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LEAN - A PHILOSOPHY HIGHLIGHTING THE VALUE ADDED THROUGH SELF IMPROVEMENT AND WASTE REDUCTION, CONCEPTS PRESENTED FROM THE EXPERIENCE OF THE ROMANIAN AUTOMOTIVE INDUSTRY

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ABSTRACT

The definition of Lean n is: eliminating all sources of error, time and effort that are not necessary starting with the raw materials and up to the final product, from order to delivery and from design to launch. TRW is a Romanian company from the automotive domain, having experience in using new concepts based on the lean manufacturing philosophy.

KEYWORDS: Lean evaluation, flexible production philosophy, reaction time

1. Introduction

The Lean evaluation is performed by taking into account multiple factors, among which the socio-technical system, namely the internal elements (the internal system) and the environment. The Lean evaluation is performed for achieving a mutually defined target. For the Lean evaluation, the inputs of the internal system, the environment and the desired outputs are taken into account. The inputs of the internal system are defined by labor, materials, capital, energy, information, by the correlations, influences and continuous interactions of the internal system with the environment that is in a state of constant change. The environment is represented by society, natural environment, market, technology, government, etc. The desired outputs can be products/services, or undesired outputs such as pollution, losses, wastage.

2. Lean Methods

The Lean evaluation, according to studies published by the well-known expert James P. Womack [1], can be performed through various measurements and analyses, from which data is collected and analyzed, immediate feedback is received for problem control and actions are taken according to the data collected for performance improvement.

The most well-known and used instruments for problem identification are:

1. PDCA (Plan-Do-Check-Act).
2. Analysis - Cause – Effect (Ishikawa).
3. Pareto Analysis (ABC-Analysis, 80/20-Rule).
4. Constraint management.

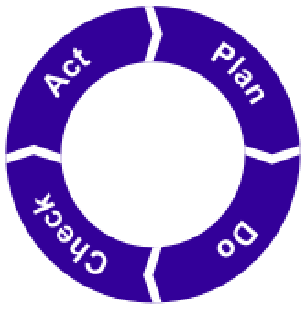

Fig. 1. *PDCA (Plan-Do-Check-Adjust) diagram* [1]

PDCA (plan–>do–>check–>adjust) is a management method used in business for the control and continuous improvement of processes and products. Also known as the so called "Stewart cycle", it consists in four iterative steps which are described below:

PLAN-ing - Establish the objectives and processes necessary to deliver results in accordance with the expected output (the target or goals). By establishing the output expectations, the completeness and accuracy of the specification are also a part of the targeted improvement. When possible, start on a small scale to test possible effects.

DO – The step of attacking plan implementation, process execution, of making the product or good. It also assumes data collection - used later on for analyses, graphs, charts and conclusions.

CHECKING - Study the actual results (measured and collected in "DO" above) and compare them to the expected results (targets or goals from the "PLAN") to ascertain any differences. Look for deviation in implementation from the plan and also look for the appropriateness and completeness of the plan to enable the execution, i.e., "Do". Charting data can make much easier to see trends over several PDCA cycles and in order to convert the collected data into information. Information is what you need for the next step "ADJUST" [1].

ADJUST - If the CHECK shows that the PLAN that was implemented in DO is an improvement to the prior standard (baseline), then that becomes the new standard for how the organization should ACT going forward. If the CHECK shows that the PLAN that was implemented in DO is not an improvement, then the existing standard will remain in place. In either case, if the CHECK showed something different than expected (whether better or worse), then there is some more learning to be done... and that will suggest potential future PDCA cycles. It should be noted that someone who teach PDCA assert that the ACT involves making adjustments or corrective actions, but generally it would be counterproductive to PDCA thinking to propose and decide upon alternative changes without using a proper PLAN phase, or to make them the new standard (baseline) without going through DO and CHECK steps [1].

