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Hybrid Analytical Hierarchy Process and Continuous Improvement Methodology to Enhance Sustainability: A Case Study on a Beverages Industry

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Abstract. Aims of sustainability in the industries are to create manufactured products, which use processes and practices that maximize profits, reduce waste, minimize resource use, minimize negative economic and environmental impacts, and are safe for consumers and employees. These aims can achieve through continuous improvement methodologies (CI). Therefore, CI have emerged as a major part of the sustainability answer. The purpose of this research is to investigate the application of hybrid methodology consist of analytical hierarchy process (AHP) and continuous improvement methodology in the beverages industry, and to evaluate the impact of this methodology on sustainability. The proposed methodology framework consists of five steps (Identity, Measure, Analyze, Prioritize, and Implement). This research highlights some of the important elements that should be considered when using AHP and CI as a contributor toward greater environmental sustainability in the beverages industry. The results show that the main causes of waste relate to machines, materials and others cause. This paper present observations and experiences from the application of AHP and CI at a beverages industry, with the aim of bringing out pertinent factors and useful insights that help us to understand how AHP and CI can contribute toward greater sustainability in this industry type.

1. Introduction

The environment of beverages industry is very competitive. The industries seek continuously to find a new improvement methodology so as to sustain and enhance competitive advantage. Today, one of the hardest obstacles that industries face is obtaining success through methodologies that are appropriate and that support of sustainability [1]. The concept of sustainability refers to the protection of resources and characteristics that allow the company to outperform its competitors in the same field [2]. "Green thinking is thinking lean" [3]. This is no difference between two concepts in manufacturing, the term green manufacturing, often utilized interchangeably with the notion of sustainability [4]. "Sustainable production": A global challenge [3]. In recent years, the use of new methodology to solve the challenge of sustainability has been explored such as continuous improvement methodologies [5]. CI culture is factor of important sustainability factors [6]. CI from lean six sigma (LSS) viewpoint is a culture of sustained improvement with continuously focuses on searching for root causes of problem, sources of waste and variation in order to identifying ways to reduce and in the end eliminate them [7],

and improving quality, performance, speed and costs [8], minimize negative economic and environmental impacts, and are safe for consumers and employees [5], naturally leads to more environmentally sustainable operations [3]. LSS methodology has emerged as an essential piece of the sustainability answer [5]. LSS principles are becoming popular use in sustainability studies in practice and research [9]. There are three main focus areas for sustainability which are economic, social and environmental areas [7]. In terms of the economical view of the company, sustainability points out to constant value creation and addition and works in line with the LSS principle [10]. Because variation and waste may cause several problems, AHP was used to prioritize areas of focus. AHP introduced by Saaty is called Saaty's AHP, which is an approach for system analysis by splitting the whole obstacle into small obstacles [11][12]. AHP is a "powerful multiple criteria decision making" approach which has been used to solve the decision problems[12]. It is used in various fields, and widely decision-making approach in industrial problems and applications [13] [14] [15] [16]. In many applications of industrial engineering, the final decision is based on the assessment of number of alternatives in terms of number of criteria (17). There are lacks of a research that discuss or explores that hybrid AHP with (LSS) in same methodology in order to enhance sustainability in manufacturing sector such as beverage industry. Based on these premises, the ultimate objective of this paper is twofold. First, the intention is to create methodology in order to hybrid between lean six sigma and analytic hierarchy process bases on the setting of the Alforat factory. Second, based on the methodology that consist of several tools, that identify, analyze, and prioritize of major causes of waste and non-added value activates generation, then some proposal solutions to enhance sustainability will be suggested.

