the basic metric for assessing the accomplishment of a TPM implementation program. OEE is used in order to find improvement and or getting worse in equipment effectiveness over a couple of time [7].

D. Purpose of OEE

[7] have stated the minor purpose of OEE in their study and it was supported by [35]. Both of the parties agreed that OEE could be invoked as a yardstick for measuring the preliminary performance of a manufacturing plant completely. [2] stated OEE is a quantitative metrics used for controlling and monitoring the productivity of production equipment, it is also an indicator and driver of process and performance improvement.

2.5 The Six Big Losses

The losses have been classified into six major categories that affect the overall performance of the equipment [25]. [47] categorize the major loss of equipment's effectiveness into six features according to its three main elements, which are availability, performance rate, and quality rate. [46] classify six major losses into three main kinds of elements that are time losses, speed losses and defects losses. The six major losses identified are equipment failure/ breakdown losses, set-up, and adjustment losses, idling and minor stoppage losses, reduced speed losses, defect and rework losses and start-up losses. [34] identified these six big losses and few researchers like [25], [46], [47], [36], [35] and also [44].

They defined "Six Big Losses" as follows:

1) Equipment failure/ breakdown losses are considered as time losses are due to a decrease of productivity and quantity losses, which resulted from a defective product.
2) Set-up and adjustment losses are categorized as time losses caused by downtime and defective product that occurs when the equipment is adjusted to meet the requirement of another item.
3) Idling and minor stop losses are speed losses and happened when the production disrupted by a momentary breakdown or when equipment is idling.
4) Reduced speed losses are speed losses that occurred when the speed is slow as real speed slower than design speed or the design speed is slower than the expected or desirable requirement. It might also refer to as the difference between the equipment design speed and actual operating speed.
5) Defect and rework losses are caused by malfunctioning production equipment. It required repairing defective product to improve the product quality and turn it into an outstanding product.
6) Start-up losses happen during the initial stage of production by machine start-up stabilization. At the start of a production run, typically there is a waste as parts may be defective in some way. These losses also influence the quality rate of equipment.

E. Components in OEE

OEE is composed of three main components that are Availability Rate (A), Performance Rate (P), and Quality Rate (Q). In order to identify the OEE value of equipment performance [31], [32]; availability rate, performance rate, and quality rate should be computed [34] as follows.
Formula of calculating OEE proposed by [34]: OEE = A x P x Q

- **Availability Rate**

  Availability is defined as the amount of time for equipment is available for production and it could be defined as a measurement on how extensive the downtime losses for equipment are [35]. Fore & Zuze (2010) have found that availability is an essential part of the operation in their study as low availability of machine in the entire company had caused the OEE become lower than expected.

- **Performance Rate**

  Performance rate is the proportion of theory processing time and the actual processing time [47]. According to him, performance rates able to indicate the real situation of equipment's performance. [35] explain performance rate by taking speed loss into account, which included all elements that caused the process of the equipment operates less than the ideal speed. Performance rate is obtained by dividing actual production output of equipment with its theoretical production output. The theoretical output is interpreted as the output that the equipment could achieve in the theory if the entire equipment able to produced at maximum speed during the moment it really operated and this theoretical output will be reduced by minor stoppage and reduced speed [14].

- **Quality Rate**

  The quality rate is used to indicate the comparison of a defective product to the total product produces [7]. The quality rate also describes the relationship between the total production volume and the number of products produced that meet the specification [14].

F. Relationship between Human Errors in Maintenance and OEE

Maintenance is a function in an organization that operates in parallel with production. Human errors in maintenance basically will effect on availability, equipment and quality. These three parts are the principal components in OEE. Thus, human errors in maintenance will affect OEE too.

[10] did a research on the effect of the human error, common-cause failure, redundancy and maintenance policy on the performance of a system. This research has shown the occurrence of human errors and common-cause failure caused a significant reduction in the system availability. [15] stated in their research, human error in maintenance increase repair time. This indicates the total downtime is increasing while the actual operating time is decreasing. Increasing in total downtime will decrease the availability rate as mentioned in the section 2.6.1. This could be supported by research done by [7] as they found that maintenance error is one of the major causes of unplanned downtime. An increase in repair time wills also causes minor stoppage and increase in idling time which will reduce the performance rate.

