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Full Length Research Paper

The application of cause and effect diagram in the oil industry in Iran: The case of four liter oil canning process of Sepahan Oil Company

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Manufacturing is currently being used as a continuous quality improvement tool, providing a planning, implementing, monitoring and evaluating framework for the quality improvement measures on a sustainable basis. A cause-and-effect diagram, also known as an Ishikawa diagram or fishbone diagram, is often used in quality management in manufacturing industries. Fishbone diagram (also known as Ishikawa diagram) was created with the goal of identifying and grouping the causes which generate a quality problem. Gradually, the method was used also to group into categories the causes of other types of problems which confronted an organization. This made fishbone diagram to become a very useful instrument in the risk identification stage. In this paper, the six sigma technique and cause-and-effect diagram is used to demonstrate how to relate potential causes of a major presenting problem in Sepahan Oil Company. For this purpose, the four liter production line of the company has been selected for investigation. The findings imply that the application of cause-and-effect diagram has reduced the scraps from 50000 to 5000 ppm and has resulted in a 0.92% decrease of the oil waste.

Key words: Cause-and-effect diagram, Sepahan Oil Company, canning, waste, six sigma.

INTRODUCTION

A process that is stable and repeatable should produce products to meet or exceed customer expectations. More precisely, the process must be capable of operating with little variability around the target or nominal dimensions of the product's quality characteristics. The use of total quality managements (TQM) and six sigma methodology, quantitative tools ensures better decision-making, better solutions to problems, and even improvement of quality and productivity for products. Seven parent chart (SPC),seven magnificent tools is the most popular quantitative tools and were used to identify the most important cause of defects, then a cause and effect (C and E) Diagram was created through brainstorming sessions to investigate the major causes of nonconformities, root causes of the quality problems. SPC is comprised of seven tools often called "The Magnificent Seven", Pareto Chart, Histogram, Process Flow Diagram, Control Charts, Scatter Diagram, Check Sheets and C and E Diagram.

The fishbone diagram (also called the Ishikawa diagram) is a tool for identifying the root causes of quality problems. It was named after Kaoru Ishikawa, a Japanese quality control statistician, the man who pioneered the use of this chart in the 1960's (Juran, 1999).

The fishbone diagram is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. Because of the function of the fishbone diagram, it may be referred to as a C and E diagram (Watson, 2004) Figure 1.

Abbreviations: TQM, Total quality managements; **SPC,** seven parent chart; **DMAIC,** define, measure, analyze, improve, and control; **CTQs,** critical to qualities; **FMEA,** failure mode and effects analysis; **RPN,** risk priority number **MSA,** measurements systems analysis; **C and E,** cause and effect.