2. Basic Theory

2.1. Continuous Improvement (CI)
Today, some companies are utilizing the continuous improvements in order to realize operational excellence and service are a result of the increase economic profit and competition [18]. Process improvement methodologies, Total Quality Management, Lean and Six Sigma as the best methodologies used by various industries around the worldwide [19]. The purpose of Lean Six Sigma is to help companies to get continuous improvement [18]. Lean Six Sigma is a methodology for process optimization that starts from the voice of the customer VOC and then identifies the most effective method to reach customer satisfaction, by reducing the variables in each stage of the process, in both the cases of production of goods, and supply of services [20]. LSS methodology is to achieve quality improvement and waste reduction, and consist of two methods of quality improvement which are Lean manufacturing and six sigma [21]. Philosophy of lean manufacturing is to maximize create value and minimizing waste in order to create a production flow and improve value-added products to customers [22] [23]. On the other hand, Six Sigma focuses to achieve high levels of quality and low levels of process variability [24].

2.2. Analytic Hierarchy Process (AHP)
AHP includes three basic stages are hierarchy design , the procedures of prioritization , and calculation of outcome, in order to details a complex multi-criteria decision-making problem into a hierarchical structure [25]. AHP uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives and designed to solve a complex multi-criteria problems [26]. On the other hand, problems will be in decision making according to on a relatively simple solution hierarchy, and can find the best decisions by synthesis of the outcome of pairwise comparison matrices[21]. Applications of AHP have been researched in variety areas such as manufacturing, projects planning, and serves sector [25]. However, many industries utilize AHP as it is valuable for making decisions for selecting or prioritizing the alternative [27].

3. Methodology
This study is a case study and a hybrid approach is used, where the AHP and Lean Six Sigma are employed together for attempt to identified, analyze and prioritize the major causes of waste and non-added value activates that generated in the industrial environment (Beverages - soft drinks) and some

proposal solutions will be suggested to enhance sustainability. Figure 1 shows the proposed methodology used in present study. The proposed methodology has five steps, where each step consists of several tools. Collection of data includes data related to products, defects rate, machine, workforce, materials, cycle production time, setup time, environment, capacities and capabilities of the production and process flow. Data collection is carried out based on observation in the production line, discussion with the experts, supervisor, manager, and operator of the Alforat factory. The first step begins with the identification of the factors causing the high waste in production line. Establish performance metrics in order to measurement of waste carried out in the next step, and Defect Per Million Opportunity (DPMO) is used to measure defect of product. Analyze data to identify sources of variation and waste, and then identify root causes. Additionally, because variation and waste may cause several problems, analytic hierarchy process was used to prioritize areas of focus. Evaluate and develop potential solutions and implement selected alternatives are carried out in order to enhance sustainability by reduce production waste and improve production performance.
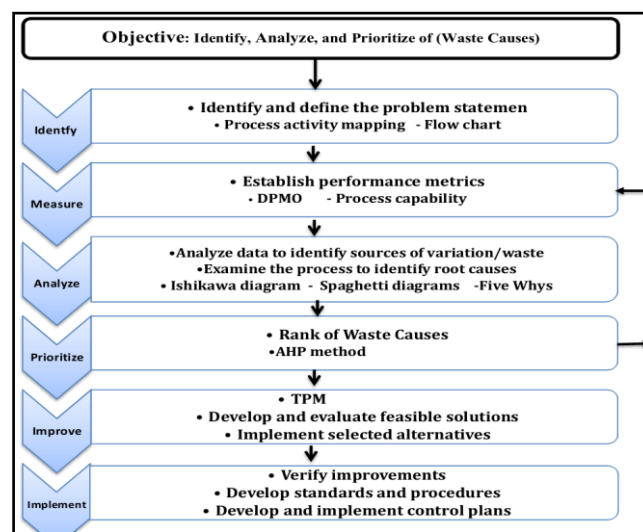

Figure 1. Framework for proposed methodology

Using AHP in solving a decision problem, there are basic steps involved in AHP approach are [28] [29]:

1. Identify and define the problem and its objective specified.
2. Decision-makers gave scale (1-9) on each criterion and sub-criteria data were collected for support the AHP objective.
3. Construct the problem into a hierarchical structure with decision elements, decision-makers are asked to make pair-wise comparisons between criteria, and sub criteria utilizing a nine-point scale, as show in Figure (2).
4. Construct a set of pair wise matrix.
5. Calculate the consistency index (CI) for each matrix by the equation:

$$CI = (\lambda\ max - n) / (n-1) \tag{1}$$

Where: λ max. = Eigen value (λ) is obtained from the summation of each element of eigen vector (priority vector) and the sum of columns of the matrix, and (n= Number of criteria, or sub-criteria).

