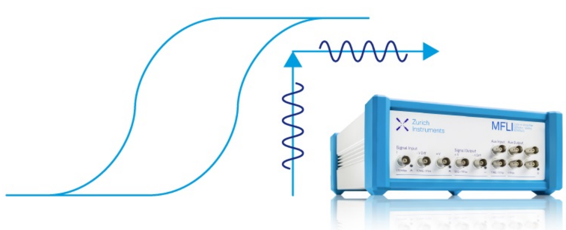
Failure mode and effects analysis (FMEA) of furniture production: A case study in Kelantan state, Malaysia

Cite as: AIP Conference Proceedings **2339**, 020025 (2021); https://doi.org/10.1063/5.0044245
Published Online: 03 May 2021

M. F. Ahmad, S. Ahmad Sobri, N. A. Nik Abdullah, N. M. F. Nik Kamarudin, M. Mohamed, A. Hermawan, J. G. Boon, W. O. A. S. Wan Ismail, and M. N. Norizan



Failure Mode and Effects Analysis (FMEA) of Furniture Production: A Case Study in Kelantan State, Malaysia

M F Ahmad[1], S Ahmad Sobri[1,a)], N A Nik Abdullah[2], N M F Nik Kamarudin[3], M Mohamed[1], A Hermawan[1], J G Boon[1], W O A S Wan Ismail[4] and M N Norizan[5,6]

[1]*Advanced Material Research Cluster, Faculty of Bioengineering & Technology, Universiti Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia.*
[2]*Nik Lah Sdn. Bhd., Lot 1066, Batu 8, Jalan Sabak, Pengkalan Chepa, 16100 Kota Bharu, Kelantan, Malaysia.*
[3]*Malaysian Investment Development Authority, MIDA Kelantan Office, Aras 5-C, Menara Pejabat Kelantan Trade Centre, Jalan Bayam, 15200 Kota Bharu, Kelantan, Malaysia.*
[4]*Faculty of Innovative Design and Technology, Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia.*
[5]*School of Microelectronic Engineering, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.*
[6]*Center of Excellence Geopolymer and Green Technology (CeGeoGTech), Universiti Malaysia Perlis, Perlis, Malaysia.*

Corresponding author: [a)]sharizal.s@umk.edu.my

Abstract. The primary objective of this research is to study the critical region of the local furniture manufacturing company by using a Failure Mode and Effects Analysis (FMEA). At the same time, the study also aims to help the organization to minimize production costs by presenting the preliminary stage of the results of the assessment. Many industries used FMEA as a method to improve the evaluation of the reliability of a production process. The use of FMEA is to analyze the layout characteristics of the planned production process in order to ensure that the final product meets customer requirements and expectations. It uses probabilities of detection and occurrence added with a few severity standards to create a risk priority number (RPN) for rating improvement action considerations. Utilized in both the manufacturing and design processes, they notably help to reduce cost factors with the aid of determining product and process improvements early within the development process while changes are inexpensively and relatedly easy to do. Based on the results, there were two failure modes with a higher RPN. The assessment is deductive as it periodically moves from one source to another. Thus, it can assist the company in improving its manufacturing process by reducing the mistakes that been made by identifying the cause and effect of it.

INTRODUCTION

In a world full of production and technical advancement, we often forget the importance of the quality value that we have given to the quantity of production in this process of advancement. Theoretically, quality can be defined as conformity with product and process requirements [1]. It is essential to understand that not every customer is looking for quantity. Besides, as we live in this modern age of technology, many customers are now starting to look at the quality of the product as today's production rate has increased dramatically. However, with things now working, satisfying the customer seemed to be more important than just creating excellent products.