MATERIALS AND METHODS

The cause and effect diagram

C and E (also known as fishbone and Ishikawa) diagrams,

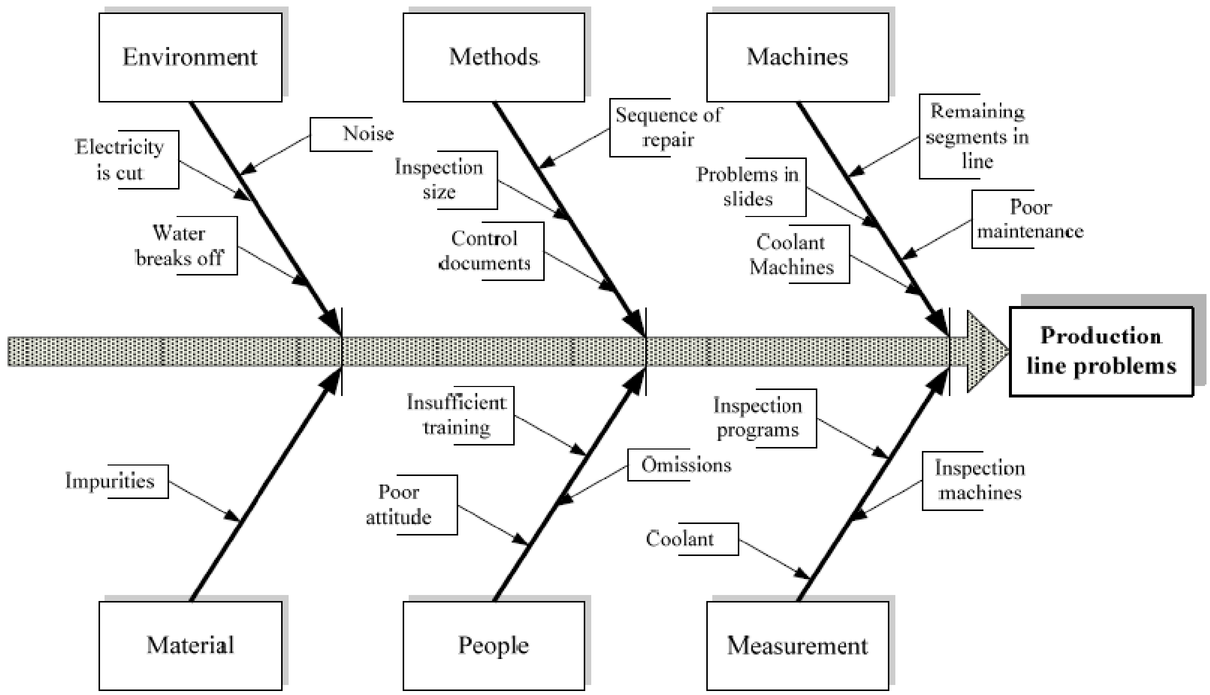

Figure 1. Cause and effect diagram for production line problems.

developed by Ishikawa in 1968, help users to think through problem causes (Ishikawa, 1986). The approach combines brainstorming and a concept map. The process has four major steps: identifying the problem; working out the major factors involved; identifying possible causes and analyzing the cause and effect diagram, which are used to resolve numerous problems including risk management in production and services (Dey, 2004). The technique has been well applied to obstetrics and gynecology and emergency department healthcare management (White et al., 2004). Fishbone (Ishikawa) diagram mainly represents a model of suggestive presentation for the correlations between an event (effect) and its multiple happening causes. The structure provided by the diagram helps team members think in a very systematic way. Some of the benefits of constructing a fishbone diagram are that it helps determine the root causes of a problem or quality characteristic using a structured approach, encourages group participation and utilizes group knowledge of the process, identifies areas where data should be collected for further study (Basic tools for process improvement, 2009).

The design of the diagram looks much like the skeleton of a fish. The representation can be simple, through bevel line segments which lean on an horizontal axis, suggesting the distribution of the multiple causes and sub-causes which produce them, but it can also be completed with qualitative and quantitative appreciations, with names and coding of the risks which characterizes the causes and sub-causes, with elements which show their succession, but also with other different ways for risk treatment. The diagram can also be used to determine the risks of the causes and sub-causes of the effect, but also of its global risk (Ciocoiu, 2008). The C-and-E diagram has nearly unlimited application in research, manufacturing, marketing, office operations and so forth. One of its strongest assets is the participation and contribution of everyone involved in the brainstorming process. Solutions are developed to correct the causes and improve the process. Criteria for judging the possible solutions include cost, feasibility, resistance to change, consequences, training and so forth. Once the solutions have been agreed to by the team, testing and implementation follow. Diagrams are posted in key locations to stimulate continued reference as similar or new problems arise. The diagrams are revised as solutions are found and improvements are made. The diagrams are useful in:

1. Analyzing actual conditions for the purpose of product or service quality improvement, more efficient use of resources and reduced costs.
2. Elimination of conditions causing nonconforming product or service and customer complaints.
3. Standardization of existing and proposed operations.
4. Education and training of personnel in decision-making and corrective-action activities.

Implementing Fishbone diagram

To implement, fishbone diagram of the logic scheme in Figure 2 is used. A special attention must be given to problem identification and its risk formalization.

Six sigma

Six sigma, on the other hand, is a data driven methodology used to identify root causes for variations in a production processes in order to achieve organizational excellence. Six sigma management strategies require process improvement through identifying problem, root causes, process redesign and reengineering and process management. Six sigma follows a model known as DMAIC (Define, Measure, Analyze, Improve and Control).

