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Defect Analysis of Printing Process in Offset Printing Industry by Using Failure Mode Effect Analysis (FMEA) and Fault Tree Analysis (FTA)

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Abstract

KOP Corp. is an offset printing company, especially in packaging printing (folding boxes). KOP Corp. faced many defects in production. This has an impact on increasing cost and customer dissatisfaction. This paper discusses Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) to find root cause of problem. FMEA use to prioritized sources of problem. Moreover, FTA is used for finding out the root of the problem. Based on Risk Priority Number (RPN), three failure modes with the largest RPN, namely defect printed, color is not up to standard and defect in the picture. By using the FTA method, analyzed the root problems of these failure modes. After creating a Fault Tree Diagram and looking for a minimum Cut Set, it can be recommended several improvements such as the socialization of a good sampling plan, the design of a training program, Quality Control Circle development, and the selection of good suppliers.

Keywords: defect, failure mode and effect analysis, fault tree analysis

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1. Introduction

Every industry is faced with fierce competition. Quality refers to a product's ability to compete in the marketplace. Producing a high-quality product necessitates the company's own commitment. Product quality assurance necessitates a concerted effort in the form of a quality assurance program. Failures and nonconformities in production reduce competitiveness by affecting the availability of assets, hence their prevention and control are crucial for boosting competitiveness (Schmitt and Lima, 2016). The analysis of failures and their prevention throughout the design process constitutes an effective strategy for lowering the incidence of manufacturing failures since failures could be avoided or minimized at an early stage and in a proactive manner (Alruqi *et al.*, 2021).

KOP Corp. is one of the printing enterprises, specializing in offset printing. KOP Corp. manufactures packaging boxes for a variety of items, including toothpaste, cigarettes, and medications. The number of defective products produced is one of the issues. As a result, there are financial losses as well as challenges with client trust. PT. KOP produces a wide range of products for a wide range of clients. As a result, each product has its own set of standards and tolerances. As a result, quality control is difficult, and there are many faults. As a result, identifying the defect's cause is necessary for improvement. Printing is a significant and crucial activity that can affect the outcomes of future processing. This post will go over how to analyze process failure modes to figure out which failures need to be fixed first and how to find the root cause of failure. Failure mode effect analysis (FMEA) and fault tree analysis are two of the methodologies to be applied.

FMEA is a way of identifying probable failures in a system or process, their impacts to improve the system or process. FMEA will generate a Risk Priority Number (RPN) which will be used to rank the importance of problems that need to be resolved. Fault Tree Analysis is used to further analyze the risk of failure after it is discovered which has the highest RPN value (FTA). FTA is a Top-Down approach analytical technique for identifying the elements that contribute to failure.

2. Literature Review

2.1 Quality Control

Quality Control is viewed in many different perspectives. Quality Control (QC) is a process used to ensure that a product's quality meets specified criteria. Quality control is widely understood to be a system that upholds a desired level of quality through feedback on product/service characteristics and the deployment of corrective measures when such characteristics deviate from a predetermined norm (Mitra, 2012)**.** Customers were dissatisfied with the items produced at the start of the Mass Production sector because the products were mainly non-uniform. QC used to be limited to the accept/reject or Go/No Go procedures.

The simplest kind of QC is the Go/No Go Procedure, in which the producer compares the manufacturing results to the desired product's drawing or design. The product is rejected if the final product does not match the required product drawing, and vice versa. However, because all production processes have a natural cause of disability, this strategy began to be regarded inefficient. This means that none of the things created will be identical or will always vary. As a result, the tolerance limits were established in 1840. This tolerance limit serves the same purpose as the desired product's sketch or design; the difference is that rejection occurs when the final product does not meet the tolerance limit.