Few researchers declared maintenance is part of the critical factors for a sustainable performance of manufacturing equipment [6]. Maintenance error resulted from human error probably will reduce the performance of a technical system [33]. [10] stated aircraft engine operating performance is correlated with the failure rate of an aircraft engine due to maintenance error. Besides, research was done by [3] determined two main protection failure in their research is related to human error in maintenance. They claimed that the protection facilities did not fully repair during the maintenance process and this resulted in system operating with a hidden fault, consequently affected the operating system performance.

[4] stated equipment, which did not well maintenance and fails continuously, consequently will experience speed loss and lack of accuracy. This eventually will result in defection in production. [1] claimed that using an effective maintenance able to improve the utilization of manufacturing systems as much quantity of product produced with good quality due to maintenance efficiency and effectiveness. As found by Bargelis (2014), human factors and errors are one of the vital reasons for the non-quality product. Besides, [18] implementing a proactive practice to administer and reduce human errors in a semiconductor industry. They adopted a practice in reducing human error from a nuclear plant to reduce human errors during preventive maintenance, and this result an improvement of their product quality.

Summarize from the above, human errors in maintenance affecting three main components in OEE that are availability rate, performance rate, and quality rate. Even though previous studies study the effect of human errors on these three components separately, but it could not deny human error in maintenance affecting OEE of equipment badly. Therefore, human errors correlated with availability rate, performance rate and quality rate towards OEE.

G. Conceptual Framework and Hypotheses

Based on the literature review discussed in the previous section, a conceptual framework in Figure 2.2 and several hypotheses have been developed as shown below.

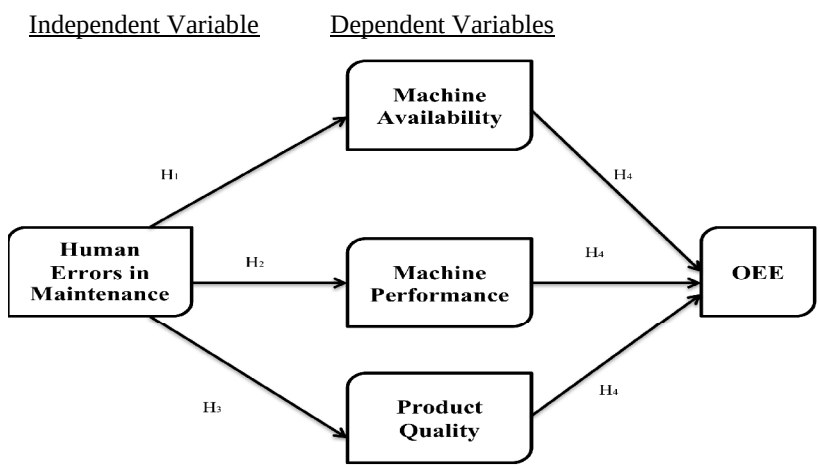

Figure 2.2: Conceptual framework

H_1: There is a significant relationship between human errors in maintenance and availability rate towards OEE.
H_2: There is a significant relationship between human errors in maintenance and performance rate towards OEE.
H_3: There is a significant relationship between human errors in maintenance and product quality towards OEE.

H_4: There is a significant relationship between human errors maintenance and OEE.

III. METHODOLOGY

The methodology is a backbone of a study as it provided a guideline to a researcher in term of collecting and analyzing data [24] in order to achieve the objective of the study. This part discusses the methodology has been used in order to success in the study. It included research design, research process, sampling design, population and sample, and data collection instrument.

A. Population and Sample

The population of this research was the maintenance personnel who were from the food industry in Batu Pahat, Johor. There were total 44 food processing companies in the food industry of Batu Pahat with a total number of 180 maintenance personnel. Data was gathered from 123 maintenance personnel out of 180 maintenance personnel by using purposive sampling method. Besides that, the sample size of the respondents was identified by using the table of [23].

B. Data Collection Instrument

This research was carried out by survey and the research instrument used was questionnaire as it was the easiest and the most popular method among academicians of extracting data in a highly economical way [39] and in a short time frame [5]. [37] stated questionnaire is one of the most popular instruments to collect data as the questionnaire is easy to design and use. There were five sections in the questionnaire which are about demographic (Section A), human errors in maintenance (Section B), impacts on machine availability (Section C), impacts on machine performance (Section D) and impacts on product quality (Section E). Section B till Section E were used five points Likert Scale as a measurement.

