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Application of Pareto Analysis and Ishikawa Diagram on Bottling Industry: A Case Study Ambo Mineral Water Share Company

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Abstract: ***This research focuses on minimization of defects which causes for product packaging quality of control failure in AMWSC. The purpose of this research is to increase the quality and productivity improvement in the company by minimizing reworks that usually occur in the company product packaging process. Due to this qualitative method has been conducted to provide insights and understanding about the problems. Regarding to this important data was collected from PET production packaging line. In this process the identification of defects which causes failures for quality control product packaging has been conducted. Then, it was analyzed using Pareto Analysis and Ishikawa diagram. As the analysis made for 80/20 rule the production quality of PET on packaging section mostly affected defects by filler centering bell problem 11.3%, Labeler sensor fault 9.95%, Air filler leakage 8.4%, Air conveyor problem 7.79%, syrup ratio problem 7.34%, filler under fill and leakage 7.02%. Then, the root causes of PET product packaging process categorized by cause and effect diagram. Generally, based on the application of Pareto chart and Ishikawa diagram analysis the paper suggests how to handle these issues and minimize reworks or bring down defects rate.***

Keywords: AMWSC, PET, Defects, Pareto Analysis, Ishikawa diagram

1. Introduction

In bottling Industry, it is usual that there will be few rejected products because of most of the manufacturers believed that industry are soft goods and non-repairable defect may occur due to low quality of raw materials or faulty process or employee casual behavior. Furthermore, many of the previous studies have found that consumers are ambiguous about the meaning and understanding of quality. According to Montgomery (2005), quality is one of the most important decision factors in the selection of products and services. Therefore, quality leads to business success, growth, and increases competitiveness, as well as improves the work environment. Thus, as (Gurnani, H. 1999) quality has been identified as the competitive strategy to improve business performance in a global market. However, high quality product is very demanding for the customers (Mc Daniel, C., Lamb, C. W., & Hair, J. F. 2011). Moreover, consumers are easily used to seeing the advertisement from branded companies and having their trust built on it where they think that their products are in better quality (Lew, S., & Sulaiman, Z. 2014). The Ethiopian process industries are facing serious weaknesses and constraints hindering their productivity and competitiveness. One of the processing industries that play an important role in the economic development, especially for developing countries like Ethiopia is Soft Drink Industry. A soft drink is a cold beverage, usually sweet drink, which does not contain alcohol. In Ethiopia, soft drinks are known by the Amharic word "leslassa", by Afaan Oromoo "Lallaafaa", meaning literally "smooth". Soft drink bottling or manufacturing involves five major processes treating water, compounding ingredients, carbonating product, filling product, packaging.

There are two Soft Drinks Industry Share Company exists in our country, Ethiopia. They are MOHA Soft Drinks Industry Share Company and East African Bottling Share Company. Ambo Mineral Water Factory is one of the East African Bottling Share Company. The mineral water bottling plant obtained its name from the town of Ambo where the factory was first established some seventy-five years ago. It is a popular drink in Ethiopia, and has been described as the "oldest modern mineral water" and Ethiopia's "oldest mineral water bottler."

The general objective of the study is to Increase quality control, Productivity improvement, and assurance product Packaging of Ambo mineral water Share Company in order to identify specific problems cause defects by using the application of Pareto Analysis and Ishikawa diagram (Cause and Effect diagram). The major importance of the research is to provide concrete information to the reader about the quality engineering and management in production of bottling industry. It is also important to minimizing defects of product in the AMWSC. Moreover, the organization may benefit from this finding as well as gives them an idea what they need not to do in future for their improved productivity. In addition to that, it could also give a guideline for who is interested to conduct further study in this area.

2. Materials and Methodology

In industries there are variety of problems occurred to reduce the product quality and productivity due to varying degrees of abnormality and inefficiency, which ultimately causes rejection of components. Therefore qualitative method of analysis has been conducted to provide insights and understanding about the problems.

