

KEYS TO SUCCESS FOR SIX SIGMA

Gabriele Arcidiacono

g.arcidiacono@aiss.it

Università di Siena

Via Roma, 56

53100 Siena

Italy

ABSTRACT

This paper describes how the characteristics of the Six Sigma methodology are able, if properly used, to bring new light to process comprehension and problem solving. Each of the 5 phases in which Six Sigma is structured (DMAIC) sets few milestones that indicate the walk to do. The way these milestones are defined, the ability of the people to understand the contest, the proper effort in order to gain the goal are issues that may influence the final results. Correct use (right one for the right information) of the tools, the rigour of the method, the step-by-step approach and a strict time management on projects are surely the basis for a success. The different examples provided in this pages, show what is the most important aspect of the methodology: its possible application to everything we may define as process. Key issues therefore are: extensive application of the methodology to all the processes, great flexibility and customization, the improvement opportunities identification and selection; results evaluation and validation.

Keywords: Six Sigma, DMAIC, Culture, Method and Project

1. INTRODUCTION

In the modern business contest, while setting the strategies, the deep need of having immediate reaction time due to the speed and the rapidity of the market evolution, must not sacrifice the process close examination and analysis.

Among different management techniques, Six Sigma is the one that gives a scientific approach (through the use of proper tools, both statistics and not) and a severe method (that develops in 5 steps, DMAIC¹, starting from the criticalities recognition and ending with their resolution), that respects the above need. In particular Six Sigma is the most effective and efficient business strategy for optimizing existing processes; it may enforce a business vision able to consolidate a company market leadership.

The mission for contributing to the company success and to the brand consolidation is to fully satisfy customers in order to create a competitive advantage through internal resources growth and development (a “Thinking-Being Company” produces better).

The continuous improvement action, that has taken place along the years, forces company to concrete the services and products

quality in a daily action plan. Productivity increase, customer fidelization growth and investment effectiveness are tools that allow to leave behind competitors: through all these aims Six Sigma strengthens company leadership by setting a steady development, based on given service and product level measurement and systematic analysis, on internal processes continuous improvement, performance indicators constant monitoring, market demand behaviours and on internal competencies to meet the Voice of Customer (VOC).

Six Sigma is not just a language, a statistical measuring or a process management technique, but it is also a strategy that involves all the organization in the challenge to reduce defects in order to satisfy the customers. Six Sigma catches up TQM philosophy, ISO principles, EFQM model concepts (Leadership, Human resources management, Continuous Improvement, Process Oriented Business, etc.), but it doesn't limit itself to a general knowledge of the theory or of the potential results, indeed it applies immediately lesson learning to field projects with a Top down approach: it circumscribes major criticalities of the entire process in a sub phase, dividing the general problem into small areas to improve the analysis and to ease solve it with “surgical” precise actions. Fundamental condition is to have short-term projects (few months) so to keep a high and concentrate focus from the teamwork on the problematic issues and mainly to have immediate responses on the planned actions. At last only the effective improvement validates the action planned method and extend it, just in case, to other business areas. Problems will be tackled not only by studying the symptoms, but the root causes too; decisions will be taken not based on opinions, but on data; behaviour will not be reactive, but proactive.

2. SIX SIGMA FOR INDUSTRIAL PROCESS EXCELLENCE: THE DMAIC METHOD

Regarding the process improvement, the Six Sigma method has basically 3 strengths: the rigour of its application (a step by step approach divided in the 5 phases of the DMAIC); the extensive and constructive use of statistical and managerial tools; the possible application to all the kind of processes. In the following pages we will explore the three aspects by analysing and introducing each of the steps, by providing example of the tools that may be used in each of the phases and by providing real example coming from different business-processes or geographical areas.

¹ DMAIC stands for Define, Measure, Analyze, Improve and Control

Define has the goal of indicating the purpose and the scope of a certain project. It must also provide a deep knowledge of the process focused and of the customer expectations (the so-called VOC, Voice of the Customer). In concrete terms Define is determined by:

- criticalities that may force the company to focus on some specific processes;
- project scope and, therefore, action contest; by considering a physical border of action, it allows the company to narrow attention to sub phases or equipment or areas or worker;
- customer: the person or entity that uses the result of the process;
- measurable indicator “Critical To Quality” (CTQ) from the customer perspective (what is important for the customer) and customer satisfaction level pushed by a proactive rather than reactive attitude;
- financial benefits evaluation of the examined project;
- actual process map (critical process phases selection with the identification of those ones value added VA and those not value added NVA).

