Improving performance with Six Sigma. A case study of an aeronautics SME

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Abstract

Although continuous improvement methodologies to enhance quality are virtually indispensable in aeronautics, Six Sigma (6σ) implementations are scarce and all too often unsatisfactory. The literature shows that not having a model for achieving the targets may doom 6σ to failure. Our objective is to study the applicability of 6σ in aeronautics SMEs and identify the main success factors and obstacles to its implementation. Action Research is followed in an aeronautical SME supplier, where DMAIC is applied to a 6σ project. The findings suggest that success/failure depends on key factors, such as team commitment, the availability of resources and previous training.

Keywords: Six-Sigma; DMAIC; Quality; Aeronautics; Action Research

Introduction

Companies currently face the pressure of a challenging economic environment, and global uncertainty is a difficult hurdle to overcome. In this scenario, which requires a reduction in production costs while maintaining high levels of quality and reducing delivery times, the use of methodologies for the improvement of production and/or organisational processes would seem to be a very interesting proposition for any sector. This paper specifically focuses on the concept of continuous improvement in a firm in the aeronautics industry.

The aeronautics sector is especially interesting for the study of continuous improvement. This is a highly competitive industry, where the priority is ensuring safety and airworthiness. Due to their operating conditions, aerospace products are subjected to very high quality, reliability and sustainability standards. Therefore, the use of continuous improvement methodologies to enhance internal quality levels becomes virtually indispensable.

In recent years, there have been many incursions made into this sector with Lean Production and they have finally started to achieve excellent results (Crute et al., 2003; Mathaisel, 2005; Bhuiyan et al., 2006), particularly in regard to achieving an efficient supply chain (Alfalla-Luque et al., 2012; Sacristán-Díaz et al., 2012). The same is not true of Six Sigma, whose implementation has been scarce. Furthermore, although Six Sigma has been exploited by many world class organisations, there is still little documented evidence of its implementation in SMEs (Antony et al., 2008). This is coupled with a study of aeronautics companies that followed Six Sigma improvement programmes that shows that the outcomes in a non-negligible percentage (over 50%) of these were totally unsatisfactory (Zimmerman & Weiss, 2005). In the same vein, other studies for different sectors show similar results (e.g., Feng & Manuel, 2007). In most cases, it appears that the absence of a practical model for achieving the targets may doom the Six Sigma improvement project to utter failure.

This last point is an incentive to conduct a study of the specific case of a Six Sigma project implementation at a company in the aeronautics sector. The objective of this paper is to study the applicability of Six Sigma in this context and to identify the main success factors and obstacles to its implementation.

Six Sigma projects implementation. Key factors and obstacles

Two key aspects of Six Sigma are usually combined for its definition (Harry & Schroeder, 2000; Linderman et al., 2003; Kwak & Anbari, 2006): the maximization of financial performance that is typical of any business organisation, and the way to achieve it (reducing waste and increasing customer satisfaction). So, Six Sigma is considered as (a) a business strategy used to improve financial performance and the effectiveness and efficiency of all operations with the primary objective of satisfying customer needs, as well as (b) a statistical tool which pursues defect rates of 3.4 units per million (equivalent to a quality level of 99.9997%) where sigma is a term representing the variation or standard deviation from the mean of the process.

Originally, Six Sigma was applied to purely manufacturing processes, but quickly spread to other areas, such as marketing, engineering, purchasing, the service sector, etc. (Zimmerman & Weiss, 2005; Kwak & Anbari, 2006; Feng & Manuel, 2007). Thus, Six Sigma has evolved from its application merely as a quality tool to be included as one of some companies' core values as part of their philosophy of action.

Most studies reported on Six Sigma implementation emphasise the same obstacles and the same key factors on which its effectiveness lies. Thus, the following should be considered to ensure the success of a Six Sigma project (Antony & Banuelas, 2002; Johnson & Swisher, 2003):

- There must be the real and visible commitment of senior management, it must be communicated to all members of the organisation, and resources must be allocated to maximise results.
- The organisation must have a clear understanding of Six Sigma methodology and the tools needed to achieve technical objectives.
- A real connection must be established between Six Sigma and business strategy.
- Organisational, human and material structures will be needed that dovetail with Six Sigma.
- There must be a cultural shift towards Six Sigma.
- The team must develop typical project management skills if Six Sigma projects are to be chosen and seen through properly.
- The Six Sigma culture has to be transmitted to the supply chain.