C. Preliminary Test of Questionnaire

According to [26], in order to examine the suitability of the questions appointed to the respondents, a pilot study must be done before the questionnaire distributed as pilot study able to test the level of understanding of respondents towards the questions stated in the questionnaire. Therefore, in order to ensure the accuracy of the questionnaire and the respondents have no difficulty to answer the questionnaires; a pilot test had been conducted before the questionnaires distributed to refine the questionnaire. After a pilot test was performed, some improvement had been made on the entire questionnaire after collected feedbacks and comments from the respondents.

D. Data Analysis

Data collected was analyzed by using a scientific approach, which was IBM Statistical Package Social Science (SPSS) Version 23. SPSS was used to perform a descriptive statistical analysis and Spearman Correlation Analysis. Spearman Correlation Analysis was utilized to analyze the relationship between human errors in maintenance and OEE.

IV. RESULTS

This section discussed the results from data analysis. It included survey return rate, validity, and reliability of the questionnaire, demographic of the respondents, descriptive statics, normality test and also correlation test to determine the relationship of human errors in maintenance and OEE.

A. Survey Return Rate

A total of 123 sets of questionnaires were distributed to and few food process companies located within Batu Pahat area. After deleted invalid questionnaires, 75 sets of questionnaires remained, hence resulted in a valid rate of 60.97%. The survey returned rate had been summarized at Table 1.

TABLE 1: SURVEY RETURN RATE

Questionnaire	Quantity	Percentage (%)
Distributed	123	100.0
Returned	75	60.97
Discarded	48	39.03

B. Reliability and Validity Test

TABLE 2: RELIABILITY STATISTIC RESULT

Variables	Cronbach 's Alpha Coefficient	Number of Items	Number of Respondents
Human error in maintenance	0.818	6	75
Machine availability	0.761	5	75
Machine performance	0.823	5	75
Product Quality	0.776	6	75

Table 2 shows the results of the reliability test for all the four variables in the actual study. The Cronbach's alpha coefficient of all these variables in actual study is lower than the pilot study. However, the reliability of the questionnaire is still satisfied the requirement of a reliable questionnaire.

C. Descriptive Analysis

The main purpose of the descriptive analysis is to describe the main features of a collection of data. Descriptive statistics aims to quantitatively summarize a data set, rather than being used to support inferential statements about the population that the data are thought to represent. It provides summaries about the sample and observations that have been made. The descriptive analyzes used in this research are a measure of central tendency and a measure of dispersion. A measure of central tendency included mean, median and mode while a measure of dispersion included range, standard deviation, and the variance.

The mean level of all these four variable is then classified into low, medium and high range according to the extent level of mean created by [43] as shown in Table 3

TABLE 3: EXTENT LEVEL OF MEAN [43]

Extent	Range
Low	1.0 – 2.3
Medium	2.4 – 3.7
High	3.8 – 5.0

D. Descriptive Analysis for Human Errors in Maintenance, Machine Availability, Machine Performance, Product Quality and OEE

TABLE 4: MEAN, STANDARD DEVIATION

	N	Mean	Std. Deviation
Human errors in maintenance	75	4.02	0.52
Machine availability	75	3.96	0.51
Machine performance	75	3.59	0.58
Product quality	75	3.75	0.51
Overall equipment effectiveness (OEE)	75	2.22	0.86

This section summarizes the overall mean score distribution and standard deviation for all the variables. The dependent variable, OEE was computed by using the data from machine availability, machine performance, and product quality. The mean score as shown in Table 4 of these three variables had been converted to a percentage and the product of these three percentage converted back to mean score and it was the data for OEE. Human errors in maintenance stand the highest means

which are, 4.02 while OEE had the lowest mean which is 2.22. Basically, all the variables were in high extent while the only OEE in low extent.

E. Normality Test

This section summarized the overall mean score distribution and standard deviation for all the variables. The dependent variable, OEE was computed by using the data from machine availability, machine performance, and product quality. The mean score of these three variables had been converted to a percentage and the product of these three percentage converted back to mean score and it was the data for OEE.

TABLE 5: NORMALITY TEST RESULT TABULATION

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Human errors in maintenance	0.13	75	0.03
Machine availability	0.15	75	0.01
Machine performance	0.10	75	0.058
Product quality	0.13	75	0.005
Overall equipment effectiveness	0.10	75	0.042

Table 5 shows human errors in maintenance, machine availability, product quality and OEE were non-normal distribution as $p<0.05$ while product quality is normal distribution as its $p>0.05$. However, overall normality for this research was non-normal distribution. Therefore, the non-parametric test would be carried out to test the relationship between human errors in maintenance and machine availability, machine performance and product quality towards OEE.