2.2 Failure Mode and Effect Analysis (FMEA)

FMEA was introduced for the first time in the US aviation manufacturing division in the 1950s. It was initially employed to address the challenges with military product quality and dependability. FMEA has been widely used in many sectors to examine and enhance system quality and dependability as part of the ongoing effort to improve product quality (Wu, Liu and Nie, 2021). FMEA is a systematic method of identifying and preventing the failure of a product or process. Focus of FMEA is on preventing disability, improving safety, and customer satisfaction. FMEA is a method that can be used to improve quality of products and processes by determining priority of improvement. FMEA was utilized to undertake risk analysis using the Risk Priority Number (RPN), which is created by combining the terms occurrence, severity, and detection (Ng *et al.*, 2017). Determination of priorities based on the risk priority number (RPN) value obtained from the multiplication of severity (S), probability of occurrence (O), and probability of detection (D) (Boral *et al.*, 2020). FMEA is widely applied for several reasons, namely to identify the priority of failure mode in the system, to determine and reduce the incidence of failure and perform failure analysis to be used as a comprehensive reference to overcoming future problems (Ebrahemzadih *et al.*, 2014).

Mode failure is not only identified, but also specified which mode of failure is the most important to complete. This can be seen from the RPN value that the failure mode has. RPN is a Risk Priority Number that serves to set the corrective priority of a failure mode, The higher the RPN value, the failure mode is a failure mode that has a high risk and must be completed immediately. RPN values are calculated by multiplying the values of three indicators, namely Severity, Occurrence, and Detection. The values for each indicator have a value range of 1-10. So RPN value will range between 1 and 1000. If the RPN value more than 100, failure modes should be a priority. The failure mode requires corrective action if RPN = 100 while if RPN = 98 it needs to be considered corrective action (Shafiee, Enjema and Kolios, 2019). In determining how much value should be given to each indicator, there are several criteria as a benchmark for giving value to provide more accurate value. The criteria for each severity, occurrence and detection indicator can be seen in Table 1- Table 3 (Stamatis, 2015).

Table 1. Severity rating

Effect	Description	Ranking
No	No effect noticed by customer	1
Very Minor	Very minor disruption to production line	2
Minor	Minor disruption to production line	3
Very Low	Very low disruption to production line	4
Low	Low disruption to production line	5
Moderate	Moderate disruption to production line	6
High	Major disruption to production line (> 30 %)	7
Very High	Major disruption to production line (close to 100 %	8
Hazard with Warning	Failure will occur with warning	9
Hazard with no Warning	Failure will occur with no warning	10

Table 2. Occurrence rating

Occurence	Description	Frequency	Ranking
Remote	Failure is very unlikely.	<1 in 1,500,000	1
Low	Relatively few failures	1 in 150,000	2
		1 in 15,000	3
Moderate	Occasional failures	1 in 2,000	4
		1 in 400	5
		1 in 80	6
High	Repeated failures	1 in 20	7
		1 in 8	8
Very High	Failure is almost inevitable	1 in 3	9
		> 1 in 2	10

Table 3. Detection rating

Effect	Ranking	Criterion
Almost certain	1	Almost certainly detect the potential cause of subsequent failure modes
Very high	2	Very high chance the design control will detect the potential cause of subsequent failure mode
High	3	High chance the design control will detect the potential cause of subsequent failure mode
Moderately high	4	Moderately high chance the design control will detect the potential cause of subsequent failure mode
Moderate	5	Moderately chance the design control will detect the potential cause of subsequent failure mode
Low	6	Low chance the design control will detect the potential cause of subsequent failure mode
Very low	7	Very low chance the design control will detect the potential cause of subsequent failure mode
Remote	8	Remote chance the design control will detect the potential cause of subsequent failure mode
Very remote	9	Very remote chance the design control will detect the potential cause of subsequent failure mode
Very uncertainty	10	Control will not or can not detect the potential cause of subsequent failure mode

2.3 Fault Tree Analysis (FTA)

A graphical way for simulating how faults spread throughout the system is the use of fault trees (FTs). FTA investigates how reliable the system is designed to be. It offers techniques and resources to compute several attributes and measurements (Ruijters and Stoelinga, 2015). The basis for the FTA approach is the intrinsic level and causative relationship between the cause of the failure and the results, which synthesizes the correlation of the fault event. For example, a reason may lead to numerous results, and one result may be caused by several reasons (Wang, Yang and Kang, 2018).