Fortunately, after generations of development and advancement, researchers have developed tools or methods to identify potential failures before real problems arise [1–3]. Failure Mode and Effect Analysis (FMEA) is a structured technique for discovering capability failures that may exist within the product or process layout [4]. The use of FMEA in a deliberate production process is to convert design layout and process features into a practical work situation

Proceedings of Green Design and Manufacture 2020
AIP Conf. Proc. 2339, 020025-1–020025-9; https://doi.org/10.1063/5.0044245
Published by AIP Publishing. 978-0-7354-4091-3/$30.00

described and to ensure that the final product and overall performance of the results meet the needs and expectations of the customer. Such a deliberate manufacturing process is the process of manufacture of furniture. Furniture production can be said to be one of the largest developing sectors in the wood-based industry in Malaysia [5-6]. More attention needs to be paid to the economic importance of this industry. The industry is generally driven by comparative advantages derived from low input cost factors, which have deteriorated in current years due to increased manufacturing costs.

Consequently, the importance of this industry cannot be taken lightly. It is, therefore, crucial to implement the FMEA as a tool to improve the quality and efficiency of the furniture industry. Failure modes are the possible ways or methods to detect an asset's failure. Effect analysis involves predicting the effects of each failure mode [5]. The forestry industry in Malaysia has consistently contributed to the nation's economic growth and foreign exchange earnings. To date, there are almost 3,900 forest products manufacturing companies in the country [5]. The wood industry in Malaysia has assisted in four major sectors, such as sawn timber, furniture, veneer, and panel products, including plywood and other reconstituted panel products such as particleboard, chipboard, fibreboard, moldings and carpentry, and carpentry.

Among these four significant sectors, furniture production is the most advanced. As distinct from its design, furniture production is a primary mass-production industry in Malaysia, Europe, and other advanced regions. It is very much in large part of the 20th-century industry, its improvement having been expected by the increase of the mass consumer market in addition to the improvement of the mass production technique [7]. This process for selecting the specific type of wood that the customer wanted will involve several aspects such as the quality of the wood, the moisture content. Also, the strength and size of the wood needed to make all the difference in the furniture. Most types of wood suppliers and types of wood for different types of parts used. After the best possible selection of wood, the next step is the cutting and molding of wood. This process is critical in the manufacture of furniture. Because in this step, the wood will be precisely cut to size needed for the part of the difference. Then, in the molding process, this is where part of the wood that has been cut achieves the shape and size required for the manufacture of furniture.

FMEA was first developed as an assessment tool to improve the assessment of the reliability of military systems and weapons in the US Army in the late 1940s. This method was also used by the National Aeronautics and Space Administration (NASA) for Apollo space missions in the 1960s [8]. The objective of FMEA is to analyze the layout characteristics concerning the planned production process in order to ensure that the resulting product meets the needs and expectations of the customer. While failure modes are identified, improvement can be made by lowering the possibility of occurrence by taking a few correct actions. FMEA provides an organized assessment of the failure modes of the system being defined and identifies the causes of the failure.

In order to try to understand the process or system reliability, the standard route is to carefully list and pass through each process. This typical method of analysis was later improvised and revised not only to make it easier but also manageable with the diagram form. This method has been called the Fault Tree Analysis (FTA) method. FTA is a system analysis approach. The purpose of the fault tree analysis is to determine the underlying potential cause and the possibility of the occurrence of a distinctive undesired event. The fault tree is a model that logically and graphically represents the various combinations of viable opportunities. Fault trees are a graphical diagram that uses logic gates and fault activities to rewrite the reason for the impact relationships involved in causing the undesired occasion. The graphical model can be translated into a mathematical model if all the system failure rates are known.

The primary objective of this research was to study the critical region of the furniture manufacturing company in Kelantan state, Malaysia, by using FMEA. At the same time, the study also aimed to help the organization to minimize production costs by presenting the preliminary stage of the results of the assessment. By using FMEA as a quality management tool that can help the company to ensure the development and growth of production quality, it will be at the most optimized level. This is possible through an FMEA data analysis that can identify the best course of action that a company can take to avoid failure and unprofitable actions. FMEA is an engineering technique used to define, identify, and eliminate known or potential failures, problems, and systems, design, process errors. At the end of the analysis, it is hoped that the company will provide better design and production quality in order to improve productivity and meet the expectations of the customer.