F. Inferential Analysis

The inferential analysis is a statistical analysis that able to identify and analyze the differences in a variable among different subgroups, the relationship between two variables or how several different independent variables might explain on the dependent variable [40]. In the context of this research, Spearman correlation is used to identify the relationship between human errors in maintenance and machine availability, machine performance and product quality towards OEE. Spearman correlation is chosen, as the overall data is not normally distributed

G. Spearman Correlation Test

The inferential analysis is a statistical analysis that able to identify and analyze the differences in a variable among different subgroups, the relationship between two variables or how several different independent variables might explain on the dependent variable [40]. In the context of this research, Spearman correlation was used to identify the relationship between human errors in maintenance and machine availability, machine performance and product quality towards OEE. Spearman correlation was chosen, as the overall data is not normally distributed. [19] developed Guilford's Rule of Thumb to identify the strength of the relationship. Table 6 shows the Guilford's Rule of Thumb.

TABLE 6: GUILFORD'S RULE OF THUMB

Multiple Correlation Coefficient, r	**Correlation Strength**
< 0.20	Very Weak
0.20 - 0.40	Weak
0.40 – 0.69	Moderate
0.70 – 0.90	Strong
>0.90	Very Strong

1) Spearman Correlation Test for Relationship between Human Errors in Maintenance (HEM) and Machine Availability (MA)

TABLE 7: SPEARMAN TEST FOR HEM AND MA

			HEM	MA
Spearman's rho	HEM	Correlation Coefficient	1.000	.641**
		Sig. (2-tailed)	.	.000
		N	75	75
	MA	Correlation Coefficient	.641**	1.000
		Sig. (2-tailed)	.000	.
		N	75	75

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

From the output of the correlation test, the value of the Spearman correlation coefficient, between the variables of human errors in maintenance (HEM) and machine availability, was 0.641 and the correlation was significant at the 0.01 level. As shown in table 4.8, the **Sig** value was 0.000, which was lower than 0.05 and indicated, the relationship between these two variables was significant. Therefore, HEM was significantly positive correlated with MA at the medium level of strength. In the context of this research, this verified human errors in maintenance will reduce the machine availability.

2) Spearman Correlation Test for Relationship between Human Errors in Maintenance (HEM) and Machine Performance (MP)

TABLE 8: SPEARMAN TEST FOR HEM AND MP

			HEM	MP
Spearman's rho	HEM	Correlation Coefficient	1.000	.547**
		Sig. (2-tailed)	.	.000
		N	75	75
	MP	Correlation Coefficient	.547**	1.000
		Sig. (2-tailed)	.000	.
		N	75	75

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

From the analysis of correlation, the value of the Spearman correlation coefficient between the variables of HEM and MP was 0.547 and the correlation was significant at the 0.01 level. The positive value of correlation coefficient indicates that there was a positive relationship between HEM and MP and the value of correlation coefficient was 0.547 indicated the strength of the relationship was significantly moderate between these two variables. Therefore, it could be concluded that, at the context of this study, HEM had significantly moderate positive relationship with MP.

3) Spearman Correlation Test for Relationship between Human Errors in Maintenance (HEM) and Product Quality (PQ)

TABLE 9: SPEARMAN TEST FOR HEM AND PQ

			HEM	PQ
Spearman's rho	HEM	Correlation Coefficient	1.000	.709**
		Sig. (2-tailed)	.	.000
		N	75	75
	PQ	Correlation Coefficient	.709**	1.000
		Sig. (2-tailed)	.000	.
		N	75	75

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

From the output of the correlation test, the value of the Spearman correlation coefficient, between the variables of HEM and PQ, was 0.709 and the correlation was significant at the 0.01 level. As shown in table 4.10, the **Sig** value was 0.000, which was lower than 0.05 and indicated, the relationship between these two variables was significant. Therefore,

HEM was significantly positively correlated with MA at the high level of strength. Meanwhile, HEM and MA had a strong relationship.