1) Calculate the consistency ratio (CR) by using the equation:

$$CR = CI/RI \tag{2}$$

Where: The value of RI depends upon the size matrix, Table (1) show values of (RI) for matrices of order (n) of 1 to 13.

Table 1. Random index of analytic hierarchy process (AHP)

Order n	1	2	3	4	5	6	7	8	9	10	11	12	13
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56

2) Rating and prioritize each criterion by the weight. The result represented which criterion was more important than the others, including the weight on each evaluation criterion.
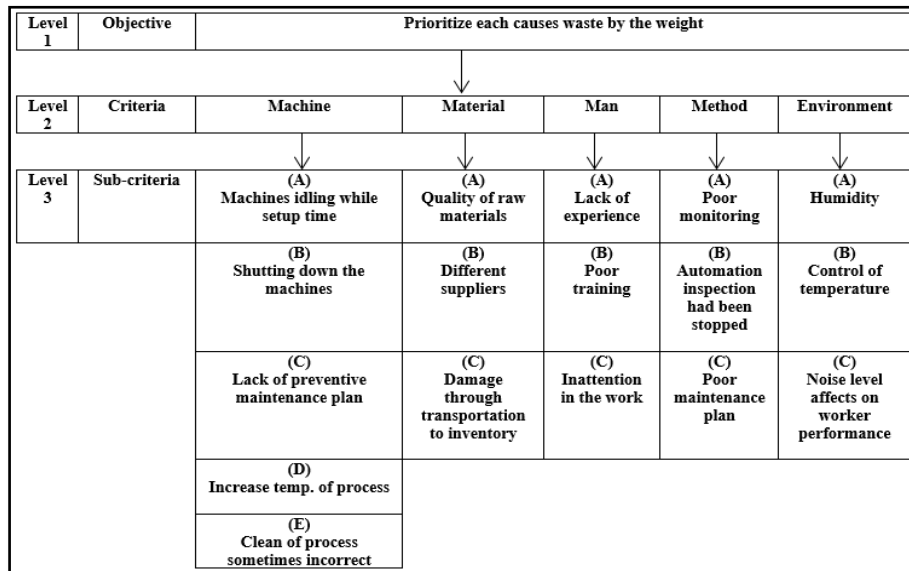
Figure 2. Hierarchical structure of waste causes

4. Result and Discussion

4.1. Identify

This step defines the objective and boundaries of the study. Information about the present processes was documented and collected in order to define the nature of the existing problems. Data collection includes data regarding production quantities, defect rate, and setup time of the production line and process flow. The production line is produced several types of flavors, where the volume of cans is (250 ml). Data is collected based on observations in the production line, and the results were discussed with the supervisor, operator, and manager of the Alforat factory in company (AAA), as shown in Table 2. Flow chart represents the main processes in the beverage industry, as shown Figure 3. The inputs of materials through different manufacturing processes are Cans, Cap (cover), Base carton, Nylon sheet, Printing ink, CO_2 gas, Sugar, Flavor and juice. Suppliers of materials are different according to the country of Origin. Products are licensed by (P.C. I.C) of specifications for raw material, suppliers, syrup recipe, and allowable percentage of defects (less than of 1%).