METHODOLOGY

The primary method used in this study was the Failure Mode and Effects Analysis (FMEA) analysis on the furniture production process, and the method was adopted from previous studies [1,4,7,9-10]. The Fault Tree Analysis (FTA) diagram is used as a process flow to ease the planning of the analysis [11-14]. Several aspects of FMEA have also been improvised to match the present situation in the facility. Data and information were collected for the first part of this analysis. The data used originated from the manufacture of furniture in a furniture manufacturing company. In order to carry out the FMEA, the production data on furniture were mandatory in order actually to highlight the problem in the furniture production process.

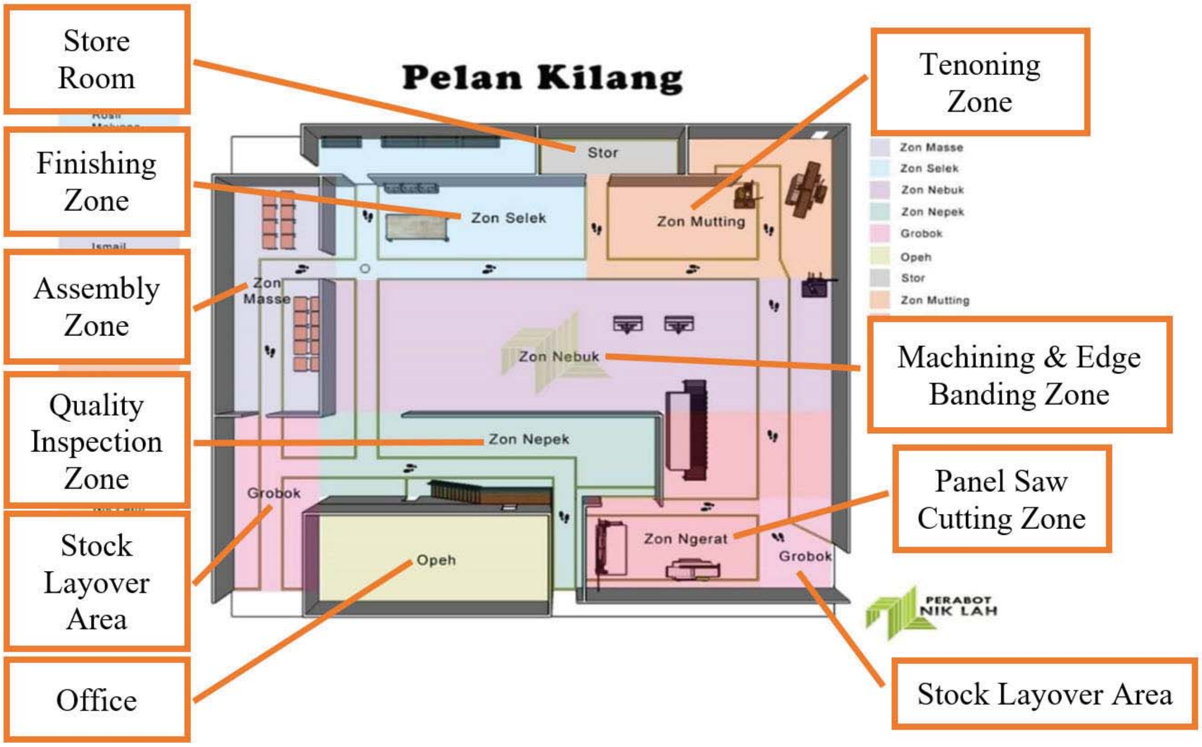


FIGURE 1. The Company's Factory Layout

In the process of data collection that has been carried out, it has mostly come from the observation of the production process itself. The observation was made at the furniture factory itself, Nik Lah Sdn. Bhd. It is located at Lot 1066, Batu 8, Jalan Sabak, Pengkalan Chepa, Kota Bharu, Kelantan, Malaysia. Figure 1 shows the layout of the company's production process. Researchers were not allowed by the company to publish any sensitive data or information except that the data or information had been checked and approved by the company