- An ongoing Six Sigma methodology training programme must be set up for participants.

Moreover, many of the improvement methodologies that organisations use to enhance the performance of their processes often involve deep, mainly structural, changes that sometimes produce rejection from workers. Six Sigma compounds these potential setbacks even further since its success depends largely on the training that workers receive and, therefore, on a profound cultural change that enables this methodology to be assimilated with sufficient efficiency.

The main obstacles that an organisation can encounter when considering using Six Sigma to improve some of its processes might come from one of the following sources (Kwak & Anbari, 2006):

a) Problems arising from the strategy: to ensure the long-term sustainability of this methodology, organisations need to know what their strengths and weaknesses are, and assess whether they are prepared to integrate Six Sigma into their strategy.
b) Problems arising from organisational culture: organisations that do not integrate this concept and do not make the changes that the use of Six Sigma involves are likely to fail in their objectives. Likewise, if there is no commitment and support for the use of resources, Six Sigma adoption should not be considered.
c) Problems arising from the demanding training programme that its adoption requires (Belt Program): the training programme should start from the top management down and be applied throughout the organisation. It should provide the routine for taking both qualitative and quantitative measures from processes, as well as the acquisition of project management skills that allow the organisation's specific needs to be known precisely and conclusively. Members of the work team should receive specific training according to their relationship with the process studied and the function that they perform within the team.

Regarding SMEs, a pilot survey in UK manufacturing firms showed that SMEs are not aware of Six Sigma and do not have the resources to implement Six Sigma projects (Antony et al., 2008). Together with this, the low implementation of Six Sigma in the aviation industry, perhaps due to some particular characteristics of the sector (volume of production, long production time, etc.) means that its implementation in aeronautics SMEs poses an even more difficult challenge.

Methodology

Although a large volume of literature is available on Six Sigma, the topic is still under development and the case study is the dominant empirical research approach (Aboelmaged, 2010). For this study, Action Research (AR) is the methodological approach followed. This is an approach capable of producing research that, while making contributions to theory, is of special value for practitioners (Westbrook, 1995). One of the authors worked on the Six Sigma project at the firm being analysed for three months. This has enabled a close detailed study of the system, interaction with company members, and learning through the practical implementation of the activity (Coughlan & Coghlan, 2002).

This research has specifically focused on problems in the aerostructure final paint area in an organisation in the aeronautics sector: a newly established company focusing on responding to the aeronautics industry in integral management services, from raw materials to build-to-print subassemblies. Its productive organisation is based on three core technologies: machining, surface treatments and assembly.

The company where the project has been carried out had some serious quality problems in the aerostructure final paint area in some of the contracted programmes. A Six Sigma Committee was created to address these problems. It comprised the person responsible for production in the painting area (playing the champion role), someone from outside organization and a co-author of this paper (Black Belt), the person in charge of verification (Green Belt), and the operators that owned the processes analyzed. The members of the team were instructed in Six Sigma methodology with the aim of conveying the importance of the project and asking all participants to create synergies that favoured continuity and the rapid deployment of solutions.

Once the Six Sigma Committee had been instructed, several brainstorming sessions were held. The problems aligned with the organisation's business strategy that best adapted to the methodology according to the selection criteria (viability, business benefit and impact on the organisation) were set out, especially taking into account the feasibility factor.

Two possible projects were considered for analysis (PG001 and PG002). After analysing these projects on the basis of the definition given in the Project Charters, the project prioritisation matrix (Table 1) was developed with the evaluation criteria that the company considered of greatest interest.