Table 2. Detailed production data

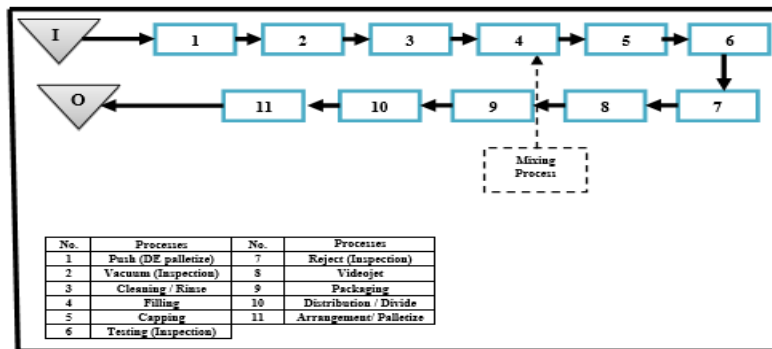| Month	January	February	March	April	May	June	July	August	September	October	November	December
Production (packs)	417194	415326	263037	296419	716728	384772	259638	586527	963423	744062	113158	61955
Defect (packs)	4825	3603	2578	3016	7884	3549	2767	6852	11988	6760	934	420
Defect rate %	1.16	0.87	0.98	1.02	1.1	0.92	1.07	1.17	1.24	0.91	0.83	0.68

Figure 3. Flow chart of processes

Good quality, quantity as (demanded) within at the right time are customer requirements.

Process activity mapping is created in order to have an insight into the current state of the processes, which gives a closer look at the process so that opportunities for improvement can be identified. According to process activity mapping, DE palletize, vacuum, and divider processes are non-value-added processes with (27.2 %). Cleaning, test, reject, and video jet are non-value-added processes but necessary with (36.4%). While four processes are value added, which are filling, capping, package, and palletize with (36.4%). In addition, processes activity map shows three preparations time through the work. Preparation one is (35 min.) include setup time of DE palletize and palletize processes. Preparation two is (20 min.) include breakdown of capping process. The last preparation time is 35 min which include setup time of valve of fill process. The preparations time cause to stop working, and lead to increase cycle time of production. Any delay during production processes is a waste. On the other hand, excessive transportation for products is a waste. Types of waste identification during production process are shown in Table 3. The type of waste will be analyzed in order to identify the root causes of high waste in the analyze step.

4.2. Measure

According to results of the observations, there are different types of waste identified are defects, idle/waiting time, excessive transportation, inventory, human experiences. The most popular and effective waste are defects and idle / waiting time, which will be analyzed. According to table (2) the total output, defect quantity, defect rate. Furthermore, these data were used to calculate defect per million opportunities (DPMO) and sigma level (S.L) for each month from January to December 2014. Sigma level can be calculated and other values by DPMO program [30]. Therefore, lowest sigma level was 3.74 for the month september and the highest sigma level was 3.97 for the month december. The research will be focused on the month september. This data will used to identify the problem that cause to highest defect rate and other problems.

Table 3. Types of waste

No.	Type of waste	Details
1	**Defects**	Different sources of the raw materials, and variation in raw materials, concentrates and syrup level, specification of raw materials, increase temperature, and taste will affect the product quality and this may lead to increase the defect rate. This is because the specific tolerance of raw materials is crucial to product quality and the production line processes.
2	**Idle/waiting time**	Setup time, breakdown, and maintenance time are crucial to the machine. Any delay time is a type of waste, and not added value. Time ineffective is a waste.
3	**Excessive Transportat**	If the product is in movement and has not been addressed, there is no value-added. Transport of products to more warehouses.

	ion	
4	**Inventory**	The company production strategy is making to stock. Unnecessary storage of products or raw materials is considered a waste of money.
5	**Human experiences**	Unskilled workers. Lack of training.