Example:

One fundamental aspect that may influence the proceeding of a Six Sigma Project is the right and concrete definition of the Scope. Scope is the physical place of action where the project is taking place by focusing on a part of the process rather than on a person or equipment or even part of a machine. This sharp definition of the field of the game allows avoiding future mistakes (it is defined where to put eyes and attention) and over providing useless data or losing attention from the contest.

In the example here below, a company that produces mechanical components had designed a project to increase Service Time (ST) in 2 assembling lines. The initial Scope was considering to collect data in all the machines belonging to the 2 assembling lines in order to verify where the problem of late Service may occur. The Scope defined was too broad to make the proper Six Sigma project to be implemented. One principle in starting the Six Sigma project is to proceed in the definition of the problem by going “ 1 cm wide and 1 km deep” and not the opposite. 17 different equipment were part of a single assembling line and 10 persons were designated to the job. Where to focus? Where to collect data? Did they need to consider the whole lines? (See the dotted area in Fig. 1).

The scope was to refine! The problem was too big to be tackled. Through the experience and interviews of the personnel on the line, it was then decided to focus just on a single machine for each line (see the rectangles in Fig. 1) in order to see what was the problem there and how much it may influence the whole process measure (Service Time in Assembling Line).

The border was set, focus was established, data were to be collected easily, and the entire and very complex process was reduced, in simpler contest made by just 2 machines. Problem was narrowly approached and information could be more detailed. Less resources consumed, more focus set.

Measure (the second DMAIC phase) aims at gathering data (the needed information) on a certain problem in order to have a

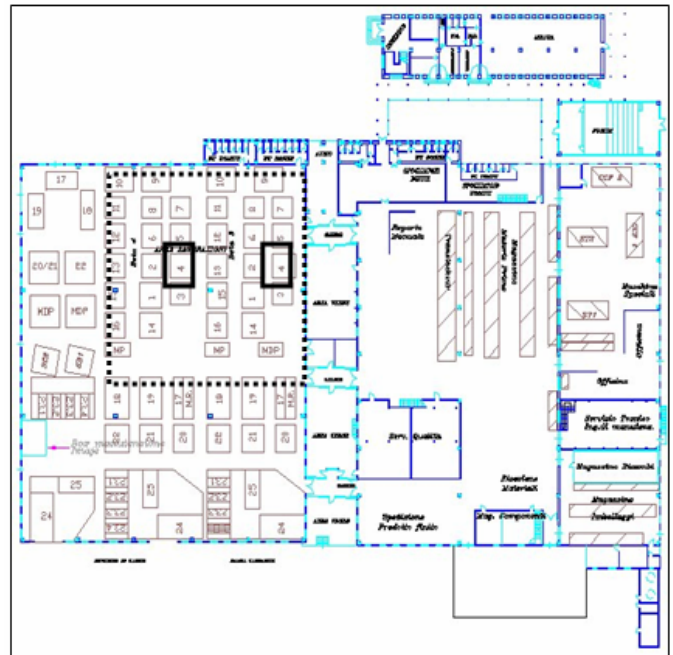


Fig. 1 – Scope Refined

baseline of the current situation and to have a clearer problem statement. More specifically it considers:

- measurement system reliability;
- collection of significant data, performed according to the defined scope: this collection needs an accurate, effective and efficient planning and analysis;
- data display and comprehension through the use of statistical tools (the collected samples must be representative and significant);
- process map through significant data.

Example:

The first step in this phase is to verify if the measurement system is reliable or not. The test to be performed is the so called GAGE R&R (that is a part of the Measurement System Analysis, MSA): through this it is possible to evaluate if the measurement system is acceptable in terms of reproducibility and repeatability (R&R), in order to check the influence of different operators, of differences in their way of measuring etc, so to detect the real differences among the parts (part to part variation).

The following example is taken from a project, selected by a company that produces white goods, aimed at reducing defects coming from a moulding system. The CTQ to be collected was the height of a plastic cover. The first step made was a Gage R&R (Fig. 2) of the measurement system performed by 2 operators using the same measurement tools and measuring the same pieces different times. As indicated in the comments in the figure below, the system is quite robust (see Fig. 2, first graph upper left corner): in the measurement system variation the greatest contribution was given by the real differences among the parts considered, while the less was due to the 2 aspects of the system reliability taken into consideration: repeatability and reproducibility.