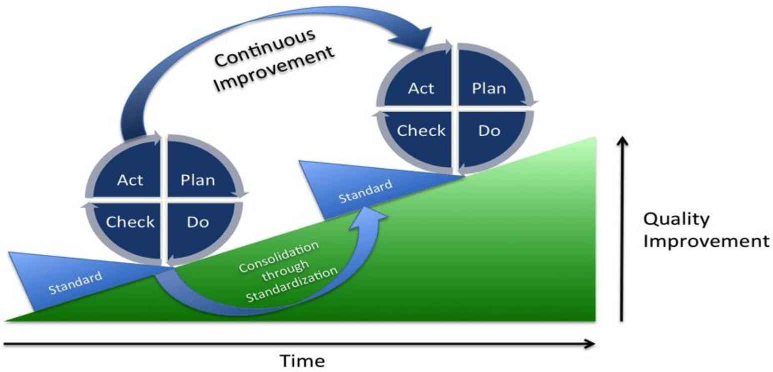

Fig. 2. *Quality improvement cycle through PDCA method* [20]

The fishbone diagram identifies many possible causes for an effect or problem. It can be used to structure a brainstorming session. It immediately sorts ideas into useful categories.

Where can a Fishbone Diagram be used? [2]

First - when we are trying to identify potential root causes of problems;

Second – when analyses performed by the team have become dull and unproductive but it is hard to change them.

Stewart circle comes with a kind of "procedure" -including several steps to be fulfilled, steps listed below:

The effect of the problem- symptom- is to be collected into the center of the whiteboard, circumcised by a box. A horizontal line, the "spine" of the "fish", is to be drawn underneath.

Use the "5 M" approach in order to brainstorm on the top categories of root-causes. "5 M" approach assumes touching all potential areas of root-causes, i.e.:

MAN
METHOD
MACHINE
MATERIAL
MOTHER NATURE (Environment)

Write the categories of causes as branches from the main arrow [1].

Brainstorm on all the possible causes of the problem. Ask: "Why does this happen?" As each idea is given, the facilitator writes it as a branch from the appropriate category. Causes can be written in several places if they relate to several categories [1].

Ask again "why does this happen?" about each cause. Write sub–causes branching off the causes. Continue to ask "Why?" and generate deeper levels of causes. Layers of branches indicate causal relationships [1].

When the group runs out of ideas, focus attention on places of the chart where ideas are few [1].

Fishbone Diagram Example:

For example, under the heading “Machines,” the idea “materials of construction” shows four kinds of equipment and then several specific machine numbers.