4.3. Analyze

Aim of this step to analyze and identify the major causes of waste types, and determine the significant processes that causing the waste. The five major factors of the defect source are machine, methods, man, environment, and materials. The ishikawa diagram is used to identify and analyze the factors that cause the occurrence of waste. On the other hand, several discussions and brainstorming with supervisor, manager, technical worker are doing directly related to the process, as shown in Figure 4.
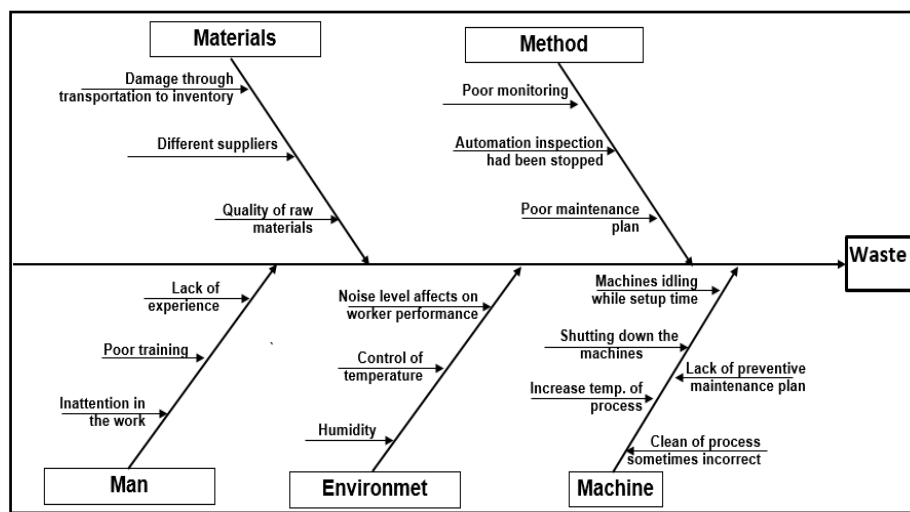

Figure 4. Ishikawa diagram for analyzing the factors that cause waste

According to Figure 4 there are various factors (criteria) that could cause waste types, such as, machine, material, man, method and environment. In addition, there are several sub-factors (sub-criteria) is the clarification of each of the main factors. The normal way to construct ishikawa diagram is achieved through brainstorming and discussions with the managers, supervisors, and operators of the production line. After doing this diagram, can asked them which causes they thought created more waste, from their point of view and years of experience, the machines are major reason cause of high waste rate, materials and then other factors. From this data, three types of processes will be identified that lead to defective cans. High defects are due to syrup variation inside cans (242.5 to 245 ml) in the filling process. This is may be due to valve failure or close off due to poor sanitation, or increase in syrup temperature due to downtime of filling machine. Defects formed in capping process between cans and cap (due to incompatible cans and cap (cover) dimensions, or poor raw materials specifications due to different suppliers. Rest of defects is due to can distortion resulting from increase in internal pressure inside can and increasing test process temperature that may also lead to this type of defect. In order to identify the root causes of waste types, five whys analysis tool will be used. This tool is used to analyze root cause of processes that causes waste, as shown in Table 4. The table shows how the tool was used to reach to the roots cause of the main causes found in the previous steps (measure and analyze) of the methodology, and create proposed solutions and implemented through the improve step on how to address the major causes.

Table 4. Root causes of waste types

Factor / Cause	**Fill process (Shutting down) Close off valve**	**Test process (Increase temperature)**	**Capping process (shutting down)**	**Man**	**Materials**	**DE, Palletize Process (Waiting time)**
Why 1	Viscous syrup	Leak in hot water pipes	Failed seaming chock	Poor monitoring by workers	Raw materials of different suppliers.	Long process set-up times
Why 2	Poor cleans.	Failure sensor.	Incompatibility between cans and caps.	Poor experience.	Specified supplier according to company requirements.	Sudden electrical power breakdown.
Why 3	Work doesn't standardize	Poor calibration	Different dimensions	Poor training.		No backup power supply available.
Why 4	Poor worker experience.	Poor maintenance.	Different raw materials suppliers.	No documented instructions to follow.		Unleveled scheduling
Why 5	Poor training					Poor Communication