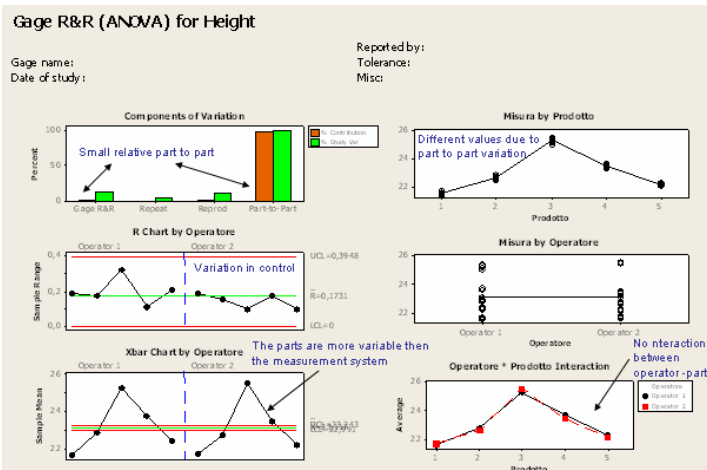


Fig. 2 – Gage R&R: 2 operators and 5 components

Other information may be collected as the range of the measures of the operators (middle graph on the right), interaction between operator and part (see Fig. 2, bottom right graph) in order to notice if operators may have different behaviour on a specific part.

Once that measurement system is validated and after making the proper data collection plan and schedule, the measures are collected and showed using proper statistical tools. Different tools may give different information. According to the problem, project leaders may need different information; therefore there is a specific tool for “all the seasons”.

For a correct deployment for further actions, surely the first absolute step is to get all the basic descriptive statistical data regarding the process. Mean, Standard Deviation and Normality Test may give important clues regarding the considered process. Graphics as Histograms or Box Plot may help in getting ideas of the data distribution (see Fig. 3).

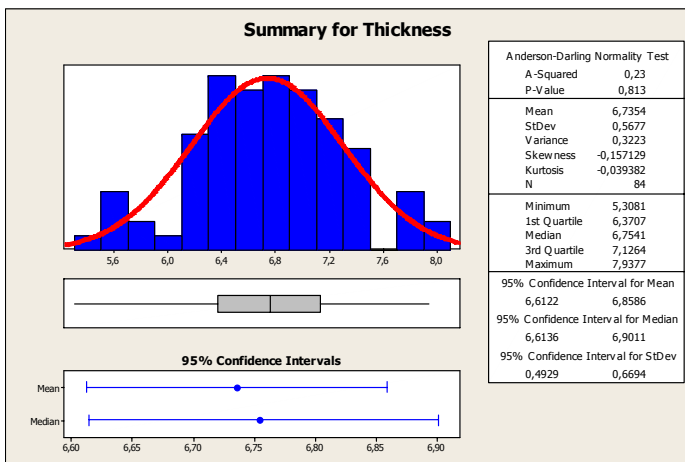


Fig. 3 – Descriptive Statistics Basic Information. Thickness of certain metallic plate

One common statistical tool used is the Control Chart. It gives information regarding the evolution through the time of the performance of a certain process, verifying if the process is stable or not. The stability of a process is broken up whenever a

“Special Cause” appears. The easiest Special Causes to be seen are those that are coming out from the Control Limits (the border of the usual Voice of the Process, VOP, according to the data collected); but other may come out: Trend (some consecutive points increasing or decreasing); Saw tooth (some consecutive points alternatively up and down); Shift (some consecutive points on the same side of mean). Special Cause must be absolutely recognized in order to act properly and avoid them in the future. In the following example, that considers the reduction of the defects coming out from a moulding system, the scope is defined by considering 4 different moulds able to produce the same piece. The example provided (in Fig. 4) is considering the Control Chart of a single mould and the Special Cause (one out of the Control Limits (1) and one trend (2)) are immediately recognized.