2.1 Study Area

The study area selected for the case study of research is Ambo Mineral Water Share Company (AMWSC). It was located at Sankale, near to Ambo town, 130 km to the west in Oromia region, Ethiopia. This area is comfortable for receiving and shipping of the raw material and products of the company. The environment is good condition for living.

2.2 Data sources, Collection and Analysis

The data required for the case study have been found from Ambo Mineral Water Share Company. The company has two major production lines with six different products.

The data collected through probable interviews and gathering of in-house documentary evidence. A combination technique for data collection has been employed in the research. This comprises with literature review, actual photo taken from the area and interviewed key persons in the company like the respective professionals. The information collected from the personal interviews through oral questionnaires.

The collected data was analyzed with statistical process control tools, which is Pareto Analysis and Ishikawa diagram (Fishbone diagram). These would helpful to minimize the defects and categorize specific problems for improving product quality. There are different statistical process control (SPC) tools available and that can be used for identifying specific problems and obtaining the interrelationship between the variables. Some of them are Histograms, Check sheets, Pareto charts, Cause and Effect diagrams, Scatter diagrams, Control charts etc. These different techniques can be applicable based on their functions, the type of data, their flexibility, ease to use etc. In this research we choose the Pareto Analysis and Ishikawa Diagram (Fishbone diagram) to analyze the product quality. The both the techniques we selected due to their availability, flexibility, ease of use, ease-to-read format and display the importance of data.

2.3. Production line of Ambo Mineral Water Share Company

The company has two major production lines with six different products. These lines are RGB (Reverse Glass Bottle) and PET (Polyethylene Terephthalate). The product of RGB is Original Ambo Mineral water whereas the products of PET are Ambo flavor Jiva, Apple, Pineapple and Lemon. The permissible working design capacity of the first bottling line (RGB) is about 24, 000bottles/hr. but now the actual production is 7, 483bottles/hr. i.e. about one third of the working designed capacity. For the second bottling line (PET) the permissible working design capacity is about 10, 000bottles/hr., but now it is being produce 4,977 bottles/hr. Here it can be seen that the main problem is with the production system. It can decrease the demand responsiveness, lowers the level of performance below the standards and reduce the production output.

2.4. Packaging Process of Ambo Mineral Water Share Company

Product packaging has an important role to the producer in order to give consumer satisfaction and convenience. Therefore, quality control of packaging process becomes curtail to the producer. Packaging is the science, art and technology of enclosing or protecting products for distribution, storage, sale, and use. Packaging also refers to the process of designing, evaluating, and producing packages.

The production process packaging system diagram of AMWSC for RGB and PET production line is not the same. Because both of them achieve their product qualities have their own paths. RGB process packaging system starts from loading, unpacker, bottle washer, filler, labeler, date coder, packer and unloader whereas PET process packaging system starts from preform, blow mold, PET filler, labeler, dryer, date coder, shrink wrapper, stretching wrapper, palletizer and unloader. Generally, the flow diagram of the RGB and PET packaging system summarized as follows respectively.