FTAs are commonly used for system failure analysis using Boolean logic (Waghmode and Patil, 2016). FTA is based on deductive logic and can also be adjusted to risk identification to analyze how the impact of risk arises. Effective implementation of the FTA needs a detailed explanation of the area under discussion. Unwanted events are identified initially, followed by all conceivable conditions/failures that led to the event. Its goal is to identify potentially hazardous elements at each stage of the project. An FTA enables a group to consider and specify the order or pattern of failures that must occur to determine failures at a certain level. A high-level failure is a distinct form of failure. Many FTAs may be used in complex projects, each exploring a different mode of failure. The key advantage of FTA is the analysis, which provides unique insights into the project's functioning and potential failure. Before going deeper into the Fault Tree Analysis approach, a minimal cut set is sought, which is a mixture of numerous Basic Events that can result in a Top Event. Boolean algebraic rules are used to find the Minimum Cut Set. Table 4 illustrates this rule.

Table 4. Boolean algebra rules

Rule	Mathematical Form
Commutative	$A \times B = B \times A$
	$A + B = B + A$
Associative	$A \times (B \times C) = (A \times B) \times C$
	$A + (B + C) = (A + B) + C$
Distributive	$A \times (B + C) = A \times B + A \times C$
	$A + (B \times C) = (A + B) \times (A + C)$
Idempotent	$A \times A = A$
	$A + A = A$
Absorption Rules	$A \times (A + B) = A$
	$A + A \times B = A$

2.4 Methods in Preparation of FMEA and FTA

2.4.1 Preparation of FMEA

The steps to do FMEA include the following:

a. Determine the process to be analyzed. The process to be analyzed is the printing process.
b. Identify the type of failure mode.
c. Identify the consequences of failure (effect of failure). In this step, identify the consequences or consequences of failure. These consequences can affect the next process, operation, customer, production, and government regulations/rules.
d. Identify the cause of failures that occur in the process (failure causes). In this step, failure is identified to find factors or causes of failure.
e. Set a Severity Rating (S).
f. Set the Occurrence Rating (O).
g. Identify actions that the company has taken (current control) to prevent failure mode. In this step, it is identified the actions that have been taken to overcome the failures that occurred.
h. Establish a Detection Rating (D).

i. Calculating the Risk Priority Number (RPN). RPN aims to indicate the priority level of a failure mode. RPN value depends on the severity rating, occurrence rating, and detection rating. RPN has the following formula:

$$RPN = S \times O \times D \tag{1}$$

2.4.2 FTA Preparation

A fault tree indicates the state of the basic event or system component and the relationship between the basic event and the top event connected within a logic gate. The following are the steps in performing the Fault Tree Analysis (FTA) method:

a. Identify Top Level Events. This step identifies unwanted events (undesired events) to identify problems with the system. The system and its scope also need to be studied and understood for more accurate identification.
b. Create a Fault Tree Diagram. Fault Tree Diagram shows how top-level events can appear on a network. This diagram is deductive and top-down (from top to bottom). Fault Tree Diagrams are created with symbols containing an event description on the system and logic gates to explain the relationship between events to each other.
c. Analyzing fault trees. Fault Tree Analysis aims to get clearer information about a system and its improvements. Before doing a deeper analysis, the first thing to do is to find a minimum cut set. Minimum cut set is a variety of possible combinations of failures (basic events) contained in the Fault Tree that may cause the Top Event to occur. A minimum Cut Set can be found by representing the Fault Tree as Boolean algebra. Once the fault tree is changed in mathematical form, the mathematical form can be reduced using the rules of Boolean algebra to obtain a minimum cut set.

3. Result and Discussion

3.1 FMEA Results

The printing division's procedures, such as paper preparation, ink proofing, and printing, are used to identify error mode. The preparation of paper refers to the process of preparing papers for use in manufacturing. This comprises retrieving paper from raw material warehouses, inspecting the quality of the paper, and cutting paper as needed. The discovery of unclean and/or wavy paper, which can impair color variations and the accuracy of printed images, is a common concern in this process. In addition, the Cut Division is involved in the paper cutting process. This division oversees cutting paper to satisfy demand and final product design. The rolling ends of the paper, as well as the occasionally erroneous pieces of paper, are problems that happen throughout this process. The wrong way to stack paper damages the paper that will be used, resulting in the paper rolling to a halt. The paper may become stuck on the machine during the process.