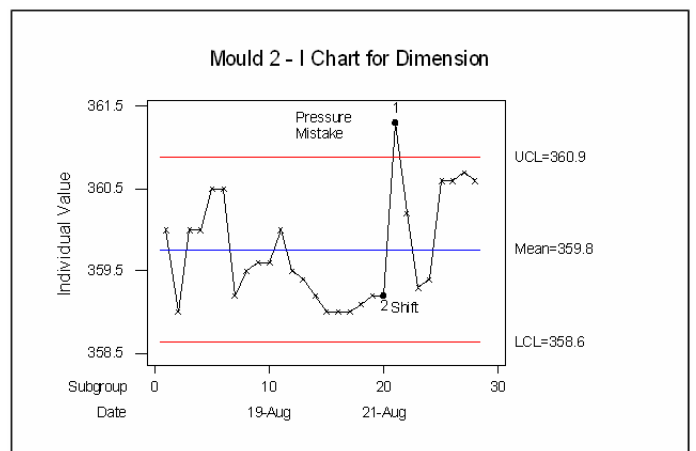


Fig. 4 – Individual Control Chart for door length with 2 recognised Special Cause

Other information on the single moulding machine could be the ones connected to the Capability Analysis. The Capability Analysis pinpoints if the process considered is able to meet the specifications or not. The information maybe used in order to understand if by making minor or major changes the process would be able to perform according to the VOC.

In this example (Fig. 5, coming from the same project of the

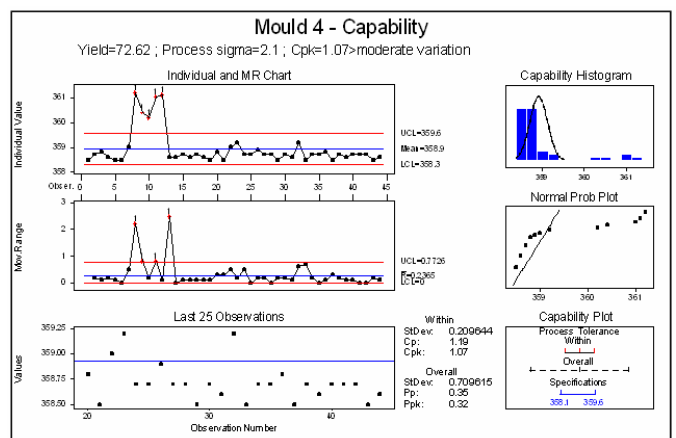


Fig. 5 – Capability of a Process, broad information

moulds) the Capability of a single machine is studied. In the graph bottom right we have the comparisons between the specifications, the short-term Capability (Within) and long-term Capability (Overall). Even if the process in short-term is able to meet the specification (USL = Upper Specification Limit and LSL = Lower Specification Limit), in long-term could have some instability problems (Overall bigger than the specifications).

Other tools that may give some specific information could be the Stratified Time Series Plot. This graph is able to consider different discriminants (operators, equipment, machines etc) in order to make a comparison of different performances through the time. The example regarding the moulds is lining up the 4 machines in the project Scope so to have an overview of the performances and to check when eventually they perform differently.

In the example (see Fig. 6) the measure collected is the length of a fridge door; the specification range is 358.1-359.6. The different marks indicate the single machine performance. It was realized that equipments were performing really differently. M3 and M4 very far from each other while M1 and M2 closer. Further consideration had to be done.

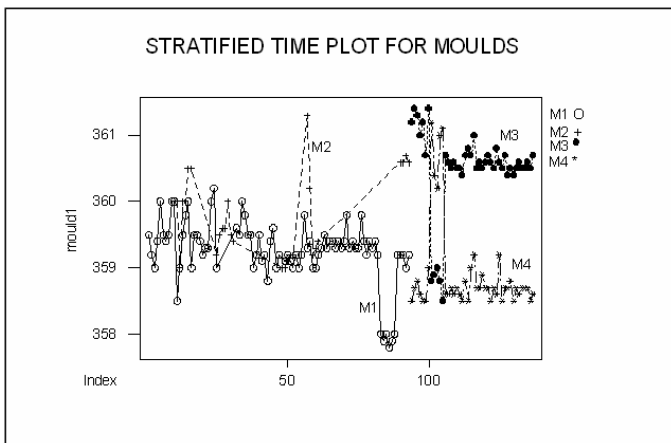


Fig. 6 – Stratified Time Series Plot for 4 different moulds

Analyze (the third phase of the DMAIC) through the study of the data and the information-collected points out the causes of the problem considered. The main result of this phase is to release a theory regarding the problem occurrence that is tested and confirmed by the results. It is mostly characterized by:

- finding variables correlation (Scatter Plot, Matrix Plot, Regression);
- finding cause-effect relationship (Cause-Effect Diagram);
- analysing statistically significant differences among variables that may influence system response (Hypothesis Testing).