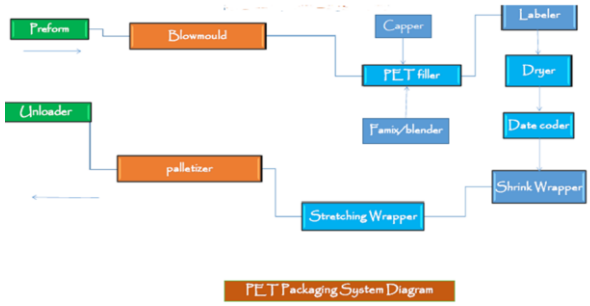

Figure 2.1: RGB Packaging System Diagram of AMWSC

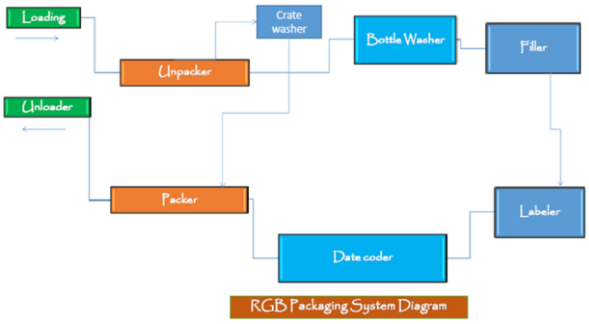

Figure 2.2: PET Packaging System Diagram AMWSC

AMWSC has three sections. They are: Water process flow line, RGB Packaging system flow line and PET packaging system flow line. However, the general flow diagram starts from water process flow line and includes all the Packaging system flow lines. But water process flow diagram starts from the first raw material required which is source of water and other services. The figure below shows that the water process flow diagrams of AMWSC.

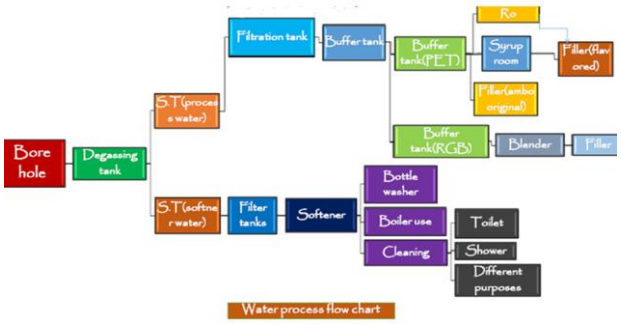

Figure 2.3: Water process flow diagram

2.5. Causes of product defects (Quality Loss) in the Company

2.5.1 Actual Downtime: It may be due to technical failure, machine adjustment, maintenance, or non-availability of inputs such as materials, labor, power.

2.5.2 Shutdown loss: The loss incurred by deliberately shutting down the equipment within the production plan. It also Period during which an equipment, machine, or plant is out of service.

2.5.3 Down time loss: It is unplanned stop that is five minutes or longer. There are two general causes of downtime:

(a) Planned downtime: It is scheduled when upgrades and routine maintenance of hardware and software requires.

(b)Unplanned downtime: It is something when unexpected crash happens to the systems.

2.5.4 Performance Loss: It accounts for time where machinery runs slower than the Ideal cycle time.

2.5.5 Quality Loss: It account for defective parts produced during steady state production. This includes scrapped parts as well as parts that can be reworked.

2.6. Quality Control Sections of Ambo Mineral Water share company

It is concerned with the operational techniques for detecting, recording, and taking actions to eliminate quality problems. However, for AMWSC have three types of Quality Control Sections:

2.6.1 Physiochemical Quality section: Physiochemical Quality section pertaining to both physical and chemical properties, changes, and reactions of the raw materials.

2.6.2 Organoleptic Quality section: It is pertaining to the sensory properties of product ie taste, color, odor and feel. Organoleptic quality sections obtained these aspects of product with the experience of senses ie by the taste, sight, smell, and touch.

2.6.3 Packaging Quality section: The present study has been focused on Packaging quality section because it is essential and critical for the productions of the plant, where many defects found in this section. Therefore, to analyze the quality product, it needs to focus on the packaging process of production line of PET products. Packaging quality section is a coordinated system of preparing goods for transport, warehousing, logistics, sale, and end use. Therefore, after product packaging finished we must have to full fill the Closure and Corky fit, Labeling should be okay and Data coder must be visible

Based on the identification and interview with the packaging quality section manager of AMWSC, the packaging standard demanded by the customers can be Packaging is not dirty, Packaging is not leak, Lide is not defect and Carton box is not leak
Therefore, Packaging is one of the steps of the planning, creating, manufacturing, wrapping, boxing, or bottling of goods for consumer in the company. It is the most significant in bottling industry. Different types of faults or defects arise in packaging section which should be reduced to maintain the required quality of product. Therefore, some types of defects, number of defects per day and checked products per day of the two months are recorded to analyze their priorities.

