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AN APPLICATION OF SIX SIGMA IN MANUFACTURING COMPANY

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Abstract:
This article presents an application of Six sigma into medium sized manufacturing company. Although there is a wider acceptance of Six-Sigma in many organizations today, there is still a lack of in-depth case study of Six sigma in the existing literature. Their production is typically individual for known customer.

For the presented research the case study methodology was used. The annual analysis shows that in the company higher importance should be given to non conformity process management. The company decided to reduce waste and improve selected process using Six sigma methodology.

Although all corrective and preventive actions have been defined and performed in details in accordance to the Six sigma methodology the final results of performed intervention will be known not earlier than at next annual analysis.

Regarding the fact that there is a lack of case studies dealing with Six sigma especially in individual manufacturing this article could be of great importance also for the practitioners. This paper presents a real case study illustrating the effective use of Six sigma methodology to reduce waste in individual manufacturing.

Key Words: Quality Management, Six Sigma, Case Study

1. INTRODUCTION

Six sigma is a philosophy and methodology that is gaining wide acceptance in the industry [1]. It has followed the TQM movements to improve quality, delivery and reduce costs. Although the tools and techniques in Six sigma are similar to quality management approaches, Six sigma provides different approach to the organizational structure. Despite a wider acceptance of Six sigma method in many companies there is still a lack of in-depth case study of Six sigma in the existing literature.

This article is divided into five sections. In addition to Section 1 (Introduction), Section 2 presents the literature review and contributions of previous research results. Section 3 describes the methodology used. In Section 4, the case study is presented and discussed in details. Finally, in Section 5, the conclusions of this study are presented, along with suggestions for future research.

2. THEORETICAL BACKGROUND

Six Sigma is a philosophy, a measure, and a methodology that provides businesses with a perspective and tools to achieve new levels of performance in both services and products. In Six Sigma, the focus is on process improvement to increase capability and reduce waste.

Six Sigma is a concept that was originally developed by Motorola in about 1985. At the time, they were facing the threat of Japanese competition in the electronics industry and needed to make drastic improvements in their quality levels [2]. Six Sigma was a way for Motorola to express its quality goal of 3.4 defects per million opportunities (DPMO) where a defect opportunity is a process failure that is critical to the customer.

Six sigma has two major perspectives [3]. The origin of Six sigma comes from statistics and statisticians. From the statistical point of view, the term Six sigma is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997% where Six sigma is a term used to represent the variation about the process average [4]. Fig. 1 shows the relationship between DPMO and Process Sigma assuming the normal distribution. If an organization is operating at three sigma levels for quality control, this is interpreted as achieving a success rate of 93% or 66.810 defects per million opportunities. Therefore, the Six sigma method is a very rigorous quality control concept where many organizations still performs at three sigma level [5].