FIGURE 2. Inside the Nik Lah Sdn. Bhd. Factory

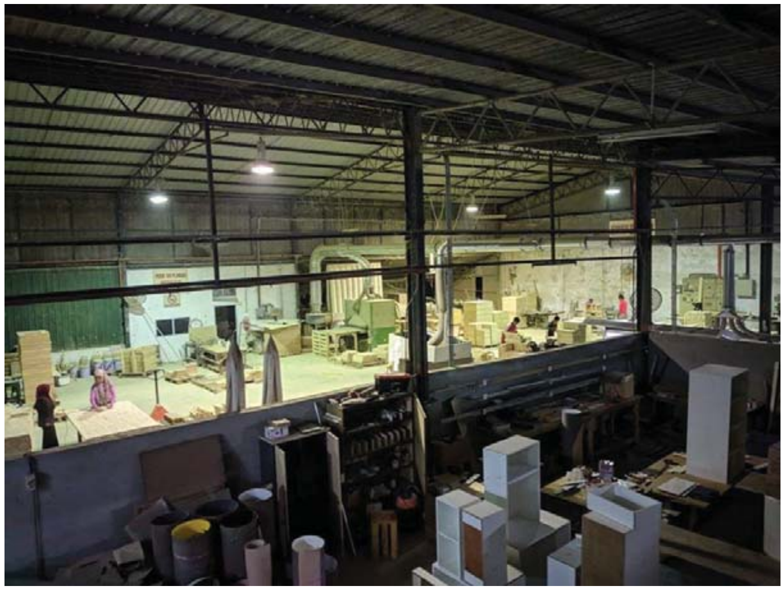


FIGURE 3. Overview of the Factory

Through studying the manufacturing cycle of the business carefully, as seen in Figs. 2 and 3, researchers were able to achieve a deeper understanding of the structure and structural cycle flow of furniture making. Observation is used in all sorts of systems as a way of gathering data on people, procedures, and knowledge. It has been shown that observation has been used since the compilation of information itself was established. In this study, the whole process of manufacturing of furniture has been studied, from the first stage in the procurement of materials all the way to the final product. There are two primary forms of observation. Researcher evaluation requires being both an observer and a researcher in the environment under review. Direct observation requires observation without communicating with objects or individuals understudy in the environment [15]. As with this research, the best approach to direct observation includes observing without communicating with objects or people under research in the environment. First, the data obtained was integrated into the Fault Tree Analysis (FTA) to enable data processing.

Application of Fault Tree Analysis (FTA) diagram

In order for the FTA to function, this data was then rearranged into a visual model. The diagram helped to emphasize the main production factor in the furniture production cycle, such as making joints and connecting parts as the main cycle while drilling as a sub-production process. This simple data was then reviewed to ensure that any essential aspect was not omitted by the observation and data collection process. The rational structure of the technique makes a simple description of the process that usually recognizes any defects within the system that might cause a total failure without any external constraints in place. In particular, the feeder resistor in parallel has been designed with a cable to eliminate this problem. The feeder cable will function as a transducer to send the signal for processing the signal to perform the next task.

Application of Failure Mode and Effects Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is split into three categories and two essential measuring criteria. The three classes contain the potential failure mode, potential cause of failure, and recommended action taken. The possible cause and mode of failure are determined by the evaluation and analysis of the furniture production cycle. The suggested intervention would at least avoid the recurrence of a possible failure state. Value for this review was determined from a mixture of:

- Risk matrix
- Criticality analysis (FMEA)

Severity, detection, and occurrence can be multiplied with each other in order to achieve a Risk Priority Number (RPN). The lowest risk target number rating for this research project was 30. Any number below the lowest priority rating has been classified as not targets for future development. RPN that has exceeded higher than the lowest risk target interest requires extensive work that has not been addressed by this initiative since the factory has been actively engaged in the execution of customer orders. Criticality was the quantity of the results of the failure mode defined by its severity and the likelihood of its occurrence. Severity was the calculation of the amount of damage done by the malfunction mode on the different components. The occurrence was the amount of loss that resulted in a particular process or the production environment. Detection was the ability to predict loss until it disrupted the production cycle. The description of the rate of severity, occurrence, and detection was then translated to the value assigned to the RPN.