Table 1: Recorded Type of Defects and Amount of product defected in Packaging process of PET products of AMWSC for the past two months (July to August 2018)

Date	Types of defects	No of Defected products	Checked products
02/07/2018	Air Compressor Shortage	13	139
05/07/2018	Air conveyor problem	76	139
07/07/2018	PET bottler rinse clamp breakage	45	100
10/07/2018	Filler air leakage	80	8352
11/07/2018	Filler centering bell problem	108	3852
13/07/2018	Syrup Ratio Problem	70	1335
14/07/2018	Blender product tank filter fault	40	1166
16/07/2018	Blow molder short stoppages	15	1077
17/07/2018	Preform conveyor problem	13	1007
18/07/2018	Closure Stuck In Capper Head	17	122
20/07/2018	Stopper Sensor Fault	40	322
21/07/2018	Glue Heating Temperature Getting Low	30	3010
23/07/2018	Labeler Short Stoppage	37	3479
24/07/2018	Labeler Glue Line Cleaning & Adjustment	25	3000
24/07/2017	Glue Drained Outside Of Tank &Adjustment	47	2105

26/07/2018	Unwritten date coder	37	4227
27/07/2018	Date coder printing fault	50	2753
28/07/2018	Full Bottle Conveyor Fault	26	367
29/07/2018	Shrink Wrapper Temperature Drop Down	20	4886
30/07/2018	Speed Loss Due To Lack Of Pallet	63	427
01/08/2018	Guide Adjustment Rinse Infeed	20	159
03/08/2018	Washer Finger Griper Rinse	30	100
04/08/2018	Filler Under fill & Leakage Problem	67	4152
05/08/2018	Filler Safety Valve Problem	20	3852
08/08/2018	Blender/Carbonator Problem	50	1320
12/08/2018	Syrup Pump Leakage	60	1335
14/08/2018	Blow Molder Compressor Failure	15	1077
15/08/2018	Blow Molder Short Stops Due To Cooling Problem	65	10, 707
17/08/2018	Labeler Sensor Fault	95	3947
19/08/2018	Short Stoppage Of Labeler Adjustment	29	2345
22/08/2018	Labeler Roller Bearing Damage	30	2345
23/08/2018	Date Coder Short Stoppage	28	1489
25/08/3018	Date Coder Printing Fault	58	4227
26/08/2018	Short Stoppage Of Date Code Adjustment	31	1532
27/08/2018	Full Bottle Conveyor Fault	26	387
29/08/2018	Shrink Machine Adjustment	60	6092
30/08/2018	Shrink Wrapper Problem	48	4287
31/08/2018	Shortage Of Orange Closure	34	437

Table 2: General Defect category, their numbers and percentage defectives in the packaging PET products of AMWSC

Types of Defects	No. of PET packaging product defects	Total (%)	Cumulative (%)
Filler air leakage	80	8.4	8.4
Syrup ratio problem	70	7.34	15.74
Date coder printing fault	58	6.08	21.82
Speed loss due to lack of pallet	63	6.6	28.42
Filler under fill and leakage	67	7.02	35.44
Labeler sensor fault	95	9.95	45.39
Blow molder short stops	65	6.8	52.19
Shrink wrapper problem	48	5.03	57.22
Syrup pump problem	60	6.29	63.51
Unwritten date coder	37	3.88	67.39
Stopper sensor fault	40	4.2	71.59
Filler centering bell problem	108	11.32	82.91
Bottler rinse clamp breakage	45	4.72	87.63
Blender tank filter fault	42	4.40	92.03
Air problem conveyor	76	7.97	100
TOTAL	954	100	100

2.7. Pareto Analysis Diagram

Quality problems appear in the form of loss (defective items and their cost). It is extremely important to clarify the distribution pattern of the loss. Most of the loss will be due to a very few types of defect, and these defects can be attributed to very smaller number of causes. Thus, if the causes of these vital few defects are identified, we can eliminate almost all the losses by concentrating on these particular causes, leaving aside the other trivial many defects for the time being. By using the Pareto diagram, can solve this type of problem efficiently. It is also considered as one of the seven statistical quality tools applied frequently to break a problem into several parts and identify which parts directly affects the issue and which parts doesn't.