Paper damage can also be caused by suppliers. If raw materials are not thoroughly checked, it is possible that poor raw materials may be used in manufacturing, which could have an impact on the production process. Following the preparation of the paper, the ink must be proofed. The ink proofing procedure involves inspecting the ink and the color it produces. The goal of this procedure is to alter the resulting hue to meet the consumer's expectations. This procedure is repeated until the color produced matches the set. Inappropriate color defect goods and miss registers are frequently the outcome of the proofing procedure.

The printing process follows the proofreading step, which creates colors that are consistent with the standard. The printing process' goal is to create according to the quantity demanded. The operator additionally monitors the manufacturing results on a regular basis during this process. When paper is loaded into the machine, the printing process comes to a halt. Although the operator checks periodically during this procedure, operators check in different ways. As a result, damaged items are sent on to the next phase, increasing the quantity of flaws.

As indicated in Table 5, FMEA is created from the process. Once all error modes have been located and investigated, severity, occurrence, and detection assessments are carried out. As previously said, the severity, occurrence, and detection values are determined by looking at the established criteria. The RPN is calculated by multiplying the severity, occurrence, and detection values. Table 6 shows the RPN computations. After the root cause or Basic Event of the Top Event has been determined, the failure mode with the highest RPN value can be used as a Top Event in the FTA technique. For finding these underlying causes requires determining minimal Cut Sets of Basic Events.

Table. 5 Failure mode and effect analysis (FMEA)

Process	**Possible Failure Mode**	**Possible Failure Effect**	**Possible Failure Causes**	**Current Control**
Paper preparation process	Dirty paper	Color does not enter color tolerance	Lack of material checking	Separated/retrieved by the operator. If there are many, the operator follows up.
	Corrugated paper	color fluctuations	a Warehouse conditions are not standard, suppliers, lack of material checking	Separated/retrieved by the operator. If there are many, the operator follows up.
	Broken/torn paper	color fluctuations, stuck on the roll	Supplier, less material checking, cut parts	Separated/retrieved by the operator. If there are many, the operator follows up.
Ink Proofing Process	Color is not up to standard	Color does not enter color tolerance	Ink profile used by the operator is not precise	Color reset
	Thick ink	Color does not enter color tolerance	Machine technology that has been left behind the times	Separated by the operator when starting the printing process
	Thin ink	Color does not enter color tolerance	Paper causes fluctuations, color settings are not precise	Separated by the operator when starting the printing process
	There is a defect in the picture	Product defects	Dirty Roll/Plate/Blanket	Roll/Plate/Blanket Cleaning in the middle of the production process
Printing Process	Paper stuck in the machine during production	Production process halted	Sucker position is not right, Corrugated paper	Reset the sucker position in the middle of the production process
	Uncontrolled/ defective production results	Product variety is too great	Operators and QC parts are less thorough in checking	Checking is done during the production process by taking samples

Table 6. RPN calculation

Process	**Possible Failure Mode**	**Severity**	**S**	**Occurrence**	**O**	**Detection**	**D**	**RPN**
Paper preparation	Dirty paper	Slightly affects the color when the stain is large enough	2	Very rare	1	Very easy to detect/invisible	1	2
	Corrugated paper	Causing color fluctuations, color becomes non-standard	5	Very rare	1	Very easy to detect/invisible	1	5
	Broken/torn paper	Can get stuck in the machine, causing the machine to break down	5	Very rare	1	Very easy to detect/invisible	1	5
Ink proofing	Color is not up to standard	It can cause *waste*. Customer expectations *are* not achieved	8	Quite often, sometimes in large quantities.	6	Very easy to detect/invisible	1	48
	Thick ink	Not up to standard but may still be within tolerance limits	2	Quite often. The amount is not too much	5	Very easy to detect/invisible	1	10
	Thin ink	Not up to standard but may still be within tolerance limits	2	Quite often. The amount is not too much	5	Very easy to detect/invisible	1	10

Table 6. RPN calculation (continued)

Process	Possible Failure Mode	Severity	S	Occurrence	O	Detection	D	RPN
	Defect in the image	Can cause *waste* when certain defects occur (such as *miss register)*	3	Quite often. The amount is not too much	5	Easy to detect, chances of escape are small	2	30
Printing	Paper stuck in the machine during production	Can damage the engine or make repairs in the middle of production	8	Very rare	1	Easy to detect, the probability of escape is slightly greater	3	24
	Uncontrolled/defective production results	When it occurs, defects in the product will spread, causing more *waste*.	8	Quite often. The amount is not too much	5	Easy to detect, chances of escape are small	2	80