The severity of the finishing failure was likely that the worker would feel the impact, but the impact was small. It gave the failure mode a severity score of 2. The occurrence in this failure mode was quite unlikely. This culminated in the failure mode and the occurrence rating of 3. If the surface is faulty, the worker will often note it. The worker must check the quality of the coating. Finishing failure mode brought the Detection rating to 2. From multiplying the severity, occurrence, and detection, a risk priority number (RPN) can be obtained. The RPN of the finishing failure mode is S*O*D = RPN.

$$S=3,\ O=3,\ D=2 \text{ Risk priority number (RPN)} = 3*3*2 = 18$$

The RPN was used to select which failure mode would be prioritized first and which should be prioritized last. If the RPN became big, it could be appropriate to introduce new prescribed measures or to improve the pace of maintenance. The RPN can also be used to classify the additional measures taken. If the danger target number was small, the response or repair might be unnecessary. The critical number given for this failure mode in Table 1 is 9.

TABLE 1. Example of RPN at Finishing Zone

Potential failure mode	Potential effect of failure	S	Potential cause of failure	O	Maintenance prevention methods	Criticality number (S*O)
Finishing failure	Coating defect	3	Dust or small particle on wood surface	3	Visual inspection	9

That was the product of the measured value arising from the severity and occurrence of the failure mode. The risk matrix was then calculated using this criticality number. To categorize the number of criticalities into the risk list based on Table 2. The rating of 25 or below was rated 4. It is ranked 3 with a ranking of 50 or less. If a rating of 75 or less than that, it was rated 2. At the end of the day, the importance of 75 before 100 is rated 1.

TABLE 2. Example of Risk Matrix Number

Risk Matrix		Severity			
		1	2	3	4
Occurrence	4	4	2	1	1
	3	4	3	2	1
	2	4	4	3	2
	1	4	4	4	3

RESULTS AND DISCUSSIONS

The Failure Mode and Effects Analysis (FMEA) was assisted by the Fault Tree Analysis (FTA), which would be outlined in the development maintenance program. Table 3 shows that all high-priority failure modes need to have high maintenance and monitoring priorities in order to address them. FMEA rates the Computer Numerical Control (CNC) machine failure as the top priority for this work. Although the table saw failure, it had the second-highest RPN.

Both the failure of the CNC machine and the failure of the table saw shown should be in the maintenance and inspection process.

TABLE 3. Failure mode with high RPN

High Priority	
Failure Mode	Risk Priority Number (RPN)
CNC Machine Failure	40
Table Saw Failure	32

The failure of the CNC machine is the highest RPN. The most severe possible impact on the loss of the CNC machine failed to work correctly. Not just this, it has a risk score of three in the risk matrix. The suggested action to be taken in this failure mode was to conduct weekly maintenance and likely regular day-to-day inspection of the CNC machine. There is also a requirement for a monthly or maybe a weekly practical check with more than just rounded testing. First, develop the worrying device for optimum detection of failure. As a consequence, there is an improved probability of avoiding failure.

The table saw showed that this failure mode has a few possible failure consequences that have a high-intensity rating. Nevertheless, the one with the most RPN was the possible failure impact that the table saw stopped working. This also has the second-highest RPN of all output failure modes. The table saw failure has a significant impact on the cutting and dimensioning operation. All the raw cutting process goes mostly through the use of table saws. It is must-have equipment in the woodworking business. This means, priority needs to be given to this failure mode. The suggested action is to repair and test the table saw facilities every week. Instead, because the table saw was still covered by sawdust. The system will ultimately be overrun by this debris, which will allow the engine to stop running. Therefore, a monthly test on the state of the engine and the equipment is mainly required. In order to be more accurate, the device operational check should be conducted more often due to a high RPN.