Pareto chart was constructed based up on data collected (Tables 1 and 2) and to identify the most common defect as shown in the figure 2. Pareto chart is a special type of bar chart where the plotted values are arranged from largest to smallest. It is used to highlight the most frequently occurring defects, the most common causes of defects, or the most frequent causes of customer complaints. Juran (in 1940) applied Pareto analysis for separating the "vital few" from the "trivial many". It shows the most frequent reason for rejection of raw materials. He also the first to point out that the Pareto Principle could be used to quality improvements. In this Case study to identify the main problems which cause frequent defects of PET product packaging process of AMWSC, a two months' data has been collected (viz., July and August, 2018). The actual rejection (Tables 1 and 2) is grouped in their respective type of defects.

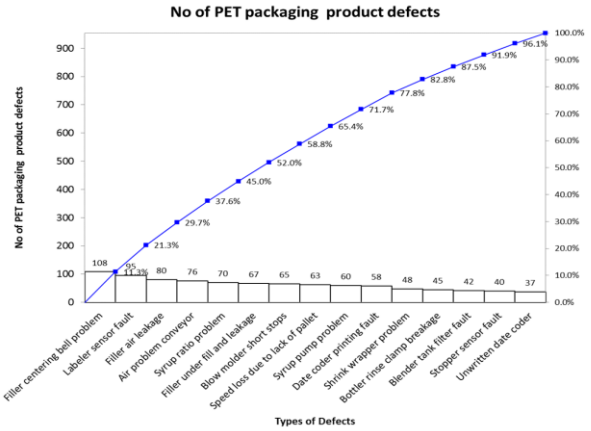

Figure 3.6 Pareto chart for some types of defects observed for the past two months

Some of the data of PET product rejected while it is on process for packaging collected by check sheet has been plotted in Pareto chart and found the 20% Rejects that causes of 80% wastes. The 20% Rejects are Filler centering bell problem, Labeler sensor fault, Filler air leakage, Air conveyor problem, Syrup ratio problem, Filler under fill and leakage, Blow molder short stops, Speed loss, Syrup pump problem, and Date coder printing fault etc. According to the above Pareto diagram it shows us the vital few of AMWSC PET Product packaging was identified. The quality production of this section is mostly affected by Filler centering bell problem which covers overall 11.3% defects. Consequently, it also affected by the Labeler sensor fault 9.95%, Air filler leakage 8.4%, Syrup ratio problem 7.34%, Air conveyor problem 7.79%, filler under fill and leakage 7.02%, Blow molder short stops 6.8%, Speed loss 6.6%, Syrup pump problem 6.29%, date coder printing fault 6.08% defects. These ten types of defects are the "vital few" factors that cause 77.8% of the total rejection observed from the result in the packaging process of AMWSC PET product. Other reasons for defects are shrink wrapper problem, Bottler rinse clamp breakage, blender tank filter problem, unwritten date coder etc. Figure 3.6 shows the types of defects and percentage of each type of factors for defects in the process with a line of cumulative percent.

2.8 Brainstorming and Ishikawa diagram

Potential causes were identified by brainstorming which is considered to be an effective technique for identifying the categories of causes utilizing an informal approach to problem solving with lateral thinking. Brainstorming is a technique used to elicit a large number of ideas from a team using its collective power. There are specific steps that are recommended prior to a brainstorming session as to clarify the subject of brainstorming session. Moreover, many rules should be observed by the participants to ensure that participation is not inhibited. These rules are as follows:

- Do not criticize anyone's ideas, by word of gesture.
- Do not discuss any ideas during the session, except for clarification.
- Do not hesitate to suggest an idea because it sounds "silly".
- Do not allow any group member to present more than one idea at a time.
- Do not allow any group to be dominated by one or two people.
- Do not let brainstorming because a gripe session.