3.2 FTA results

After the discovery of the failure mode that has the highest RPN value, the failure mode is used as a Top Event to create a Fault Tree diagram. The three failure modes that have the highest value are "Uncontrolled production result/ defect" with an RPN value of 80, "Color is not up to standard" with an RPN value of 48, and "Defect in the image" with an RPN value of 30. The researcher only chooses the three highest failure modes (Top Event) because these failure modes directly affect the occurrence of defects. Therefore, the three failure modes are considered to represent other modes of failure. Each Top-Level Event and Basic Item can be seen on Table 7.

Table 7. Top level event and basic event

Top Level Event	**Basic Event**	**Code**
Uncontrolled/defective production results (TE1)	Improper checking methods	1IE1
	Less conscientious workers	1IE2
	Vagueness of product standards	1IE3
	Methods applied incorrectly	1IE4
	Chase Target	1IE5
	Workers who are less/not yet experts	1IE6
	Late production	1IE7
	The standard of each product is different.	1BE1
	There is no SOP	1BE2
	Lack of training	1BE3
	Workers who lack discipline	1BE4
	Breakdown Machine	1BE5
	Proofing old colors	1BE6
	Downtime waits	1BE7
Color is not up to standard (TE2)	Ink profile that is not right	2IE1
	Wrong setting of the machine	2IE2
	Paper quality is not up to standard	2IE3
	Operators are less thorough	2IE4
	Paint quality is different from before	2IE5
	Defects of the cutting division	2IE6
	Error in creating Ink Profile	2BE1
	Operator lacks training	2BE2
	Paper supplier	2BE3
	Lack of checks from QC	2BE4
	Warehouse conditions are not up to standard	2BE5
	Paint supplier	2BE6
	Pieces are not true	2BE7
	How to stack the wrong paper	2BE8
There is a defect in the picture (TE3)	Dirty Roll/Plate/Blanket	3IE1
	Wrong setting of the machine	3IE2
	Paper quality is not up to standard	3IE3

Table 7. Top level event and basic event (continued)

Top Level Event	Basic Event	Code
	Wash less clean during a changeover	3IE4
	Workers are less conscientious	3IE5
	Defects of the cutting division	3IE6
	Workers lack training	3BE1
	Paper supplier	3BE2
	Lack of checks from QC	3BE3
	Warehouse conditions are not up to standard	3BE4
	Pieces of paper are not correct	3BE5
	How to stack the wrong paper	3BE6

Fault Tree diagrams with failure modes "Uncontrolled/defective production results", "Colors are not up to standard", and "There are defects in the image" can be viewed in Figure 1, Figure 2, and Figure 3, respectively. After the Fault Tree diagram is created, the next step is to find a minimum Cut Set for the Fault Tree diagram. The minimum calculation of the cut set can be seen in Table 8 – Table 10.

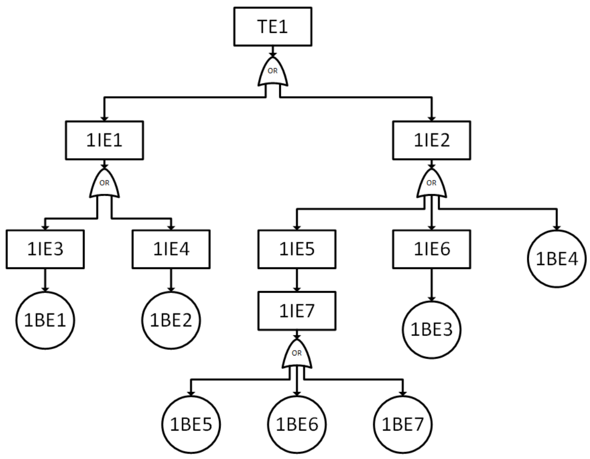

Figure 1. Fault tree diagram "uncontrolled/defective production results"