The Analyze phase is divided into 2 sub-phases: the first is qualitative and graphical; the second has the goal of testing the cause according to some hypothesis in order to verify if they have a statistical significance or not (quantitative).

Example:

Considering the first sub-phase (Causes finding and definition), the most common tool is the Cause-Effect Diagram (or Fishbone or Ishikawa diagram). After having indicated the problem, it helps

in retrieving causes (grouped in families) and in brainstorming, once all the causes are “on the table”, to find the most probable one. The example shown in Fig. 7 regards the problem of absenteeism (in the graph is the effect or head of the fish) and has defined 4 families that may group the causes (different Major Lines or Major Bones). Under those big families, the single causes are billed.

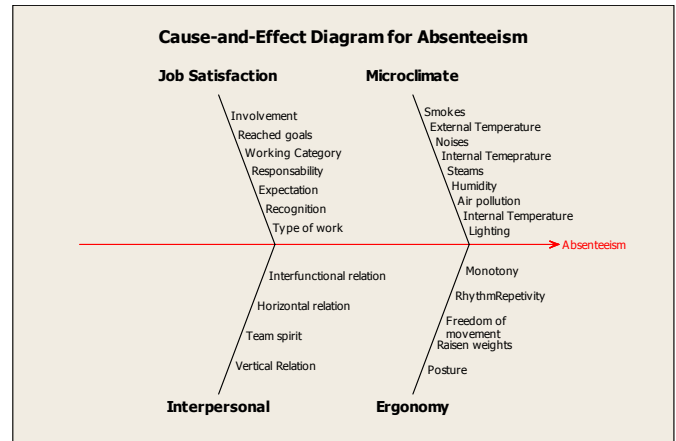


Fig. 7 – Fishbone Diagram for an Absenteeism problem

One good tool to be used in the second sub-phase (the test of the causes, also known as Hypothesis Testing) is the ANOVA. The ANOVA test, to be used with continuous data and at least 2 groups, is checking if at least a group of data collected (referred to operators, machines, shifts etc.) is behaving in a statistically different manner from the others or not. This provided example (Table 1) is considering the evaluation of a cycle time to perform a hole of the same diameter in an aluminium plate in a defined corner. The ANOVA is studying and pointing out if at least one of the 5 equipment considered performs differently from the others while making the same work, and verifies that difference is consistent with reality.

One-way ANOVA: LEFT versus OPERATOR					
Analysis of Variance for MIDDLE					
Source	DF	SS	MS	F	P
OPERATOR	4	15,338	3,839	19,00	0,000
Error	128	25,867	0,202		
Total	132	41,225			
Individual 95% CIs For Mean Based on Pooled StDev					
Level	N	Mean	StDev	-----+-----+-----+-----+-----+	
A	30	9,5657	0,4468		(---+---)
B	30	9,4940	0,4280		(---+---)
C	29	8,7590	0,4440	(---+---)	
D	22	8,9500	0,5006	(---+---)	
E	22	8,9041	0,4356	(---+---)	
-----+-----+-----+-----+-----+					
Pooled StDev = 0,4495			8,75	9,10	9,45 9,80

Table 1 – ANOVA of a Cycle Time to perform a hole in aluminium plate, having 5 equipment

Apart from a graphical consideration (A and B are different from C, D and E) the easiest numerical information is the P-Value (P in the Table 1). If the P-value is less than an threshold value, the Null Hypothesis (the one to be tested) is rejected.

Improve (the fourth phase of the DMAIC) is based on the elaboration, the production and the implementation of the solutions to the problem, when the causes have been already

identified and tested. The main result is to have a sequence of actions that tries to improve the process. It allows reaching:

- process knowledge, by considering the selection of different leverages that maybe used to improve the process performance: the actions taken will be enabled by a statistical warrant of success;
- decision making on the base of the data collected;
- solution implementation through a work program and a detailed plan of action; in this phase we decide how to monitor the process stability (Control).