The data analyzed by the cause-and-effect diagram usually comes from a brainstorming session. Brainstorming rules were taught these team members at company as to establish the cause-and-effect diagram. Cause and Effect diagram is a schematic tool that resembles a fishbone that lists causes and sub-causes as they relate to a concern. According to Bilsel (2012), Ishikawa or Cause and Effect diagrams are popular tools to investigate and identify numerous different causes of a problem and used as a guideline to allocate resources and make necessary investments to fix the problem. This is a casual diagram that shows the causes of a specific event. The causes are grouped in categories to identify the sources of variation. A figure 3.7 shows the cause-and-effect diagrams for the visual defects and physical defects. The root causes of these defects can be grouped into machine operator/man, work method, material, measurement, Mother Nature. Generally, Ishikawa diagram, also known as Fishbone diagram or Cause-and-Effect diagram which establishes a diagnostic relationship between potential causes of a problem leading to a particular effect. Therefore, the root causes of the PET product packaging process for those critical issues are discussed below by cause and effect diagram.

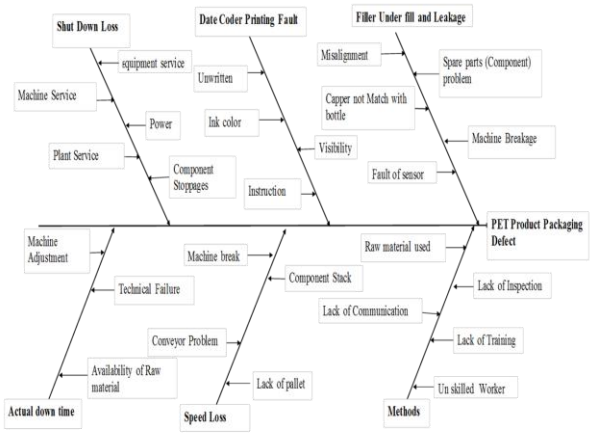

Figure 3.7: Cause and Effect Diagram (Fishbone diagram)

3. Results and Discussion

The products quality at AMWSC has been maintained by implementing quality control activities in three stages which are Control of packaging raw material, Control of packaging process and Control of product packaging. The case study research focused on the causes of defect PET product packaging process and on their control (minimization of defects). The cause of defect in packaging process of PET product activities are categorized in to two, namely General problems and Specific problems. General problems related to raw material, Worker and machinery involved in the production process, while specific problems are related to the production process. Based on the figure 3.7 the fishbone diagram made to determine main factors which would be impact to defect in PET product packaging processes.

According to 80/20 rule of Pareto analysis, in PET product packaging process the defects are found that Filler centering bell problem ranked as first 11.3%, Labeler sensor fault ranked as second 9.95%, Air filler leakage is ranked as third 8.4%, Air conveyor problem ranked as fourth 7.79%, Syrup ratio problem ranked as fifth 7.34%, filler under fill and leakage ranked as sixth 7.02%, Blow molder short stops ranked as seventh 6.8%, Speed loss ranked as eighth 6.6%, Syrup pump problem ranked as ninth 6.29% and date coder printing fault ranked as tenth 6.08%. These major defects contributed 77.8% of the overall rejection. Therefore, it is obvious that most of all rejections (defects) will decrease, if the causes for major defects are reduced. The CED methodology has been used to know top priority defect type and identify the root causes in different PET product packaging process steps. Application of CED Diagram in AMWSC creates new chances for achieving a better quality of products (final and intermediate) and higher production effectiveness. It can be accomplished by extraction and visualization of the knowledge hidden in the recorded past data. However, some best practices to control defect generation within Company were suggested as - make the workplace clean and Place quality control system in proper place. This refers that sufficient number of checkers, trained checkers, and analysis of reports take action based on the quality check reports. Therefore, set standard operating procedures (SOP) for each task performed by your employees and for quality control system for each of department. The defective percentage reduced after implementing the given suggestions is shown here below.