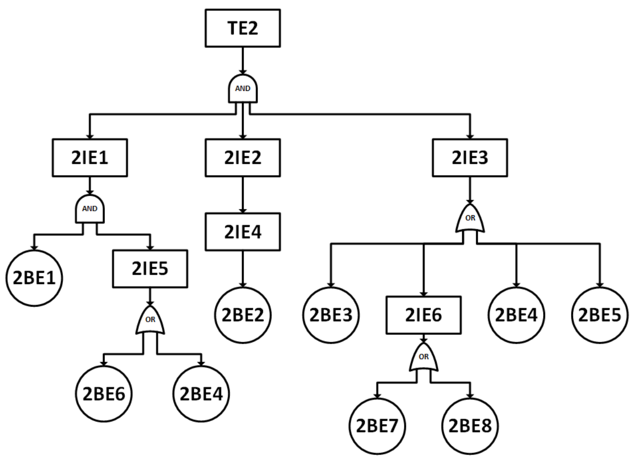

Figure 2. Fault tree diagram "color not up to standard"

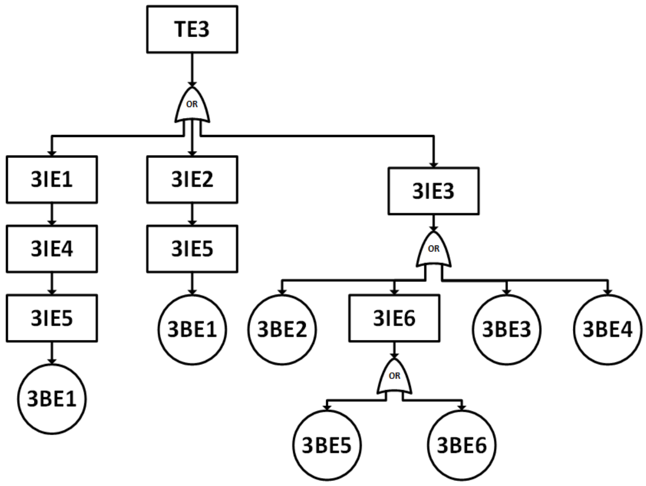

Figure 3. Fault tree diagram "there is a defect in the picture"

Table 8. Minimum cut set "uncontrolled/defective production results"

Iteration	Boolean equation
1	TE1 = 1IE1 + 1IE2
2	TE1 = (1IE3 + 1IE4) + (1IE5 + 1IE6 + 1BE4)
3	TE1 = (1BE1 + 1BE2) + (1IE7 + 1BE3 + 1BE4)
4	TE1 = 1BE1 + 1BE2 + 1BE3 + 1BE4 + 1BE5 + 1BE6 + 1BE7

Table 9. Minimum cut set "color not up to standard"

Iteration	Boolean equation
1	TE2 = 2IE1 × 2IE2 × 2IE3
2	TE2 = (2BE1 × 2IE5) × 2IE4 × (2BE3 + 2IE6 + 2BE4 + 2BE5)
3	TE2 = [2BE1 × (2BE6 + 2BE4)] × 2IE4 × [2BE3 + (2BE6 + 2BE7) + 2BE4 + 2BE5]
4	TE2 = [2BE1 × (2BE6 + 2BE4)] × (2BE3 + 2BE4 + 2BE5 + 2BE6 + 2BE7) × 2BE2
5	TE2 = [2BE1 × (2BE6 + 2BE4)] × (2BE3 + 2BE5 + 2BE6 + 2BE7) × 2BE2

Table 10. Minimum cut set "defects in the picture"

Iteration	Boolean equation
1	TE3 = 3IE1 + 3IE2 + 3IE3
2	TE3 = 3IE4 + 3IE5 + (3BE2 + 3IE6 + 3BE3 + 3BE4)
3	TE3 = 3IE5 + 3BE1 + [3BE2 + (3BE5 + 3BE6) + 3BE3 + 3BE4]
4	TE3 = 3BE1 + 3BE1 + (3BE2 + 3BE3 + 3BE4 + 3BE5 + 3BE6)
5	TE3 = 3BE1 + (3BE2 + 3BE3 + 3BE4 + 3BE5 + 3BE6)

After all the minimum Cut Sets are found for all diagrams, they can be analyzed for solutions or improvements so that the Top Event of each diagram can be prevented or reduce the possibility of Top Events occurring. From the results of the minimum cut set calculation for the FTA diagram "Uncontrolled production results/defects", the following results are found:

$$TE1 = 1BE1 + 1BE2 + 1BE3 + 1BE4 + 1BE5 + 1BE6 + 1BE7 \quad (2)$$

The AND logic gate is not used. Therefore, it can be concluded that all Basic Events have an influence in the occurrence of Top Events, but not all need to be completed simultaneously. Two Basic Events can be used as a focus in completing the Top Event, namely 1BE1 and 1BE2.