After doing this table, there is type of waste that occur when the products and materials transportation to several stations of warehouses, and no doing processed then not added value to the customer, as shown in Figure 5.
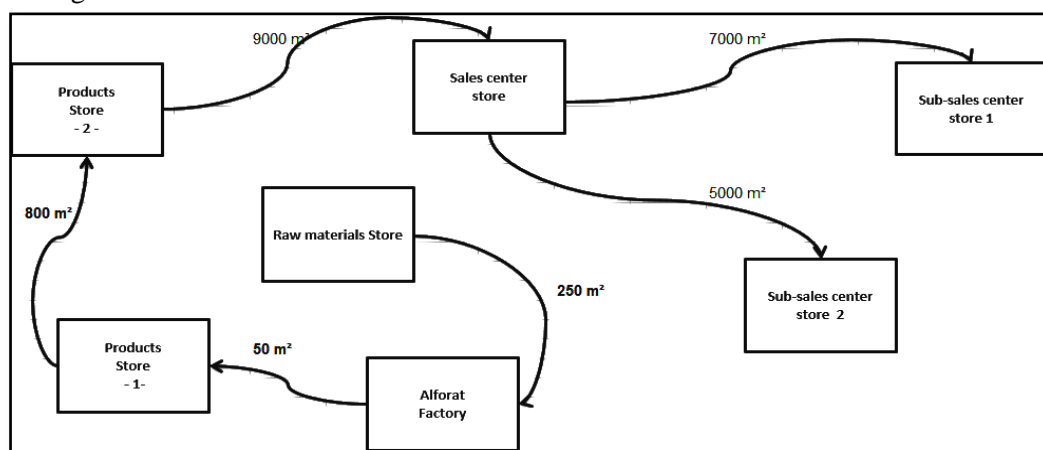
Figure 5. Spaghetti diagrams for analyzing cause of waste

There are some causes that lead to generate this type of waste are poor plant layout, poor understanding flow of the process for production, long lead times, large batch sizes, and storage spaces is large.

4.4. Prioritize

Analytic Hierarchy Process was applied to prioritize the major causes that lead to waste generation in previous steps. According to the ishikawa diagram the major factors that will be ranked that related to their impact on the generation of waste are machine, method, environment, material, and man. The AHP method was used in order to rank these factors as shown in Table 5.

Table 5. Calculated weights of the major causes

Major Criteria (Causes)	Material	Man	Machine	Method	Environment	Priority Vector (Weight)
Material	1	3	0.33	5	7	0.26
Man	0.33	1	0.2	3	5	0.134
Machine	3	5	1	7	9	0.506
Method	0.2	0.33	0.14	1	3	0.066
Environment	0.14	0.2	0.11	0.33	1	0.034

λ max. = 5.31968, CI = 0.07992, and CR = 7.13% < 10% (acceptable)

The relative weights between the major factors (causes) that compared between them are shown by the priority vector, where machine is 50.6%, material is 26%, man is 13.4 %, method is 6.6 %, and environment is 3.4 %. From view point of decision makers of the company was noticed that machine is the number one cause of waste, then material, and then others. The major causes were branched to sub-causes as shown on the ishikawa diagram in Figure (4). Similarity, the sub-causes weight was calculated by using the AHP method, as listed in the following tables. There are five sub-causes for machine (A) Machines idling while setup time, (B) Shutting down the machines, (C) Lack of preventive maintenance plan, (D) Increase temp. of process, and (E) Clean of process sometimes incorrect, as listed in the Table 6.

Table 6. Calculated weights of the sub-causes (Machine)

Sub-criteria (Machine)	A	B	C	D	E	Priority Vector (Weight)
A	1	2	4	5	6	0.444
B	0.5	1	3	4	5	0.294
C	0.25	0.33	1	1	3	0.118
D	0.2	0.25	1	1	2	0.094
E	0.16	0.2	0.33	0.5	1	0.05

λ max. = 5.08, CI = 0.02, and CR = 1.78% < 10% (acceptable).