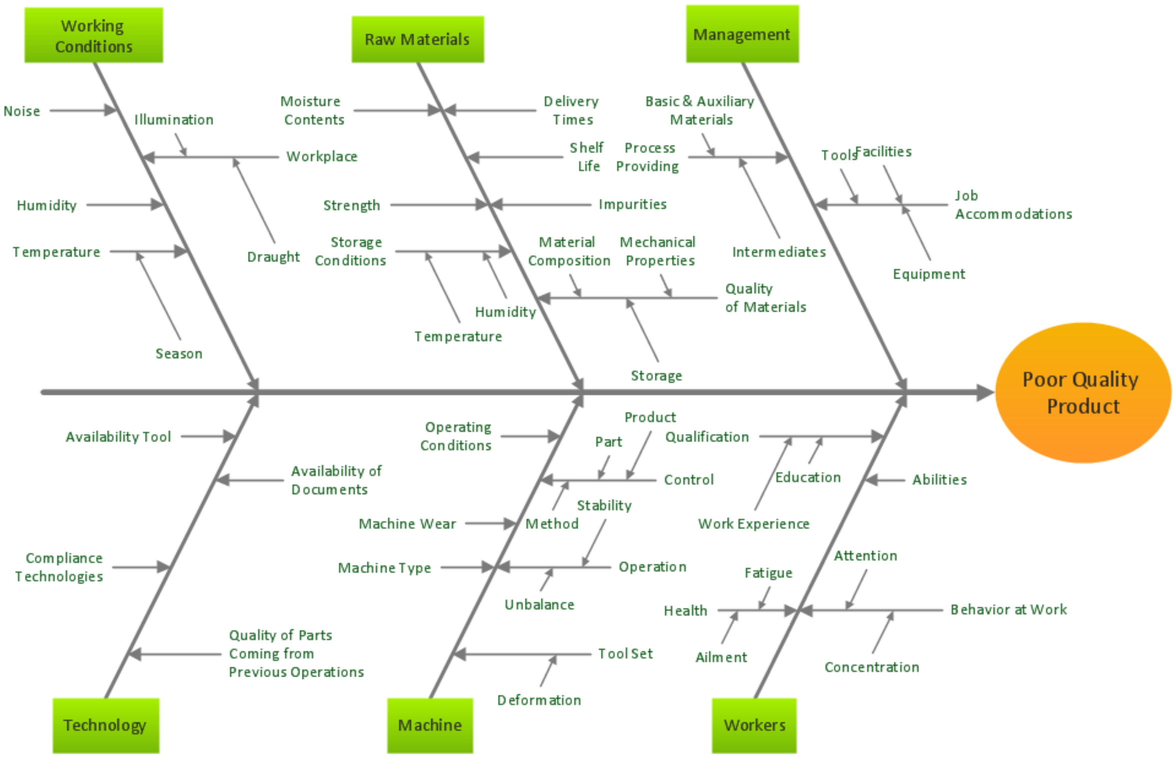

__Fig. 3.__ Continuous quality improvement example with fishbone diagram at TRW Automotive

Note that some ideas appear in two different places. “Calibration” shows up under “Methods” as a factor in the analytical procedure, and also under “Measurement” as a cause of lab error. “Iron tools” can be considered a “Methods” problem when taking samples or a “Manpower” problem with maintenance personnel [2].

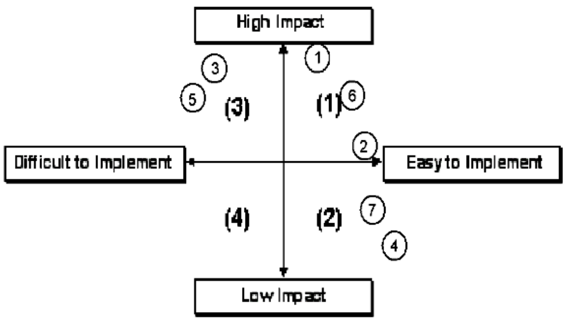

***Fig. 4.** Representation of problem identification instruments Lean/6 Sigma according to* [1]

I. The 80:20 Rule to Prioritize

When it comes to simple prioritization techniques, the Pareto technique is one of the simplest one, working under the principle also known as the "80/20 Rule" – which is the concept that 20% of causes generate 80% of results. With this tool, we are trying to find the 20% of work that will generate 80% of the results delivered by all of the work performed.

How can the tool be used? [3]

1. First thing - identify the problems. Use all available source of information in order to describe the issues as accurately as possible.
2. Apply the 5 M technique for each identified problem.
4. Create a measurement/scoring system. This scoring method needs to be adapted to your needs- the most ‘burning” issue will get the highest ranking.
5. Group Problems Together by Root Cause [1].
6. Add up the Scores for Each Group. The group with the top score is your highest priority, and the group with the lowest score is your lowest priority [1].
7. Take Action – Now you need to deal with the causes of your problems, dealing with your top-

priority problem or group of problems first. Keep in mind that low scoring problems may not be worth bothering with; solving these problems may cost you more than the solutions are worth taking into consideration [1].

Another method used intensely in the Lean methodology is named 'constraint management'. The principle is the following [4]:

1. A chain is as strong as its weakest link.
2. An interconnected process can produce as much as the weakest link can.
3. Improving the weakest link results in improving the entire system.