Example:

As the Improve phase is designed to study the solution to a certain problem, it could be still needed to disclose some important aspects that may influence the problem to occur again. One of the most common tool in Improve phase is DOE (Design of Experiments) in order to catch the influence of some factors or different combination of established factors, on a certain measure/result. DOE makes possible to explore in a more detailed form the relation between some causes and the effect aiming at:

- identifying “vital few” causes;
- identifying the impact that those causes may have on the effect;
- identifying causes’ interactions;
- identifying an equation to predict the effect (prediction equation).

In the following example a DOE is performed to study the influence of 3 factors (base material, pressure and heat) on the number of balls found on 1 Kg of “green” glass (the less balls, the better is the glass quality). Two values for each factor are set and results are collected in Table 2. In this table all the combination are explored with two repetitions in order to check Common Cause variation.

StdOrder	RunOrder	MATERIAL	PRESSURE	HEAT	BALLS
14	1	A	2	100	18
12	2	A	2	50	5
1	3	B	1	50	9
16	4	A	1	100	21
8	5	B	1	50	7
2	6	A	1	50	21
9	7	A	2	100	18
15	8	B	2	100	26
13	9	B	1	100	15
6	10	B	2	100	22
3	11	A	1	100	17
7	12	B	2	50	16
11	13	A	1	50	10
5	14	A	2	50	12
4	15	B	1	100	21
10	16	B	2	50	13

Table 2 – DOE to improve the quality of glassware. Factors definition and Results Collection

Whenever there is a need to explore in a more accurate way the Cause and Effect relations so to act on Causes to improve the Effects, another tool could be used: the FMEA (Failure Mode and Effect Analysis). As it is commonly used both in Analyze and Improve phase, FMEA has the basic goal in making a fully detailed analysis of all the failure modes of the components in a product and in estimating the impact of these failures on product performances and characteristics. The analysis is made through the proper combination of indexes (Severity, Occurrence, Detection) that supply a priority order (Risk Priority Number) of

the needed actions so to reach the imposed reliability goals. In the example shown below (Table 3), the FMEA considers a Front Door in a car and all the aspects of its components’ failures.

Control (the fifth and last phase of the DMAIC) represents the logic conclusion of this structured approach. It allows to validate the implemented solutions, it uses on going data to evaluate the goodness of the actions, it tries to acquire and standardize the new solution as part of process and it allows a continuous monitoring system. In real term Control makes possible to:

- verify goodness of the previously defined actions taken;
- validate the used method that has given these results (the new “modus operandi”);
- verify possible extension to other business areas of the found solutions;
- standardize the new actions integrating them in the existing process.

Item Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s)/Mechanism(s) of Failure	Occurrence	Current Design Controls	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results																																	
											Action Taken	Severity	Detection																															
3. Front Door	Corroded interior lower door panels. - Ingress to and egress from vehicle. - Occupant protection from weather, noise and side impact. - Support anchorage for door hardware including mirror, hinges, latch and window regulator. - Provide proper surface for appearance items - paint and seal	Deteriorated life of door leading to: - Unsatisfactory appearance due to rust through paint over time. - Impaired function of interior door hardware.	7	Upper edge of protective was application specified for inner door panels is too low.	6	Vehicle general durability test with: T-118 T-109 T-301	7	234	Based on test results (Test No. 1481) upper edge spec raised 125 mm.	A Pippo Body Engineering - 11/9/2003	Based on test results (Test No. 1481) upper edge spec raised 125 mm.	7	2	2																														
												Insufficient was thickness specified.	4	Vehicle general durability test with: T-118 T-109 T-301 - Detection	7	198	Add laboratory accelerated corrosion testing Conduct Design of Experiments (DOE) on was thickness.	08/11/2003	Test results (Test No. 1481) show specified thickness is acceptable.	7	2	2																						
																				Inappropriate wax formulation specified.	2	Physical and Chem Lab test - Report No. 125 - Detection	2	28			7	2	2															
																											Entrapped air prevents wax from entering corner/edge access.	5	Design aid investigation with nonfunctioning spray head.	8	280	Add team evaluation using design aid buck and spray head.	Body Engineering & Assy Ops - 11/9/2003	Based on test, additional vent holes will be provided in	7	1	3							
																																			Wax application plugs door drain holes.	3	Laboratory test using “worst case” wax application	1	21			7	3	1
																																										Insufficient room between panels for spray head access.	4	Drawing evaluation of spray head access. - Detection

Table 3 – FMEA for a Front Door in a Vehicle

The goal of this phase is to check if a solution has improve the situation, the common approach is to reconsider all the tools that have been used in the measure phase so to control if the changes adopted, the solutions implemented are giving those results expected. Basic descriptive statistics information along as Control Charts are fundamental elements that could be used so to have information regarding the evolution of the performance to see if it is improved or not.