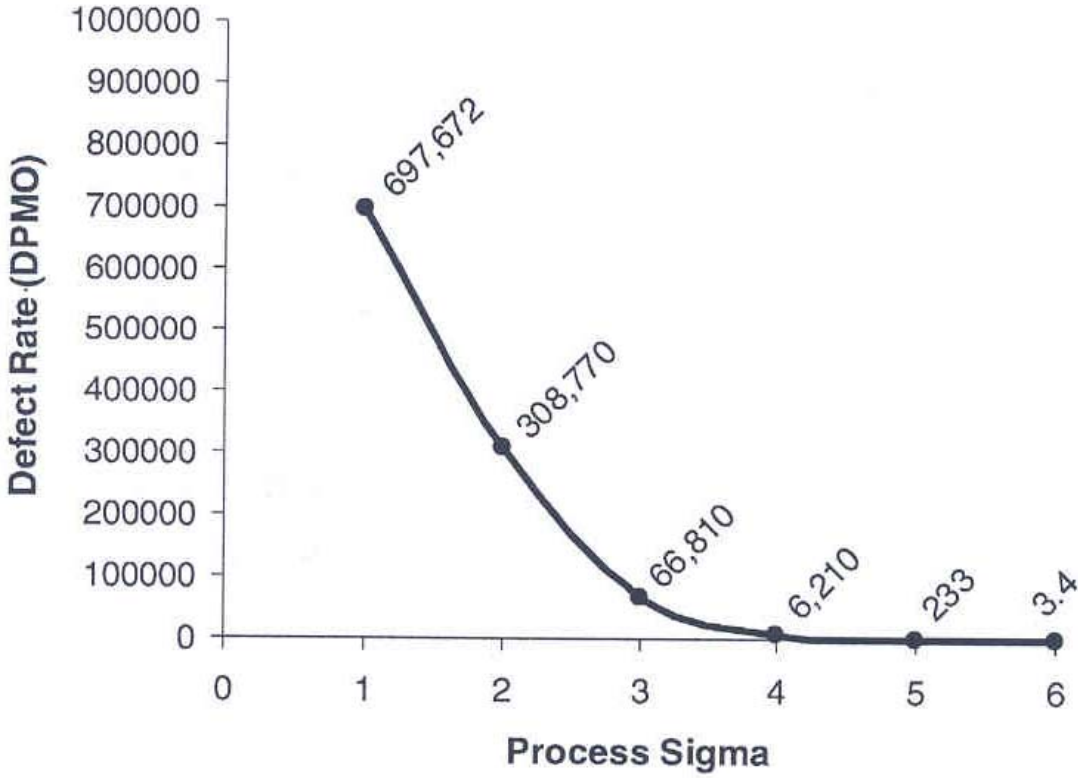


Figure 1: Defect rate (DPMO) versus process sigma level.

In the business world, Six sigma is defined as a business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customer's needs and expectations [6]. The Six sigma approach was first applied in manufacturing operation and rapidly expanded to different functional areas such as marketing, engineering, purchasing, servicing, and administrative support, once organizations realized the benefits.

2.1 Six sigma versus TQM

During the 1990s TQM was the dominant theoretical and empirical paradigm for quality management. At the first glance Six sigma looks very similar to TQM or other quality management approaches. However, leading organizations with track record in quality have adopted Six sigma and claimed that it has transformed their organization [7].

What is new in Six sigma? Distinction between Six sigma and TQM has been widely debated in literature [7]. Both TQM and Six sigma stress the importance of cross-functional design, customer input, design form manufacturability, robust design, and quality function deployment (QFD). What is different is that design for Six sigma (DFSS) emphasizes

following a structured method in design projects. Thus, the Six sigma design process is more prescriptive in nature than TQM.

In TQM the area of process management stresses clarity of process ownership, less reliance on inspection, statistical process control (SPC), total productive maintenance (PM), and process definitions [8]. Six sigma takes a somewhat different approach by stressing process improvement through the use of DMAIC or similar metaroutine for improvement. Similarities with TQM are Six Sigma's process ownership and clear process definitions.
Top management leadership is essential to both TQM and Six sigma [9]. One difference, however, is well defined structure in Six sigma that demands more involvement of leaders on improvement projects.

Training for quality is dramatically different between TQM and Six sigma. In TQM, training is typically provided for all employees in a 1-week TQM course [10]. Six sigma specialists are trained in different courses, differentiated by task (e.g. Black belt usually 4 weeks, Green belt 2 weeks).

Customer focus is an important element of TQM and Six sigma. In both TQM and Six sigma customer input is important at two levels: the organization and the project level.

2.2 Elements for successful implementation of Six sigma

Those who have implemented and practiced Six sigma agree that the most important factor for successful implementation of Six sigma is top management support and commitment [11]. Managers must be involved in the creation and management of the process management system, and also participate in projects themselves [12]. Six sigma should be part of everybody's job, including top management and senior managers – corporation, business unit or even department managers [4]. Without the top management commitment and support, the true importance of the initiative will be weakened [13].

Six sigma is a breakthrough management strategy, because it involves adjustments to the firm's values and culture for its introduction [4]. It also involves substantial change in the organization structure and infrastructure. Usually when important change occurs, the people in the organisation are afraid of the unknown and they do not understand the need for change. Some organization cultures are fear based. Mistakes are not allowed, and employees are used to hiding defects. Six sigma, on the other hand flourishes in an open and safe environment where defects are seen as improvement opportunities [14].

Six sigma organizations develop formal mechanisms to select Six sigma projects. These mechanisms involve senior management to filter out Six sigma project that do not have financial or strategic implication [15]. From this perspective the decision rights to initiate a project are allocated to senior management. In contrast, other approaches to quality have taken a bottom-up approach where are workers directly involved with the process initiate improvement projects. Giving the management the decision rights to initiate the project helps ensure that project selection is based on strategic importance and not on convenience.