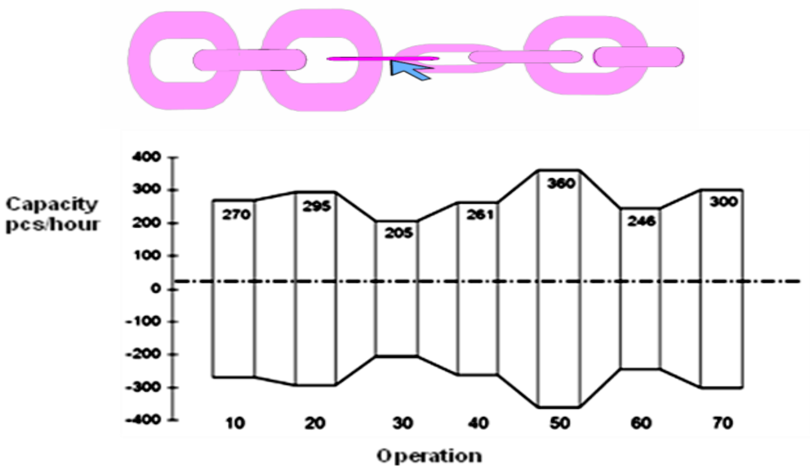

Fig. 5. *'Management of constraints' method representation – used into TRW Automotive Safety Systems, Timisoara*

Steps to follow in this methodology:

1. Identify and highlight the constraints.
2. Exploit the constraints (placing a buffer zone before and after the constraint).
3. Subordinate non-constraints to present constraints.
4. Systematically improve constraints.
5. Return to point no. 1.

The biggest issue in many enterprises is the lack of action based on the collected data, although the data is collected and reported.

A high Lean level means a higher product or service quality, while a lower level defines a low product or service quality.

II. What Exactly Can be Improved in a Plant by Using the Lean Approach

Lean Manufacturing, as it was described before, is a production philosophy that determines time reduction from the customer's order up to the product delivery, through the continuous reduction of losses.

Fig. 6. *Lean universal principles*

There are many definitions, such as:

1. Lean Manufacturing is "a production philosophy that reduces the time from the customer's order until the delivery of the products, through the reduction of losses (of activities that do not add value to the product)" [4].

2. Lean Manufacturing is "A team approach, for the identification and elimination of losses (activities that do not add value to the product) through the continuous improvement of the production flow performed upon the customer's request, targeting perfection" [5].

3. Lean Manufacturing is „a way of thinking and involving in order to completely eliminate losses,

oriented towards customer success… this is obtainable by simplifying and continuously improving all processes and relationships in an atmosphere of mutual trust, respect and complete involvement of employees" [5].

4. Lean: SPC – Statistical Process Control – Control the process before it controls you! Simple controls for the operator, in order to identify the process trends, for the purpose of making educated decision, based on data [12, 14].

III. Concepts Built on the Lean Manufacturing Methodology

A. Cellular manufacturing

The manufacture area is separated in different manufacturing cells. One cell is organized for each product family. The flow is linear and regulated for each product family, but is variable for each product within the family. The machines are located within the manufacturing cell, in a certain order, so that the materials undergo a unique material flow towards the completion of the product. It is advantageous for the machines within the manufacturing cells to be smaller, more dedicated, as they operate more efficiently than the large, multipurpose machine tools.

B. Flexible manufacturing systems (SFF)

A flexible manufacturing system is an integrated computer controlled complex of numerical command machine tools, which includes an automatic transport and handling system for parts and tools, along with automated measurement and testing equipment which, with a minimum amount of manual interventions and setup time, can process any part belonging to a specific family, within the capacity thresholds and according to a predetermined schedule. The entire system is controlled by a DNC computer, usually connected to the plant central (host) computer. SFF are dedicated to specific product families, which must be manufactured in large manufacture volumes, justifying the investment. The obtained advantages are lower costs and a lower inventory of parts in progress. SFF can be designed for various types of manufacture processes: machine cutting, metal molding, assembling, welding, etc.