Therefore, six sigma starts by analyzing defects and lean initial focus is on customer, process flow and waste identifications (Sampson, 2004). However, using one of these tools has limitations. Since lean eliminates the use of six sigma's DMAIC cycle

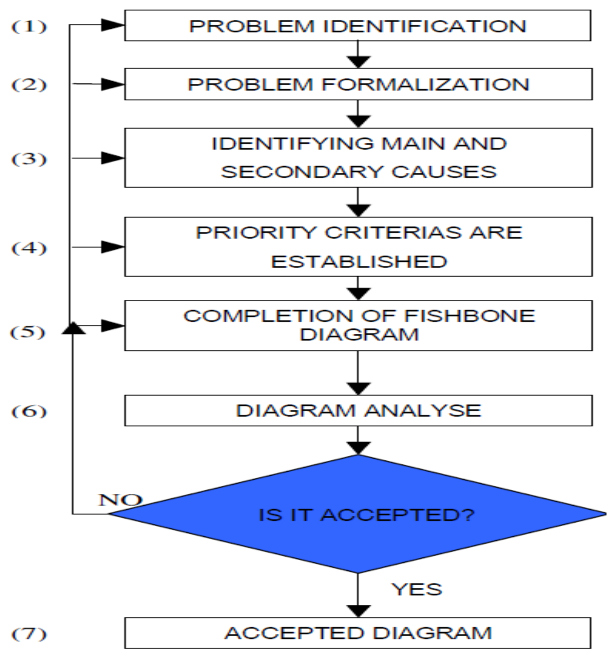

Figure 2. Logic scheme of fishbone diagram implementation (Ilie, 2009).

Table1. Percentage of waste in canning and filling processes of Sepahan Oil Company.

Wastage line production (Lit.)	Canning (%)	Filling (%)	Total (%)
1	1	0.1	1.1
4	6	1	7
20	-	0.001	0.001
210	-	0.002	0.002

as a management structure to define required process capabilities to be truly lean.

On the other hand, six sigma eliminates defects but does not address how to optimize the process flow. Hence, applying both six sigma and lean tools sets results in far better improvements than it could be achieved with either one method alone (Mandahawi et al., 2010).

Sepahan Oil Company

Sepahan Oil Company trades in petroleum and petrochemical products in the world. Today, this company operates in most of the world's counties and is best known by our familiar brand names like Exxon, Esso and Mobil. Sepahan Oil Company makes products that drive modern transportation, power cities, lubricate industry and provide petrochemical building blocks that are vital to thousands of consumers. Ever since its establishment and with regard to the type of design and anticipated capacity, Sepahan Oil Company was considered the major supplier of motor oil in the country. Sepahan Oil Company is capable of securing over 30% of approximately 600 million liters of engine oil used domestically. "Alvand" and "Arzhan" engine oils allocated the highest share of the market to themselves for years and at present, special trade names of Sepahan Oil Company such as "Speedy" and "Jey" rank first among domestic and foreign suppliers.

Research sample and sample size

In the canning hall production, a full array of production and filling lines has been installed which consist of 210-liter, 20-liter, 4-liter and 1-liter barrels. The 4-liter canning and filling production line, which encompasses most of the wastes is investigated as illustrated in Table 1.The statistics included in the table are extracted from the company's records, databases and documents.

Definition of the goal

As it is addressed in Table 2, with regard to the production plan and the existing constraints in this project, 0.3% is specified as the project target by the six sigma improvement team for canning scrap rate and 0.05% is specified for the wasted oil.

RESUTLS ANALYSIS AND DISCUSSION

Identifying critical to qualities (CTQs)

After determination of the six major failure modes for concentration, the Critical to Quality (CTQ) factors for

Table 2. Six sigma project charter at Sepahan Oil Company.

4-Liter	Actual (%)	Target (%)	Improvement (%)
Canning	6	0.3	0.95
Filing	1	0.05	0.95

Table 3. The identified CTQs at the 4-liter line.