TABLE 4. Failure mode with low RPN

Low Priority	
Failure Mode	Risk Priority Number (RPN)
Assembly Failure	6
Finishing Failure	6

Table 4 indicates low RPN failure modes. With these failure modes having low priority, less effort was taken to deter failure from occurring. It presented an opportunity to improve the operation required for high-priority failure modes. Such an improvement that can be made is that the frequency of maintenance and inspection can now be improved. It was possible due to the low inspection rate needed for the less prone failure mode. Not to mention, with less time expended on the low-risk target, maintenance teams can devote more time to the higher priority. It is making maintenance quality considerably higher. FMEA valued the assembly failure at the severity of 3 and the detection of 1. It is increasing the worker's probability of recognizing the impact of mistake and immediately correcting the failure that has been committed. Quality control can effectively reduce the occurrence of this failure mode by reducing the cause of failure. The same can be said about the finishing failure mode. The rate of the severity of 2, where the failure has a marginal impact on the process with the detection score of 1 that can easily be detected, makes the failure modes not requiring much attention. Through visual inspection, the occurrence rate of the failure mode can be reduced.

FMEA is a well-known method used by many of the world's leading businesses and has recently begun to be used by the Malaysian industry. In 1977, Ford Motors developed FMEA to address possible research and development (R&D) issues at the early stage of production, and in 1984 released a theoretical Failure Mode and Results Analysis Handbook to promote the method [16]. Later on, automotive manufacturers in America have incorporated the FMEA into supply control and took it as a core test concern [17]. FMEA can also refer to a particular form of program that is not unique to the manufacturing or distribution process. In addition to design fault analysis, the FMEA can also apply a reliable hazard assessment method, which makes it a complete methodology on its own. This critical analysis approach is a must-have and powerful technique that can be extended to any form of system. However, adapting FMEA to furniture production was a considerable challenge and time-consuming. In order to provide more thorough information, the FMEA needs to rely on only one subsystem. The furniture manufacturing process is a fascinating topic of study. Uses the Computer Numerical Control (CNC) unit, as shown in Fig. 4, but still uses a sturdy and less modern table saw machine, this range of equipment is primarily used by the company Nik Lah Sdn. Bhd. With this research, the aim of this analysis was to examine the crucial region that can be found in the furniture production process, such as the need to prioritize the use of the Computer Numerical Control (CNC) system with the highest risk potential of 40. CNC system is mainly used in the development of joints for the manufacture of parts.

FIGURE 4. CNC unit at Machining & Edge Banding Zone

Following closely to the CNC machine in RPN was the usage of the table saw, as shown in Fig. 5. This has an RPN of 32, which is the second-highest in the furniture production process. Both the CNC system and the table saw that the risk level was 3. This high-risk focus has indicated that the crucial area in the manufacturing chain of this business is the area that included heavy maintenance equipment such as a table saw and a CNC unit.

FIGURE 5. Table Saw unit at Machining & Edge Banding Zone

For the new enlightenment of the region of high priority, let us hope that the organization can now get a clearer idea of what their new program wants and requires. The organization will now make a reasonable decision rather than wholly committed to carrying out the recommendation made, or to come up with a new and updated preventive strategy that eliminates the occurrence of existing errors. The suggested measures are a recommendation to the client about how to handle the present severity and occurrence of problems that have arisen. Another such example was one where a CNC display module (i.e., as shown in Fig. 6) in this machine will not show or show the wrong display on its current state. This does not explicitly influence the manufacturing cycle, but it is an early indicator that something is wrong elsewhere. This can happen because the mainboard has been compromised, or maybe because of a programming problem. If so, the suggested measure taken to this end was to schedule a weekly servicing of the equipment so that the equipment would not be turned down without warning and also to periodically conduct a visual inspection that would minimize the risk of a concurrent incident.