C. Manufacturing process management (MPM)

Is a process of defining and managing manufacturing processes to be used for the manufacture, assembling and inspection of the final products. MPM allows manufacturers to use product drawings (made in CAD) in order to define the method through which the products will be manufactured and then electronically deliver these manufacturing processes to the workshops. MPM turns „what to manufacture" into „how to manufacture", „when" and „where". MPM represents a „collection of technologies and methods used in order to define the way in which the products will be manufactured". This definition means that MPM is a process through which manufacturing industries will use various types of technology in order to aid product execution, with various machine layouts and methods for the potential layout of the assembly lines.

3. Conclusions

At each level within a manufacturing organization, the goal is to create value for the customer, according to his/her specifications. The "Lean" concept, used in the manufacture field, becomes a way of life: We do not want any losses. The Lean manufacturing targets maximum results, with minimal resource consumption (human effort, equipment, materials, time and space), increasingly and more accurately meeting the customer's needs. It is a flexible manufacturing philosophy which allows enterprises and organizations to react quickly to the evolution of market conditions and customer needs. On this idea, TRW company applied these principles and obtained some results, having now one good reference. I am particularly proud of the clear evidence of the successful implementation of these tools into Quality area. Taking the Fishbone diagram methodology, deep-diving into it, it is quite obvious that conclusions are focusing on the exact root-cause, as in the following example (Fig. 7).

Once the root-cause is determined, it is important to treat each and every potential root-cause rigorously and implement correct actions (Fig. 8 and 9).

Correct implementation and follow up grant spectacular results into the desired area. Figure 10 below shows the evolution of quality issues on a particular area (Airbag production Q issues) in TRW Automotive Timisoara after the implementation of the above-mentioned activities.