The basic event with code 1BE1 is "The standard of each product is different" while code 1BE2 is "No SOP". These two Basic Events are very closely related and may be completed simultaneously. One way to overcome this problem is the standard socialization of each product and sampling plan. This socialization is carried out with the hope that all workers, both those in the production department and the QC section, become aware of how to achieve and maintain product quality. The standard sampling plan used is MIL-STD-105D. MIL-STD-105D is a common sampling plan standard and is still widely used by companies today. MIL-STD-105D itself stands for Military Standard or Military Standard, and this sampling plan was originally only used for military purposes in the United States. MIL-STD-105D has been introduced during the training of new workers at PT. KOP, but experienced people do not escape mistakes. It would be very good if the operator's desks listed MIL-STD-105D tables so that the production and QC workers can more easily run sampling plans. Sampling methods can also be given so that workers are not wrong when sampling.

The standard of each product produced by KOP Corp. has different quality standards depending on the customer. This means the sampling plan used can also be different for each product. This led to the idea of recording a sampling plan used for each product in the production schedule. Production schedule at KOP Corp. is created by the Production Planning and Inventory Control (PPIC) section. PPIC is part of the company that oversees scheduling both production schedules and purchases of raw materials. PPIC at KOP Corp., every day will issue a production schedule for that day only. In the schedule, it is listed what products need to be produced and how many targets must be achieved. This schedule can be made better by recording what is the minimum number of samples that need to be taken and/ or the sampling standards. Often, they take samples in a less precise way so that defects in the product are not detected. Therefore, the inclusion of these things on the schedule sheet may be able to help workers to reduce errors in sampling. Another basic event that can be used as a focus is "Breakdown Machine" with code 1BE5. This basic "Machine Breakdown" event is caused by an engine problem, so the best way to overcome this is to schedule efficient maintenance. This maintenance must be done routinely to avoid engine damage at production time.

From the results of the minimum Cut Set calculation for the FTA diagram "Color is not up to standard", the following results are found:

$$TE2 = [2BE1 \times (2BE6 + 2BE4)] \times (2BE3 + 2BE5 + 2BE6 + 2BE7) \times 2BE2 \quad (3)$$

The Minimum Cut Set for Fault Tree "Color Does Not Fit the Standard" is divided into three parts or groups namely parts [2BE1 × (2BE6 + 2BE4)], parts (2BE3 + 2BE5 + 2BE6 + 2BE7), and 2BE2. Because at least this Cut Set all use and logic gates, completing one of the parts or groups is enough. If viewed carefully, the simplest to complete or find a solution is Basic Event 2BE2 which means "Operator lacks training". Operator training or general worker training, in any company, is very important. In addition to the workers can complete the job well, training is also used as a form of character of the worker himself.

Therefore, companies need to pay attention to employee training programs. There are many things to consider creating a good training program. The first thing is to analyze the training objectives. Do not let workers be trained for something useless or unnecessary. After that make a list of things that must be learned by the worker. That way, workers and training implementers are not confused. The second thing to note is the training materials that must be prepared carefully. For operators, it may be a good idea if more directly into the field so that the operator is more familiar with his workplace and the people who work there. The third thing to consider is the evaluation of the training program. Evaluations are conducted to see what impact the training program has on the trained workers. As already explained, training is also used to form characters. Training evaluations are also used to see if the character of the trained worker has been formed according to the character that the company wants. That way, if the training program is not good or not in accordance with the company's desire, the training program can be changed to be better. In addition to training design, workers are also trained in internal discussions about problems that often occur on the production floor. This can be done by creating a Quality Control Circle *(QCC*). QCC is a meeting activity periodically by a group of employees who work together to strive for quality control by identifying, analyzing, and taking actions to solve problems faced in a job. QCC is generally followed by 7-8 employees who come from the same part, but it does not rule out the possibility of employees from other parts also participating in QCC. The result of this GKM is in the form of a solution recommendation that will later be given to the management.