FIGURE 6. CNC Operating module

However, in the end, it is all up to the company to make the decision. The manufacturing processes are all related together. If there is an upgrade of a specific operation, the other that is related to it should always change. Either in terms of the production volume, the quality of the goods, or even the lowering of the cost of manufacturing, they would all be of great benefit to the company. Accordingly, when a company follows the FMEA, it would implicitly allow the company to reduce its cost of production while at the same time increasing its output performance and production efficiency. In this research study, the measurement has uncertainty as to the interpretation value of the severity, detection, and occurrence of the failure mode. Detection and occurrence of failure mode can be viewed differently between different processes. In order to achieve a thorough and reliable understanding of this analysis, it is essential for the organization to extend the FMEA to a particular method or sub-process. This will include an objective and more thorough overview of the results. There is no final answer to the priority number. By evaluating the operation, researchers have only been able to rank the most critical area at that particular moment.

CONCLUSIONS

Failure Mode and Effects Analysis (FMEA) was first developed as an evaluation tool to improve process stability evaluation. This was used in the current research to provide a systemic assessment of the failure modes of the system being specified and to classify the associated causes. This makes use of the possibilities of detection and occurrence, in addition to a few criteria of severity, to establish a risk priority number (RPN) for the prevention of higher scores. As shown in this research, FMEA can help define the crucial area of a system that has a high-risk priority for a company.

In order to obtain more in-depth findings, the scale of the analysis should be expanded. This was a great success for the researchers to be able to observe the whole production process at this preliminary stage of research.

Nonetheless, the amount of time and the amount of site work cannot be taken lightly. Besides, the volume of data that can be stored is limited to only one person. A strong analysis team will do its utmost to carry out the FMEA in the whole process. For a particular case study, it is also advised that the extent of the analysis be more defined, such as the FMEA for the CNC machine process or the FMEA for the assembly phase in the manufacturing process. The Fault Tree Analysis (FTA) and Reliability Centred Maintenance (RCM) approaches can also be recommended. These are excellent approaches to be used along with FMEA. FTA helps define and envision the possible failure mode that will occur, while RCM will help decide the correct and most suitable treatment for each failure mode that can be identified.

ACKNOWLEDGMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors would like to express our sincere appreciation to Nik Lah Sdn. Bhd., the Malaysian Investment Development Authority (MIDA) Kelantan Office in Kota Bharu, Kelantan, Malaysia, Universiti Malaysia Kelantan (UMK), Universiti Sultan Zainal Abidin (UniSZA), and Universiti Malaysia Perlis (UniMAP) for enabling researchers to carry out this project in a triple helix collaboration model.

REFERENCES

1. N. Kim-Soon, "Quality Management System and Practices Quality Management and Practices" (InTech, 2012).
2. S. L. Ahire, "Management Science - Total Quality Management Interfaces: An Integrative Framework Interfaces" (Providence, 1997).
3. S. W. Anderson and K. Sedatole "Designing quality into products: The use of accounting data in new product development Account" (Horizons, 1998).
4. W. L. Chang, L. M. Pang and K. M. Tay, Neurocomputing 249, 314-320 (2017).
5. J. Ratnasingam, L. T. Wai, G. Thanasegaran, F. Ioras, C. Vacalie, C. Coman And L. Wenming, Cluj-Napoca 41, 601 (2013).
6. A. J. J. Braaksma, A. J. Meesters, W. Klingenberg and C. Hicks, Int. J. Prod. Res., 50, 6904–17 (2012).
7. S. A. Sobri, R. Heinemann, D. Whitehead and N. A. Shuaib, J. Eng. Technol. Sci., 50, 21 (2018).
8. K.H. Chang, Y.C. Chang and I.T. Tsai, Eng. Fail. Anal., 31, 211–24 (2013).
9. B. Rajkumar. L. Y. Patil, P. B. Waghmode, T. S. M. Chikali, J. Eng. Res. Stud. IV , 6, 8 (2016).
10. F. Langlo, Application of Reliability Centered Maintenance on a Drilling System, (Master's thesis of University of Stavanger, 2014).