Table 3: Recommended Corrective Action for PET Product packaging defects

Defect Types	Rank	Root Cause	Corrective Action
Filler centering bell problem	1	Misalignment Capper not match with bottle Fault of sensor Component problem	Before using it check whether it is lined or not Check as it is prepared with its standard and problems seen in the production line
Labeler sensor fault	2	Components stops function Adjustment error	Check each components and adjustments required technically
Filler air leakage	3	Fail of connection between filler and air conveyor Misunderstanding and Misalignment	Technically connect the filler and air conveyor to avoid the leakage. Make correct alignment and do without any complexity with the technicians.
Air conveyor problem	4	Components stack and close	Use automatic machine which report area of the problem to solve quickly.
Syrup ratio problem	5	Unskilled worker Error measurement Miss instruction	Give a chance to work with professionals and use correct measurement with attentional. Before doing something read the instruction for a minimum 2 times.
Filler Under fill and leakage	6	Filler problem Component connection Conveyor problem	Check before starting all filler components and use automatic machine to report the problem. Use additional filler line rather than stop work.
Blow molder short stops	7	Low and high temp. Material used Error Adjustment	Set up the temperature as its standard and use materials fit the standard temperature. Check adjustment of the machine with technical person
Speed loss	8	Lack of pallet Machine break Technical failure	Demand enough pallet Check each machine speed as their standard range and install as their requirement.
Syrup pump problems	9	Liquid and solid waste materials	Clean clearly all the pumps used to distribute syrups and others.
Date coder printing fault	10	Unwritten Ink color Miss instruction Visibility	Identify whether all materials are prepared correct or not for date coder printing. Use instruction of the company for date coder with clear visibility and full of color.

4. Conclusion

The productivity can be increased by adopting new practices and reducing the defects. The present case study includes Pareto chart to identify the priorities of problems and solved based on 80/20 principle. It applies at various levels of diagnosis ie finding the defects, finding the symptoms of the defects and finding the causes of the symptom. Additionally, Fishbone diagram (Ishikawa diagram) represents a model of suggestive presentation for the correlations between an event (effect) and its multiple happening causes. Some of the benefits of constructing a fishbone diagram are it helps to determine the root causes of a problem or quality characteristics, which encourages group participation and group knowledge of the process. The qualitative analysis has been conducted by the use of Pareto chart and fishbone diagram, which would provide insights and understanding about the problems. The area selected for the case study is Ambo Mineral Water Share Company, Ambo town at Sankale place. The data was taken from flow diagram of the process. The collected data was analyzed with Pareto Analysis and Ishikawa diagram (Fishbone diagram) to minimize defects and categorize specific problems for improving product quality. Hence the 20% rejects which affects the quality production of PET product packaging section are Filler centering bell problem which covers overall 11.3% defects and it also affected by the Labeler sensor fault 9.95%, Air

filler leakage 8.4%, Syrup ratio problem 7.34%, Air conveyor problem 7.79%, filler under fill and leakage 7.02%, Blow molder short stops 6.8%, Speed loss 6.6%, Syrup pump problem 6.29%, date coder printing fault 6.08%. These are the "vital few" factors that cause 77.8% of the total rejection. However, the root causes of the PET product packaging process for those critical issues are discussed. Generally, some best practices to control defect generation within Company and to improve packaging quality product of PET recommendations have been given.

5. Other Recommendations

Equalize the data recorded in the company is not clear to understand with professionals of same expert. This is because working time of the company has three shifts and when different professionals join the shifts they cannot understand each other.

The data recorded is not manual instead they used software which is called SAP. Because of this the data is not recorded automatically as the problems have been seen. However, they record the data on their own notes and record on the software after some hours, days, weeks or months.

Another problem in the company is some workers of the company are not fully responsible for their professionals, when some problems happened they do not take quick measurements. So the company should be record all the required information at each department with the use of automatic machines and reserve production lines where it is sensitive to response quickly.

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