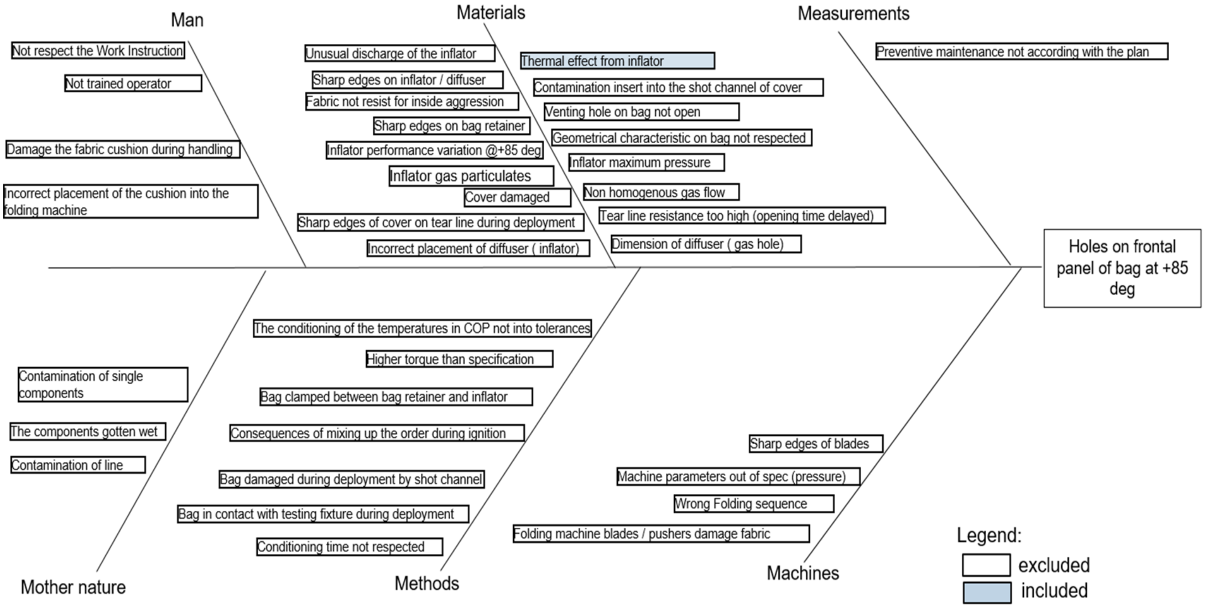

Fig. 7. *Particular example of Fishbone methodology implemented*

Fishbone item	Yes	No	Why
Not respect the Work Instruction		x	Verified shiftily by Layer Process Audit level 1 / Monthly by Layer Process Audit level 2→ The operator respect the Work Instruction
Not trained operator		x	Verified shiftily by Layer Process Audit level 1 / Monthly by Layer Process Audit level 2 → Operator trained - 3 different operators
Damage the fabric cushion during handling		x	Verified shiftily by Layer Process Audit level 1 / Monthly by Layer Process Audit level 2 → The operator respect the Work Instruction and No sharp tools used in the line
Incorrect placement of the cushion into the folding machine		x	Mistake proofing by design (sensors that are ensuring the correct position of bag into the folding machine)
Folding machine blades / pushers damage fabric		x	1. Checked 100 pcs after folding 2. Checked at First Off 3 bags after folding (general procedure) → No damages, no scratches on bags
Wrong Folding sequence		x	Automatic folding sequence
Machine parameters out of spec (pressure)		x	Verified at First Off the pressure records → Pressure into specification
Sharp edges of blades		x	Verified the blades shiftily →No sharp
Contamination of single components		x	Verified the component flow / Incoming procedure -verify 5 parts / each delivery → No risk for contamination
Contamination of line		x	Verified the line → No risk for contamination
The components gotten wet		x	Verified the components and the storage area →No wet components → the components are stored in warehouse → no risk to be wet
Preventive maintenance not according with the plan		x	Verified the preventive maintenance →The preventive maintenance was done according with the plan
The conditioning of the temperatures in COP not into tolerances		x	Verified the temperature diagram for conditioning of module → The conditioning temperature into specification
Higher torque than specification		x	The torque is automatically controlled in the line - Yearly calibration of controller / screw driver
Bag clamped between bag retainer and inflator		x	1. Checked 100 pcs after folding 2. Checked at First Off 3 bags after folding (general procedure) → No damages, no scratches on bags, no bag clamped between bag retainer and inflator
Consequences of mixing up the order during ignition		x	NA (only one stage inflator)
Bag damaged during deployment by shot channel		x	Verified the de-folding behavior of the modules → No bag damaged during deployment by shot channel
Bag in contact with testing fixture during deployment		x	Verified the de-folding behavior of the modules → No contact with testing fixture and no windscreen
Conditioning time not respected		x	Verified the records from conditioning diagram → 4 hours have been respected as conditioning time (specification: min. 4 hours; no upper limit)

Fig. 8. *Particular example of Fishbone methodology implemented- actions at TRW Automotive*