The relative weights between the sub- causes that compared between them are shown by the priority vector, where (A) is 44.4 %, (B) is 29.4 %, (C) is 11.8 %, (D) is 9.4%, and (E) is 5%.

Similarity, there are three sub-causes for man (A) Lack of experience, (B) Poor training, (C) Inattention in the work, as listed in the Table 7.

Table 7. Calculated weights of the sub-causes (Man)

Sub-criteria (Man)	A	B	C	Priority Vector (Weight)
A	1	3	5	0.636
B	0.33	1	3	0.257
C	0.2	0.33	1	0.107

λ max. = 3.048, CI = 0.024, and CR = 4.1% < 10% (acceptable).

The priority vector shows relative weights among the sub- causes that compared between them, where (A) is 63.3 %, (B) is 25.7 %, (C) is 10.7 %.

Similarity, there are three sub-causes for method (A) Poor monitoring, (B) Automation inspection had been stopped, (C) Poor maintenance plan, as listed in the Table 8.

Table 8. Calculated weights of the sub-causes (Method)

Sub-criteria (Method)	A	B	C	Priority Vector (Weight)
A	1	0.2	0.33	0.107
B	5	1	3	0.64
C	3	0.3	1	0.253

λ max. = 3.0184, CI = 0.009, and CR = 1.5% < 10% (acceptable).

The relative weights between the sub- causes that compared between them are shown by the priority vector, where (A) is 10.7 %, (B) is 64 %, (C) is 25.3 %. Similarity, there are three sub-causes for materials (A) Quality of raw materials, (B) Different suppliers, (C) Damage through transportation to inventory, as listed in the Table 9. The priority vector shows relative weights among the sub- causes that compared between them, where (A) is 55.7 %, (B) is 32 %, (C) is 12.3 %. Similarity, there are three sub-causes for environment (A) Humidity, (B) Control of temperature, (C) Noise level affects on worker performance, as listed in the Table 10. The priority vector shows relative weights among the sub- causes that compared between them, where (A) is 13.7 %, (B) is 24 %, (C) is 62.3 %.

Table 9. Calculated weights of the sub-causes (Materials)

Sub-criteria (Materials)	A	B	C	Priority Vector (Weight)
A	1	2	4	0.557
B	0.5	1	3	0.32
C	0.25	0.33	1	0.123

λ max. = 3.024, CI = 0.012, and CR = 2.1% < 10% (acceptable).

Table 10. Calculated weights of the sub-causes (Environment)

Sub-criteria (Environment)	A	B	C	Priority Vector (Weight)
A	1	0.5	0.25	0.137
B	2	1	0.33	0.24
C	4	3	1	0.623

λ max. = 3.023, CI = 0.012, and CR = 2.1% < 10% (acceptable).

Based on results of matrices tables, there are high nine sub-causes that lead to waste generation as follows:
1. Automation inspection had been stopped.
2. Machines idling while setup time.
3. Shutting down the machines.
4. Poor maintenance plan.
5. Lack of experience.
6. Noise level affects on worker performance.
7. Quality of raw materials.
8. Different suppliers.
9. Poor training.

Based on the results for causes of waste and variation in the previous steps, these issues were considered in the improvement step to be addressed according to proposed solutions.