Table 1 – Six Sigma project prioritisation matrix

ASSESSMENT CRITERIA / PROJECTS	Impact on costumer	Potential savings	Team availability	Data availability	Fast delivery	Alignment with strategy	Criterion weight x score	Likelihood project will succeed	Final assessment of the project
PG 001	C	A	B	C	B	C	120	+	**360**
PG 002	A	C	B	E	E	A	123	-	123
Criterion weight	⊙	□	□	⊙	□	⊙			

Project criteria matrix	
A	5.00 Exceeds the total fulfilment of the criterion
B	4.00 Full compliance of the criterion
C	3.00 Meets essential aspects of the criterion
D	2.00 Partially meets the criterion
E	1.00 Slightly meets the criterion
-	0.00 Contravenes the criterion

Criterion weight		
⊙	9.00	Very important
□	3.00	Important
▲	1.00	Slightly important

Likelihood of the project succeeding		
++	9.00	Very high likelihood (> 90 %)
+	3.00	High likelihood (70 % - 90 %)
-	1.00	Risky project (< 70 %)

From this matrix, the Six Sigma Committee decided to study the defects presented in PG001. The improvement pursued consisted of reducing the number of defects in the finished B-777 aerostructures that caused a high rework rate with consequent costs and delays. A DMAIC (Do/Measure/Analyse/Improve/Control) cycle was followed for process improvement (Mast & Lokkerbol, 2012), which is the most common way that a Six Sigma project is executed. Various Six Sigma tools were used at each stage, including Project Charters, Flow charts, checklists, Ishikawa diagrams, FMEA and p-charts.

Results and discussion

With the problem to address selected, the Six Sigma team applied the DMAIC methodology for process improvement. The agreed schedule, as shown in Table 2, was kept to, except for small deviations. Below, we summarise some of the activities and results of each step.

Table 2 – Timeline for the project

	2013													
STEPS	MAY					JUNE				JULY				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project selection														
Define														
Measure														
Analyse														
Improve														
Control														
Project closing														

Define step

In this step, both the project objectives and the constraints were defined, i.e.: the problem to be solved and how it was to be measured.

Firstly, although the defects and high percentage of non-conformance products (NCP) in the Boeing package components (around 70% of parts reprocessed on one or both sides) was both well-known and a major problem, except for the information provided by the people involved in the processes (VOE, Voice of Employees), there was a patent lack of data for the starting-point to be determined. However, the objective set was as big a reduction as possible in the number of defects, with 10% regarded as a realistic target.

A data collection plan was also prepared. For this, both the definition of an NCP and the way that the information was to be gathered had to be clarified. For the former, the Critical to Quality features (CTQs, Y variables) included in the customer standards (Boeing Process Specification, 2012) were taken into account. There were 13 of these: pores, lumps, orange-peel effect, cracks, etc. For the latter, check-lists were prepared to collect data on the number and types of defect for each of the references processed (as well as on product conformance or non-conformance), the area where the defects were concentrated on plan types, and the plan that located the part in the paint booth.

A major point in the DMAIC cycle definition phase was the preparation of a flow chart of the way the Boeing package parts were processed. This included all the operations carried out from the time that the package was signed in to the organisation's facilities until delivery was signed off. The chart was also used to identify and quantify NCP costs that were attributable to reprocessing. These costs could be broken down into labour, paint, power consumed by tools (sander, spray gun, dryer blow gun, etc.), direct process-linked costs (electricity and fuel consumed by the generator) and other nonquantifiable costs. These last include issues such as operator burnout (never-ending job repetition and not being able to devote time to other productive processes), disputes between operators, loss of capacity to reprocessing time that could have been devoted to getting delayed work back on track or increasing the number of processed parts, etc.

It was estimated that 70% of processed products required reprocessing during the weeks running up to the start of the project. As monthly production of these parts stands at around 28 units (with the 3/1 ratio between flaperons and flaps), non-conformance products were estimated at 14 NCP units out of 20 flaperons processed, and around 5 NCP units out of 8 flaps processed.

This information was used to make an initial estimate of the total monthly value lost to the quality problems analysed, with a final figure calculated of €3,440.85.

This same information was used to calculate the defect rate per million opportunities (with each of the 13 types of defects listed in the customer standards counted as an opportunity) and, subsequently, the initial sigma quality metric for the process, which was 3.36.