Fishbone item	Yes	No	Why
Incorrect placement of diffuser (inflator)		x	Verified the 9 inflators of NR tests → Correct placement of the diffuser Check with supplier(ZF TRW Aschau) → the position of diffuse is assured 100%
Sharp edges of cover on tear line during deployment		x	Verified the tested parts → No evidences of sharp edges on tear line
Cover damaged		x	Verified the covers → No damages on cover
Inflator gas particulates		x	1. Performed Life dissection of tested inflators of events → no abnormalities found for all 9 inflator of NR results 2. Performed the tank wash test on 3 serial inflators → no abnormalities
Inflator performance variation @+85 deg		x	Verified the Tank pressure curves → The inflators are into specification
Sharp edges on bag retainer		x	Verify the bag retainer - incoming inspection → No sharp edges on bag retainer
Fabric not resist for inside aggression		x	Verified the Quality certificate of fabric →The fabric was according with the specification
Sharp edges on inflator / diffuser		x	Verified the inflators prior to assembly → No sharp edges
Unusual discharge of the inflator		x	Verified the de-folding behavior of the modules → Opening time and bag filling time into specification
Dimension of diffuser (gas hole)		x	Verified the dimension results from ZF TRW Aschau (supplier of inflator) →All values are into the specification
Tear line resistance too high (opening time delayed)		x	1. Verify the opening time → Opening time into specification 2. Verify the tear line thickness of cover → Tear line thickness into specification
Non homogenous gas flow		x	Verified the Tank pressure curves → The inflators are into specification
Inflator maximum pressure		x	Verified the Tank pressure curves → Pressure of inflator into specification (nominal values)
Geometrical characteristic on bag not respected		x	Verify the dimension results from ZF TRW Vigo (supplier of bag) → all values into specification
Venting hole on bag not open		x	Verified all the bags of events and the movies → Venting hole are open and are working as expected according design intend
Contamination insert into the shot channel of cover		x	Verify all the covers of NR tests Verify the covers from stock and ask the supplier to check the covers from stock → No pollution insert into the shot channel cover
Thermal effect from inflator	x		TRW Aschau performed: 1. The mass flow calculation and temperature for suspicions batches were compared it with PPAP data → conclusion: mass flow calculation and temperature for suspicions batches were similar with the mass flow calculation and temperature of PPAP inflator. 2. Analysis over time of mass flow calculation and temperature by comparison , for inflators batch by batch from 2011 until 2017 → conclusion: similar behavior from one batch to the other. Root cause confirmed on the airbag module as thermal effect from inflator.

Fig. 9. *Particular example of Fishbone methodology implemented- actions at TRW Automotive*

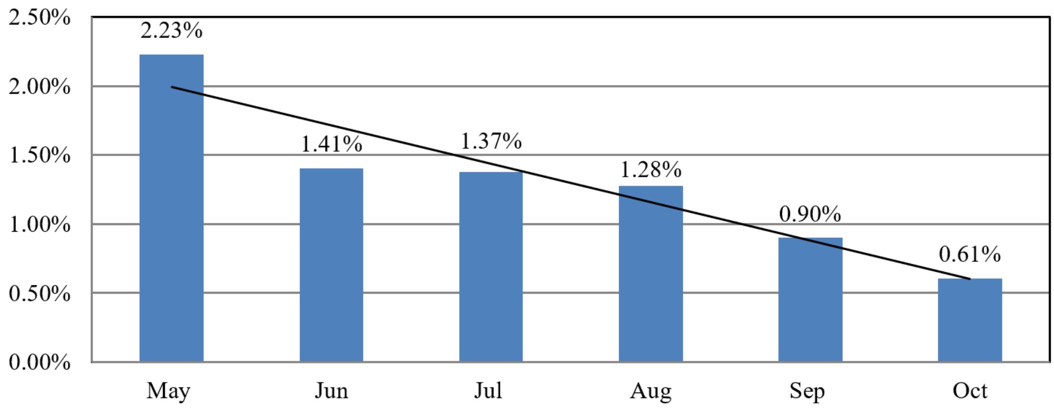

Fig. 10. *Evolution of quality issues (nonconformities) after the implementation of Fishbone driven actions at TRW Automotive*

Thus, the execution processes for products and services requested by the customer must be analyzed according to two fundamental concepts [6]:

1. Added value: Any activity determining an increase in value or utility for the product or service demanded by the market, respectively the activities for which a customer is willing to pay.

2. Loss (non-added value): Any activity that does not add value to the product or service, meaning that it “increases the product’s COST without adding VALUE” for the customer. These activities need to be eliminated, simplified, reduced or integrated.

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