4.5. Improve

The purpose of improve step is solve the problems and minimize the prospect of recurrence of its. Therefore, proposed improvements solutions are developed to solve the problems that lead to waste generation and defects. The proposed improvements solutions consist of:
1. Apply technique of total productive maintenance (TPM)
   TPM is a complete technique for reducing stoppages of machine because of failures. Two main levels to apply of TPM. Autonomous maintenance is the basic and first level. Operators, and workers every day will be clean the machines and accomplish of basic maintenance such as valves state, control panel, checking of pressure and temperature of syrup, and other parts of the machine. Second level, perform a preventive maintenance program and data collection by supervisors that related to stopping the machines, and then identify of a fixed frequency for replacing or maintaining critical parts of the machines. Regular maintenance must be carried out for all processes. Therefore, scheduled maintenance will improve processes performance and reduce machine stoppages.
2. A contract with a new supplier has all of raw materials especially (caps, cans) in order to avoid the different in specification of raw materials that lead to defect in products. Incompatibility between cans and caps will be increase defect rate.
3. It is necessary to redesign the seaming chock in capping process. Tolerance between the seaming chock and cover of cans can be modified to reduce the potential wasted products.
4. Maintenance time required to replace the mechanical valve is estimated from 25 to 35 minutes. This increases cycle production time, and then causing increased syrup temperature, leading to increase defect rate. In order to reduce defects, an electrical valve needs to be installed for improvements. Electric valve can save in production costs. Electrical valve has a control panel and sensor to problems. Defect rate decrease from 66% to 20 %.
5. In order to reduce the setup time of machine, provide a new power inverter linked with machine. This action will be reduced waste rate, thus reduces cycle production time.
6. In order to avoid the automation inspection will be stopped, that require monitoring of process and a recalibration for control panel to ensure temperature accuracy.
7. Procedures of standard operational. The development of standard operating procedure for processes can be performed by training of workers and operators. In order to avoid the problems that lead to waste generation, sufficient instructions and training must be provided to workers and operators.
8. The company's strategy should be to order rather than to stock. Because of unnecessary storage of products is considered a waste of money.
9. Rearrangement plant layout in order to reduce waste rate and then saving cost, because of transportation of products to several stations of warehouses.

4.6. Implement

in order to verify improvements and to achieve sustainability purpose, hybrid methodology implementation, as (AHP and CI) does not only objective to reduce types of waste but also to be able to sustain improvements, the carried results and to prevent degradation in the performance of processes. Therefore, standards and procedures are required, a control plan was carried out and communicated for activities of processes concerned to the aim of the study. The following points as part of control plan in order to prevent the occurrence of types of waste at different of production processes:

1. Collect data and analyze any type of waste, then classification according to causes.
2. Set schedule for maintenance plan per monthly according to standard procedures.
3. Set schedule for cleaning of fill machine to avoid viscosity of syrup, in order to avoid close off valve that lead to waste generation.
4. Checking the seaming chock at the capping process in order to avoid defects at this stage.
5. Suppliers of raw materials are re-evaluated, in order to avoid different in specifications.
6. Training workers and operators on the regarding quality issues and details of production, as well as other activities such as problems solving that related to management.
7. Improve work environment, by controlling the factory temperature, reducing noise level. These environmental factors affect workers performance.
8. The processes should be standardized to avoid variation during production.

5. Conclusions

Waste generation is undesirable as it is referred to a major reason for lower productivity of industries around the world. Also, it can be the reason of financial loss to a company and holds a threat to the industrial environment. Therefore, it becomes a major problem for the sustainability of company. There are some steps could be followed to improve the economic sustainability firstly, improve profits by "reduce the waste and variation in processes" secondly, increased process reliability by (instructions and scheduling of maintenance plan) and lastly, meeting customer satisfaction by (cost and good quality of product). Moreover, additional stages on environmental sustainability should be applied include improving resource efficiency by (reduce of variation in specification of raw materials, machines, energy), on the other hand reducing the environmental parameters such as (humidity, temperature, and reduced risks for inattention for instructions). The whole production activity can be divided into three main stages, value added activity with (36.4%), non-value-added activity with (27.2 %), and non-value-added activity but necessary with (36.4%). In this study, a developed improvement solution to overcome the flows in machines processes and raw materials in terms of idle/waiting time and defects by using hybrid methodology with statistical tools which can be applied in all sectors such as industry and services.

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