From the results of the minimum Cut Set calculation for the FTA diagram "There are defects in the picture", the following results are obtained:

$$TE3 = 3BE1 + (3BE2 + 3BE3 + 3BE4 + 3BE5 + 3BE6) \quad (4)$$

When viewed from the minimum Cut Set above, there is no AND logic gate used but only the OR logic gate. This means that a single Basic Event occurs and can cause a Top Event to occur. This becomes difficult because prevention must be done for all Basic Events. There are six Basic Events: "Undertrained workers" (3BE1), "Paper suppliers" (3BE2), "Lack of checks from QC" (3BE3), "Warehouse conditions are not up to standard" (3BE4), "Paper pieces are not correct" (3BE5), and "How to stack the wrong paper" (3BE6).

The solution provided for the Basic Event "Workers lack training" is more or less the same as the solution for the Basic Event "Operators lack training" i.e. designing, implementing, and evaluating training programs even better. Basic Event "Supplier paper" has the intention that the selection of the wrong supplier can be fatal in the production process such as the emergence of defects in production results. It is also closely related to the Basic Event "Lack of checking from QC". The solution that can be given is to choose the supplier correctly. This is so that the raw materials used are guaranteed quality. In addition to choosing a supplier, the relationship with the supplier also needs to be maintained so that a good supplier is not lost. However, the raw materials provided by suppliers are not necessarily all good. Raw materials sent may be some that are not in accordance with company standards. Therefore, QC as a party that maintains quality needs to inspect the raw materials that come carefully by using the correct sampling method and which has been agreed upon by the company and the supplier.

The next Basic Event that needs to be addressed is "Warehouse conditions are not up to standard". Every company that has a warehouse must have its own rules or qualifications for its warehouse depending on what is stored in it. At KOP Corp., especially raw material warehouses have their standards such as room temperature that should not be too hot, should not be damp, and the warehouse room must be neat and clean. Warehouse conditions that are not up to standard will damage the raw materials (in this case paper). The most important thing to maintain for the warehouse at KOP Corp. is the room temperature because if it is too hot it will cause the raw material paper to corrugate. Uneven paper surface will cause color fluctuations and other defects such as unprinted parts (small or large size) and can cause register errors (image italics). Therefore, it is recommended for warehouse supervisors to always check the condition of the warehouse both room temperature and maintain the cleanliness of the warehouse so that the quality of raw materials is always maintained.

Other Basic Events are Basic Events that are directly related to the Cut Division. Cut Division in PT. KOP is the division tasked with preparing the paper to be used for production. The preparation made is to cut the paper according to the requested size. In addition, the Cut Division is also tasked with cutting some finished products. Basic Event "Paper pieces are not right" arises because, in this division, there is a possibility that workers cut raw material paper less precisely (may be tilted or torn) so that it can affect the quality of production results. This may be overcome with proper supervision and possibly training on how to cut well so as not to damage the raw material paper. While the Basic Event "How to stack the wrong paper" arises because after the raw material paper is cut, the papers must be neatly stacked back. The wrong way of stacking paper can damage the paper (such as the ends of the paper rolling). This may be overcome by socialization on how to stack good and correct paper.

4. Conclusion

From the results of the research conducted, it can be known that there are three modes of failure that affect the occurrence of defects in the printing division, namely, "Uncontrolled production results / defects", "Colors are not up to standard", and "There are defects in the image". The failure mode "Uncontrolled/defective production results" is caused by several prominent root causes namely "The standard of each product is different", "No SOP", and "Breakdown Machine". The solution provided is socialization about how to sample a good and correct plan, the inclusion of a sampling plan on the production schedule sheet, and efficient maintenance scheduling. Mode failure "Color is not up to standard" is caused by one of the root problems that stands out which is "Operator lacks training". The solution provided is to design a good training program and make Quality Control Cycle. Meanwhile, the failure mode "There are defects in the picture" is caused by several root problems, namely "Workers lack training", "Paper suppliers", "Lack of checks from QC", "Warehouse conditions are not up to standard", "Paper pieces are not correct", and "How to stack the wrong paper". The solution is correct selection of suppliers as well as more thorough QC checks, more routine warehouse checking, supervision of the Cut Division and retraining of operators if necessary.

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