No.	Section	CTQ	Operational definitional of CTQ
1	Plate cutting	Imprecise plate dimensions	The number of scrap cans
		Low and high hardness of the plate	The number of scrap cans
		Low and high thickness of the plate	The number of scrap cans
		Unadjusted device with regard to the type of the plate	The number of scrap cans
2	Welding section	Unadjusted feeder	The number of scrap cans
		Worn out parts during production	The number of scrap cans
		Inappropriate thickness and bare electrode hardness	The number of scrap cans
		Unadjusted device crown	The number of scrap cans
		Unadjusted reel side pressure	The number of scrap cans
3	Bottom seamer	Unadjusted reel perpendicular pressure	The number of scrap cans
4	From seamer to filling (conveyor devices) before filling	Can cripple before filling	The number of scrap cans
		Dirtiness of cans	Poor quality product
5	Filling	Overflowing of oil	The percentage of the lost oil
		Air entrance into the can	The percentage of the lost oil
		Cripple of the can in the filling device	The percentage of the scrap cans and the lost oil
6	Top seamer	Can cripple	The percentage of can and oil waste
		Inappropriate sewing of the filled can	The percentage of can and oil waste

each of them are indentified. These CTQ are factors which cause scraps in the canning and filling sections and some have negative impact on the customer. The state of these CTQs is as follows: Table 3.

Measure phase

In order to effectively execute the measure phase, first a compiled plan for data collection is designed for the collection of the required data and the design of the required forms. Those responsible for data collection are trained for sampling and filling out the forms. The data of the related forms are recorded in a table. In order to approve of the measuring system and the validity of the data, the measurements systems analysis (MSA) technique and Gage R and R methods are employed. Table 4.

The capability of process and the present sigma level

After measuring the CTQ values of the addressed six failure modes, the capability of process and the present sigma level of the process before improvement are calculated (Table 5). It is important to note that the standard deviation for σ is considered to be 1.5.

Analyze phase

Based on the data obtained during the measure stage,

Table 4. The measurement of the identified CTQs at the 4-liter line.

No.	Section	CTQ	Scrap percentage	
			For filling	For canning
1	Plate cutting	Imprecise plate dimensions	-	0.11
		Low and high hardness of the plate	-	0.09
		Low and high thickness of the plate	-	0.60
		Unadjusted device with regard to the type of the plate	-	0.15
2	Welding section	Unadjusted feeder	-	0.60
		Worn out parts during production	-	0.50
		Inappropriate thickness and bare electrode hardness	-	0.40
		Unadjusted device crown	-	0.10
3	Bottom seamer	Unadjusted reel side pressure	-	0.75
		Unadjusted reel perpendicular pressure	-	0.75
4	From seamer to filling (conveyor devices) before filling	Can cripple before filling	-	0.12
		Dirtiness of cans	-	0.03
5	Filling	Overflowing of oil	0.20	-
		Air entrance into the can	0.30	-
		Cripple of the can in the filling device	0.05	0.30
6	Top seamer	Can cripple	0.40	0.75
		Inappropriate sewing of the filled can	0.05	0.75

Table 5. Process capability and production line of 4-liter sigma level before the implementation of the six sigma techniques.

	Capability of process	Sigma level
Canning section	0.55	3.14
Filling section	0.77	3.80

the following steps are taken:

1. The study and analysis of the process with the purpose of problem identification.
2. Presenting the views suggested by the problem-solving team with regard to the causes of the problem.
3. Conducting tests by means of statistical tools in order to substantiate the basic causes for the problem.

In order to implement the aforementioned steps, the failure mode and effects analysis (FMEA) technique, the cause and effect diagram and the Pareto analysis for indentifying the root causes of the problem are adopted for each of the six failure modes which are explained in the following.

Plate cutting

Table 6 shows the FMEA of the plate cutting. As it is observed, four modes of potential failures are considered to result in can scraps. Three of these four modes of potential failures are relevant to sending of unsuitable plates by the providers that result in can scrap and some problems in the production line. At the present situation, the company does not impose any control over sending of the plate; but the fourth mode of potential failure is pertained to the absence of system adjustment with due attention to the type of the applied plate. This mode has the maximum RPN and highest degree of importance. The cause behind this problem is the imprecision of the operator and lack of any effective control. The severity of this mode of potential failure is high and it is of almost high frequency.