4) Spearman Correlation Test for Relationship between Human Errors in Maintenance (HEM) and Overall Equipment Effectiveness (OEE)

TABLE 10: SPEARMAN TEST FOR HEM AND OEE

			HEM	OEE
Spearman's rho	HEM	Correlation Coefficient	1.000	.694**
		Sig. (2-tailed)	.	.000
		N	75	75
	OEE	Correlation Coefficient	.694**	1.000
		Sig. (2-tailed)	.000	.
		N	75	75

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

From the analysis of correlation, the value of the Spearman correlation coefficient between the variables of HEM and OEE was 0.694 and the correlation was significant at the 0.01 level. The positive value of correlation coefficient indicates that there was a positive relationship between HEM and OEE and the value of correlation coefficient was 0.694 indicates that the strength of the relationship was significantly high moderate between these two variables. Therefore, it could be concluded that, at the context of this study, HEM had significantly high moderate positive relationship with MP. It concluded as high moderate as the correlation coefficient of this relationship was near to 0.7 while 0.7 was considered as a strong relationship.

H. Hypothesis Testing

The research hypothesis is a systematic prediction between the independent variable and dependent variable in the research. There are two types of hypothesis, which are the null hypothesis, **H_0** and alternative hypothesis, **H1.** The null hypothesis is meant there is no relationship between the variables of interest. On the other hand, an alternative hypothesis is a statement of prediction on the relationship between the variables in the study. There were four pairs of hypothesis in this study. There were either one of the hypothesis in each pair of the hypothesis would be rejected.

Hypothesis 1
H_0 : There is no relationship between human errors in maintenance (HEM) and machine availability (MA) towards OEE**.**
H_1: There is a relationship between human errors in maintenance (HEM) and machine availability (MA) towards OEE**.**

Spearman correlation test had been conducted between HEM and MA had resulted in Spearman correlation coefficient of positive 0.641 at a significant level of 0.01. Thus, the null hypothesis rejected and it could be concluded as there was a significant correlation between HEM and MA towards OEE

Hypothesis 2
H_0: There is no relationship between human errors in maintenance (HEM) and machine performance (MP) towards OEE**.**
H_1: There is a relationship between human errors in maintenance (HEM) and machine performance (MP) towards OEE**.**

Besides, a positive 0.547 value of correlation coefficient of HEM and MP had been recorded in the test of Spearman correlation. This correlation was significant at the level of 0.01. Therefore, the null hypothesis was rejected and it was found that there was a significant correlation between HEM and MP towards OEE.

Hypothesis 3
H_0: There is no relationship between human errors in maintenance (HEM) and product quality (PQ) towards OEE**.**
H_1: There is a relationship between human errors in maintenance (HEM) and product quality (PQ) towards OEE**.**

As for the third pair of hypothesis, a positive 0.709 value of correlation coefficient had been identified in the test of

Spearman correlation, between the variables of HEM and PQ and it was significant at the level of 0.01. From the result of this test, it could be seen that there was correlation relationship between the two variables as well. The null hypothesis for Hypothesis 3 was rejected and alternative hypothesis was accepted. Therefore, it could be concluded as there was a significant relationship between human errors in maintenance (HEM) and product quality (PQ) towards OEE**.**

Hypothesis 4
H0: There is no relationship between human errors in maintenance (HEM) and OEE**.**
H1: There is a relationship between human errors in maintenance (HEM) and OEE**.**

In the final pair of the hypothesis, Hypothesis 4, a positive 0.694 value of correlation coefficient had been identified in the test of Spearman correlation, between the variables of HEM and PQ and it was significant at the level of 0.01. This was considered as high moderate positive relationship From the result of this test, it could be seen that there was correlation relationship between the two variables as well. As a conclusion, there was a significant relationship between human errors in maintenance (HEM) and OEE.

V. DISCUSSIONS

This study conducted to identify the relationship between human errors in maintenance and OEE in the food industry. In order to identify this correlation, the relationship between human errors in maintenance with the three main components of OEE should be identified. These components are machine availability, machine performance, and product quality. The product of these three components will result in OEE.

A. Relationship between Human Errors in Maintenance and Machine Availability

H_1 shown the relationship between human errors in maintenance and machine availability. The values of Spearman's rho correlation coefficient reached a positive value 0.606**. It means that the relationship had a moderate correlation. Meanwhile, the significance value was shown the value of 0.000 that is less than 0.005. It shows the correlation is significance. This means human errors in maintenance correlated with the negative impact on machine availability towards OEE.

B. Relationship between Human Errors in Maintenance and Machine Performance

H_2 shown the relationship between human errors in maintenance and machine performance. The values of Spearman's rho correlation coefficient reached a positive value 0.547**. It showed the relationship had a moderate correlation. Additionally, the significance value was 0.000 which was less than 0.005. It showed the correlation was also significance. It could conclude as human errors in maintenance have a significant moderate relationship with the negative impact on machine performance towards OEE.