Measure step

This phase included executing the information collection plan designed in the previous phase. This plan laid down the parameters that the work team considered that it would be interesting to monitor (defects and their location in parts, product parts for traceability, aerostructure positioning in the paint booth, etc.). Workers involved were also instructed as to the steps in the process; specifically, the OCIs and painters, so that data could be collected efficiently.

The data collection forms recorded the defects detected in the parts checked during the finishing phase according to the customer standards and were used to quantify these defects according to the most interesting evaluation criteria for decision making on the conformance of the part. There were three aspects to these evaluation criteria: quantity, size and location. Each of these was measured on a discrete scale of 1, 3 and 9. The arithmetic mean of these aspects provided an indicator of the seriousness of the defect which enabled part conformance or non-conformance to be specified. Plans/graphics were also used to show where the defects were located on the parts and where these parts were placed in the paint booth.

Information gathering during this phase lasted 5 weeks and was used to draw up a sufficiently coherent Pareto diagram to allow some initial conclusions to be drawn. The diagram showed that around 50% of NCPs were mainly caused by impurities. This pointed to dirt and dust in the air and in the paint booth being the main cause of the defects found. The second most common defect (around 13.5%) was caused by the presence of pores during the paint-drying process. These could have been caused by the inadequate preparation of the paint. Finally, silicones (lack of sticking-power) were the third most important cause of defects that resulted in NCPs (around 13%). These three types of defects together fulfilled the 80/20 rule.

Once the data had been collected during this phase, the next step was to verify the process metrics. Defects per million opportunities generated were again determined using the data collected during the first four weeks of the plan being in operation. At the same time, some measures were already urgently being put in place during this period with regard to the cleanliness of the paint booth. This enabled the process sigma to be more accurately valued with a quality level of 3.42 being obtained. Accumulated losses of €2,479.32 were also calculated during this phase.

Analyse step

During this phase, the possible causes (X variables) of the defects in the processed parts and, therefore, their non-conformance, were identified on the basis of the previous considerations and bearing in mind the deep knowledge that work team members had of the process.

For this, a number of both formal and informal meetings were held between the work team (VOE) and operators in the paint area (VOP–Voice of the Process) that enabled sufficient information to be gathered to establish the causes.

These analyses and the prior considerations that were taken from the Measure phase (Pareto Diagrams) enabled an Ishikawa Diagram to be prepared to classify the possible causes identified according to the 6 Ms (Manpower, Materials, Measures, Milieu (environment), Methods, and Machines).

A Failure Mode and Effect Analysis (FMEA) was also prepared during this phase for Boeing package aerostructures that included all the considerations made during the project regarding the potential causes that were identified and the effects that they might have. From the FMEA it was possible to prioritise the various causes of failure that led to the defects found in the parts. This analysis tool also enabled a list of the most urgent corrective actions to be drawn up according to the Risk Priority Index (RPI) using the product of the seriousness, frequency and detection capability of the causes of failure.

Improve step

As indicated, the FMEA carried out during the Analysis phase enabled the causes for the failure mode to be determined and ranked according to RPI. This was obtained from the tables in the FMEA reference standards. Once the causes had been prioritised, the actions that had to be taken to correct them were determined, and these are set out in Table 3.

Table 3 – Corrective actions implemented

Cause of Failure Mode	Corrective action	Head of	Target week
Dirt in paint booth (environment)	Scheduled booth cleaning (Every Monday 7am to 10.30am)	Quality and Production	Week 4 20/05/2013
	New production plan. FC A-380 paint jobs only after finishing Boeing or in a different booth. Booth study is only for Boeing finish	Quality and Production	Week 4 20/05/2013
	New filters installed in booth Maintenance plan as per planned production specifications	Quality and Production	Week 4 20/05/2013
	Water-washing of paint booth	Quality and Production	Week 4 20/05/2013
Dirt in processing elements storage area (Environment)	Use of nozzles in sanders to remove dirt caused by sanding elements	Quality and Production	Week 2 06/05/2013
	Change filters on full sanding. Use of physical separator	Quality and Production	Week 5 27/05/2013
Paint Quality (Material, Methods and Manpower)	Operator training (Technical Instructions as to how to carry out the painting)	Quality and Production	Week 7 10/06/2013
Dirt on elements (Methods)	Review handling and cleaning procedure. Writing up of finished process	Quality and Production	Week 9 24/06/2013
Improvement of environmental conditions (Environment)	Downlighter installation in Boeing area for defect detection	Quality and Production	Week 13 22/07/2013