Cause and effect diagram of the plate cutting section

Figure 3 demonstrates the cause and effect diagram and Figure 4 shows the plate cutting Pareto diagram. The

Table 6. FMEA plate cutting section.

Potential failure mode	Potential failure effects	Severity	Potential causes of failure	Occurrence	Current process control	Detection rate	RPN
Imprecision of the plate dimensions	Can scraps	5	Providers	5	No control	2	50
High and low hardness of the plate	Can scraps	3	Providers	2	No control	2	12
High and low thickness of the plate	Can scraps	4	Providers	4	No control	2	32
Unadjusted device with regard to plate type	Can scraps	8	Operator	6	No precise control	6	288

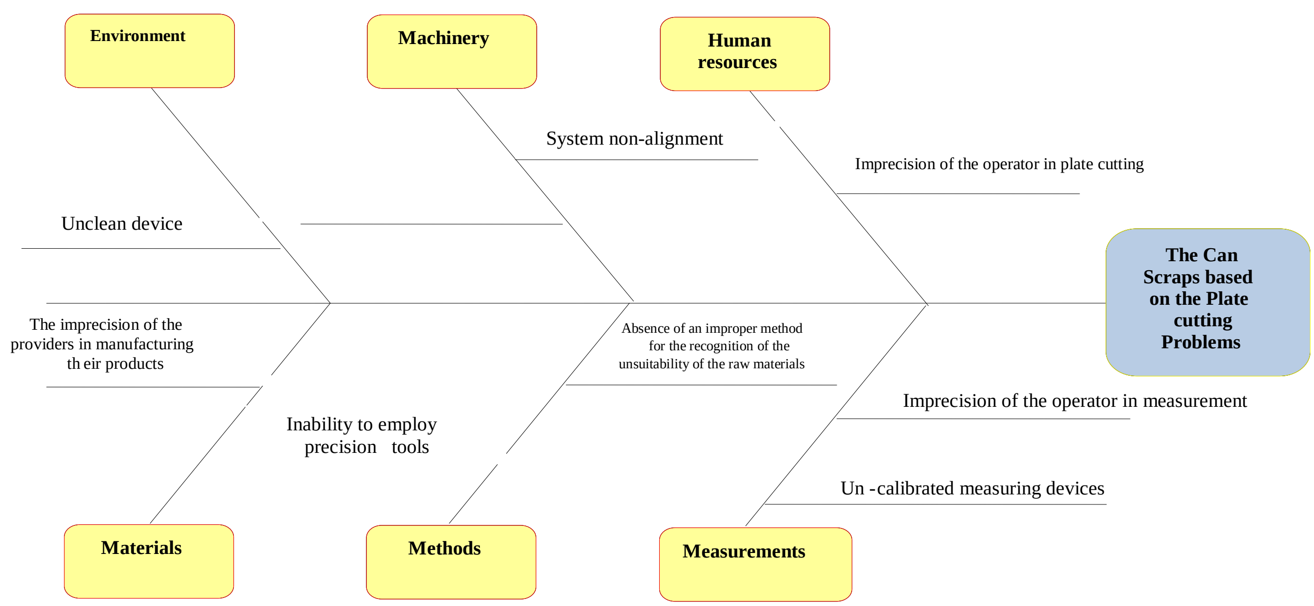

Figure 3. The cause and effect diagram of the plate cutting section.

imprecision of the operator in system adjustment is recognized as the cause for most of the section scraps. The second cause is applicable to sending of the unsuitable products on the part of the providers and the absence of a proper method for the identification of inappropriate commodities. Another cause is relevant to the unadjusted status of the machinery and measurement devices.

Improvement phase

This phase starts after the analysis of the root causes of the problems. In this phase, the improvement team identified ways to remove the root problems through brainstorming, using the creativity and innovativeness of the members in the meeting. Thereafter, each of the suggested solutions was evaluated on a cost-benefit basis. Thus, it was possible to arrive at optimal solutions. Once these solutions had been completely revaluated for risk factors in execution, and for their likely effectiveness in process improvement and scrap reduction, the improvement plan was implemented (Table 7).