C. Relationship between Human Errors in Maintenance and Product Quality

H_3 shown the relationship between human errors in maintenance and machine performance. The values of Spearman's rho correlation coefficient reached a positive value 0.709**. It showed the relationship had a high correlation. Furthermore, the significance value was 0.000 which was less than 0.005. It showed the correlation is also significance. It could be concluded that the human errors in maintenance had a significant high relationship with the negative impact on product quality towards OEE.

D. Relationship between Human Errors in Maintenance and OEE

H_4 is shown the relationship between human errors in maintenance and OEE. The values of Spearman's rho correlation coefficient reached a positive value 0.694**. It showed the relationship had a high moderate correlation as it was near to high. Besides, the significance value was 0.000 which was less than 0.005. This indicated the correlation was also significance. As a conclusion for the overall correlation test, human errors in maintenance had a significant relationship with the negative impact on OEE.

VI. RECOMMENDATIONS

Based on the research, it had found out that is a significant relationship between human errors in maintenance and OEE. This means it is undeniable human errors will result in a bad impact on OEE. Therefore, there are few suggestions made in order to reduce the human errors in maintenance and increase OEE. A managerial person must ensure all the maintenance personnel have undergone proper training on maintenance activities. This would improve their knowledge, skill and ability which help them to make a correct decision when doing maintenance activities.

Supervision on the maintenance activities is very important too. A great supervision could detect and identify the error was done by maintenance personnel quickly and response to the entire problem in short time. This will eliminate the consequence impact from the failure of maintenance activities and improve the OEE.

Standard operation procedure should be properly written and the maintenance personnel must understand about it. This would ensure all the maintenance activities completed in required standard and proper way which reduces the chance of the occurrence of human errors in maintenance.

VII. CONCLUSION

As a conclusion, the outcome of this research had shown the significant relationship between human errors in maintenance and OEE in the food industry. It gives an overview on the relationship while future research could study this with a more details research instrument. As overall, the expectation of this research is to help the production line to minimize the human errors in maintenance and improve OEE.

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BIOGRAPHY

Ir. Yunos Ngadiman is a Lecturer in Department of Production and Operation Management at Universiti Tun Hussein Onn Malaysia. His research areas are industrial and Engineering Management specifically focuses on manufacturing productivity and equipment performance. He is the author of various numbers of peer-reviewed publications and published influential in international journals. He also active in exploring research and development towards commercialization valued. He is a membership of Institute of Electrical and Electronic Engineers (IEEE) and cooperated with *Japan* Accreditation Board for Engineering Education (*JABEE*).

Professor Dr Burairah Hussin is a Senior Lecturer and a Dean of Faculty of Information and Communications Technology, UTeM, Malaysia. He has successfully obtained his PhD holder from the University of Salford, United Kingdom specific field in Management Science . His research area is mainly in Algorithms, Artificial Intelligence, Artificial Neural Network and Operational Research. He has also been a member of numerous a professional associations abroad.

Dr Nor Aziati Abdul Hamid is a Senior Lecturer and Head of Department of Production and Operation Management in Faculty of Technology Management and Busianess. She holds a PhD in Information System from Universiti Kebangsaan Malaysia, and a Master of Science and Information Technology from Universiti Teknologi Mara, Shah Alam. She has published journal and conference papers. She also has teaching experience with over 10 years beside a head of several external research grants. Her research interest include manufacturing, ISO business excellence, manufacturing and lean. She has taught courses in Research Methodology, Quality Control, Project Management, Management Information System, Computer Application and Business, to name a few. She has served a member various association and also the journal editor for the faculty. She is active for the various international conference locally and internationally.

Rohaizan Ramlan is a senior lecturer in Department of Production and Operation Management at Universiti Tun Hussein Onn Malaysia. She has multidisciplinary research interests that encompass production and operation management, decision making in management, performance measurement and process improvement. Her current research project is process improvement in Malaysia Healthcare. Her teaching areas include Operation Management, Production and Planning Management and Operational Research.

Liew Kai Boon is a student of Universiti Tun Hussein Onn Malaysia. He studies for Bachelor Degree of Technology Management (Production and Operation) with honors. His research interests include operation and production meanagement, industry engineering and maintenance management.