Control step

For the objectives of this step to be achieved (the validation, verification and monitoring of the improvements put in place and for them to continue to be complied with and any reoccurrence to be detected so that it might be corrected in a timely fashion), data collection was then done for all the references processed according to the check-lists that had been prepared for this purpose. This phase covered weeks 8 to 11 and a p-chart was prepared with the data that showed the proportion of defective parts in samples of variable size (each sample corresponds to the number of verifications per week of production). The results of the graph led to the conclusion that the process was under control and that there had been an improvement that almost doubled initial operating performance.

At the same time, follow-up and monitoring of the process indicators during the control phase (percentage of non-conformance products, sigma quality control level reviewed, costs of poor quality, etc.) and the action plans for correction and maintenance established in the previous phases continued.

Closing the project and results achieved so far

Once the project was closed (22nd July 2013), the KPIs could be quantified and the Six Sigma project assessed.

During the 2½ months of the fieldwork, process performance measurements were conducted on different aerostructure samples (flaperons and flaps) at three different times. Table 4 shows the final improvements achieved in the four performance metrics that had been defined and the goals initially set.

Table 4 – Main results: improvements in quality and costs

Metrics	Description	Units	Initial (01/05/2013)	Goal	Current (22/07/2013)
Y1	Quality level	Units	3.35	4.5	3.68
Y2	Rework total time	Hours	75	10	15
Y3	NCP	%	70	10	22.5
Y4	Rework total cost	€/month	3,500	1,000	600

On the basis of the initial objectives, the Six Sigma Improvement Plan can be considered a success in economic terms (Y4), as the current cost is much lower than the initial objective. It can also be considered a success in terms of time (Y2) as, even though the initial objective set was not fully met, in only two months of intense work a considerable reduction was achieved in time devoted to reprocessing. The lack of maturity of the work team in such major projects might be the reason why all the objectives were not fully met, and this may be why an overly ambitious objective was set for the quality level (Y3). Nonetheless, this lack of experience was not a major obstacle to the project being executed as a matter of course.

On the other hand, this reduction has not been turned into a similar increase in sigma quality levels for the process analysed (Y1) in relative terms. However, it is a feature of Six Sigma projects that the mean time required to raise a quality level from 3σ to 4σ is usually around a working year, with the required investment in implementing the actions established and the dedication of the team members involved. It would therefore be of interest to continue collecting data and to keep the action plan in place in order to see how the above indicators develop.

Conclusions

The results of this project suggest that the degree of success or failure of the Six Sigma methodology implementation process depends on key factors rather than on the specific industrial sector. These include team commitment, the availability of resources, previous training and, in reference to certain unsuccessful previous experiences, the ability to perform each phase as planned, without any interference. Regarding the latter, it is worth noting that there were certain coercive pressures from the customer while the project was being carried out. These were related to the decision-making process with respect to the initial approach to problem-solving and the availability of resources, which, without affecting the continuity of the project, sometimes diverted attention from the problem in hand.

A future recommendation that the organisation might take into account is the skilling-up of a work group devoted to improving internal processes. While not being subject to external pressures, this group should not neglect any commitments to tractors. It should enjoy greater autonomy in these matters, bearing in mind the benefits that have been achieved in a simple project such as the one reported here, the nature of which, moreover, was markedly investigative.

Another aspect that should be highlighted is that during the execution of the project no feature was noted in the organisation, or in the specific area analysed, that would suggest that the aeronautics sector has any special characteristics as far as applying Six Sigma is concerned. It can be concluded in this respect that the methodology is very useful for improving processes irrespective of the sector, and that the DMAIC cycle is a practical and easy- to-follow guide for its application, even when work team members lack maturity in the area.

Acknowledgments

This research has been funded by the Spanish Ministry of Economy and Competitiveness' project No. DPI2009-11148, and by the Andalusian Regional Government's project No. P08-SEJ-03841.

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