In the example in Fig. 8, it is possible to underline differences between before and after solution so to evaluate the goodness of a certain solution that aims at increasing the viscosity of airplane varnish. This example is considering 2 control charts: the Individual (all the data are independent one from the other) and the Moving Range (that draws differences between 2 consecutive data).

If the results are far from what was expected then a rethinking of the project is to be done through a possible jump to the previous phases (Define, Measure, Analyze, Improve) so to review the work properly or to reconsider some details.

But if the goodness is proved, then the solution is to be integrated in the new work procedure by making a standardization of the new working process.

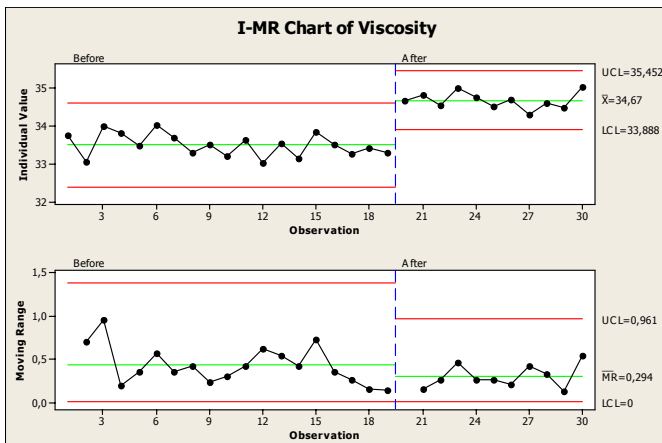


Fig. 8 – Individual and MR Control Charts to study viscosity increment after solution is implemented

Suggestion regarding a possible standardization procedure could be:

1. getting proper information regarding work environment (place, documents, procedures etc.);
2. check the differences between the old and new procedures and update the old ones by integrating the changes guaranteed by the solution;
3. implement the new standard to be used continuously;
4. monitor the new process.

The end of a project, indicated by the results collected during the Control phase, is not completed unless the lesson learning is not shared inside the people belonging to the department or to the company. The spirit of the Lesson learning sharing is to promote the results, method and the work but is also to verify if the information provided by the project completed maybe used in other business contest or in other working areas.

3. CONCLUSIONS AND COMMENTS

Summarizing, it is possible to say that Six Sigma is at the same time culture, method and project: it may be considered as a “strategic science”, strongly customer oriented, whose effectiveness (measurable through the successful projects financial benefits) is at the top level when it permeates the business context and environment. In this very sense an innovative strength is based on the great flexibility and adaptation to different business processes, through a practical and operative at once (On the Job Training) form of its education system: Training and Coaching, (the art of learning and applying developed and comprehended all together).

Taking advantage of the tools/methods synergy (today Lean Six Sigma is very spread), companies may implement a new culture aimed at obtaining financial benefits already from pilot projects.

One of the greatest key issues is the improvement opportunities identification and selection. The choice of the right process, correctly defined in terms of scope, involves key actors and ensures not only involvement, but the proper commitment too, allowing an easier implementation process and more effective results. Six Sigma tools may be applied not only to production

processes but also to those processes that mostly may characterize the business (transactional processes). Correct use of the tools will push business to high quality standards considering that a “must” is that companies begin to speak the same language of the customer and suppliers begin to speak the same language of the companies (Partnership).

This new approach starts from a company processes assessment (e.g. Lean Six Sigma Assessment, Companies Dashboards) mainly moving the first step from the measures (that have to be objective and reliable, not pure opinions); then it goes to develop future state map (possible scenarios) according to feasibility and cost/benefit tradeoffs. Lastly the method and consequently the reached results are properly evaluated and validated, so to have a robust stability in the examined process. The success of the processes implementation is strongly influenced by setting a step-by-step involvement of the different actors by focusing on some specific Change Management actions.

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