Conclusion

SPC seven magnificent tools is the most popular

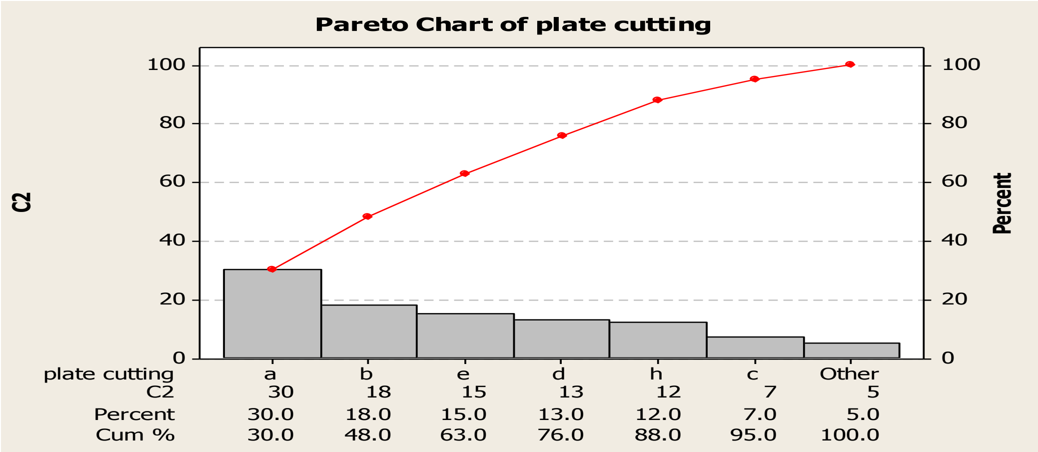

Figure 4. Pareto diagram of the plate cutting section.

Table 7. Solutions suggested by the improvement team for the identified CTQs along with the values for CTQs before and after implementation of FMEA and cause and effect diagram.

No.	Section	Improvement	CTQ title	CTQ value before six sigma		CTQ value after six sigma	
				Filling	Canning	Filling	Canning
1	Plate cutting	Operator training and use of expertise	Imprecise dimensions of plate	-	0.11	-	-
		Sensor preventing double-sheet lifting	High and low hardness of plate	-	0.09	-	0.01
		Calibration of device every few days	High and low thickness of plate	-	0.60	-	0
		Checking plate before unloading and holding vendor responsible	Device unadjusted for each type of plate	-	0.15	-	0

Table 8. Comparison of the criteria before and after the implementation FMEA and cause and effect diagram.

Criteria	Before	After
Scrap can percentage	50000 ppm	5000 ppm
Percentage of the oil wasted	1%	0.05%
Sigma level at canning section	3.05	4.08
Sigma level at filling section	3.80	4.70
Process capability in canning (considering 1.5σ shift from the process mean)	0.6	0.9
Process capability in filling (considering 1.5σ shift from the process mean)	0.81	1.155
Customer satisfaction	66.3%	94.5%

quantitative tools, used to identify the most important cause of defects then a C and E diagram was created through brainstorming sessions to investigate the major causes of nonconformities, root causes of the quality problems. In this study, the importance of the improvement team was emphasized. It is important to note that many enterprises limit the productivity enhancement of employees to the acquisition of skills. However, about 86% of productivity problems reside in the work environment of organizations. The work environment has effect on the performance of employees (Taiwo, 2010). One of the main aims of this paper was to enhance quality in the oil industry through the six sigma methodology with the SPC tools. There is lack of systematic approach in ascertaining critical factors to quality as well as the use of six sigma and its toolbox in special applications including the oil industry. According to DMAIC cycle and implementation of FMEA and C and E diagram, the phases were implemented in order of define, measure, analysis, improve and control. Each phase is comprised of different tools and various techniques which were used as required. Table 8 shows the comprised criteria before and after the implementation of FMEA and cause and effect diagram.

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