Both manufacturing and service used full-time improvement specialists called Black Belts [7]. Typically, these specialists are trained in the Six sigma structured method through 4 weeks of training with hands-on experience in improving one or more processes. Many organizations also train most, if not all, employees assigned to projects in Six sigma basics. These individuals receive 2 weeks of training and are called Green Belts. There are also Master Black Belts who receive extensive training beyond the Black Belt level and whose main responsibilities are to serve as instructors and to provide technical assistance and mentoring [16]. For each Six sigma project an improvement team is formed, consisting of employees who had substantial knowledge of the process, and have had Green belt training. The team leader is a full-time Black Belt specialist, that report to the team's sponsor, the Champion, a member of senior management, usually trained in Six sigma basics.

Six sigma uses a structured method for process improvement called DMAIC (define, measure, analyze, improve, and control) method. DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applies technology

for continuous improvement. The key steps of Six sigma using DMAIC process are presented in table I.

3. RESEARCH METHODOLOGY

In the field of operations and production management the following research methods are mostly used:

- case study,
- survey research and
- action research.

Case research is one of the most powerful research methods in operations management [15]. This is particularly true in today's environment. There are several challenges in conducting case research: it is time consuming, it needs skilled interviewers, and care is need in drawing generalisable conclusions from a limited set of cases and in ensuring rigorous research. Despite this, the results of case research can have very high impact. Unconstrained by the rigid limits of questionnaires and models, it can lead to new and creative insights, development of new theory, and have high validity with practitioners – the ultimate user of research.

Table I: Key steps of Six sigma using DMAIC process (adapted from McClusky, 2000).

Six sigma steps	Key processes
Define	Define the requirements and expectations of the customer. Define the project boundaries. Define the process by mapping the business flow.
Measure	Measure the process to satisfy customer's needs. Develop a data collection plan. Collect and compare data to determine issues and shortfalls.
Analyze	Analyze the causes of defects and sources of variation. Determine the variations in the process. Prioritize opportunities for future improvement.
Improve	Improve the process to eliminate variation. Develop creative alternatives and implement enhanced plan.
Control	Control process variations to meet customer requirements. Develop a strategy to monitor and control the improved process. Implement the improvements of systems and structures.

4. CASE STUDY

4.1 Short presentation of the company

Flenco Group is a very innovative and reactive company, able to work closely with customers in a global strategy. It is present in European, American and Asian markets, to supply a wide range of products, in particular fluid auxiliary systems (gas fuel, lube oil water,...) or skids, for gas and steam turbines, piping, various components, cylinders, etc... The group is composed by five divisions:

- Fluid Systems, Power Generation, Oil and Gas
- Hydraulic and Pneumatic Cylinders
- Steel Frame Fabrication
- Hand Tools & Jacks Automotive Components
- Lubrication Components

and three controlled Companies:

- ALC Flenco Group – Adhesives and Tapes
- Biosolar Flenco Group – Renewable Energy Sources
- Biomasse Energia – Renewable Energy from Biomass

Flenco's main customers are GE Energy, GE Oil & Gas, Exxon Mobil, Man Turbo, Siemens, Alstom, Toshiba, Ansaldo Energia and others.

Flenco Group worldwide production sites are Flenco Trino, Flenco Slovenija, Flenco de Mexico, Flenco Ningbo, Flenco Huashen, Flenco East Europe. Flenco d.o.o. located in Ptuj, established in year 2000, is one of the Flenco Group production sites, qualified for production of Fluid Systems as Lube Oil, Gas Fuel, Liquid Fuel, Ingnition Gas, Water Injection and Chemical Dosing.

As a member of Flenco Group, Flenco Slovenia shares the knowledge and experience of the all group through communication channels as: Intranet, Video conferencing and use of AS400 as a common information tool.

Flenco d.o.o. as also other production sites is certified and possess following capability:

- ISO 9001 since December 2004
- PED 97/23/EC
- Welding: Welders and welding processes are qualified according to ASME IX std, EN287/288, AWSD1.1, AS/NZ 1554 Australian Standard
- Surface treatment capability according to: SSPC, ISO12944
- NDT Testing capability according to: ASNT, ASME, EN473 – certified by Third Part Institute

An example of Lube Oil System produced in Flenco d.o.o. is shown on Fgure 2.

Figure 2: Lube oil system (Petrobras, Brasilia).

4.2 Application of Six Sigma project in Flenco d.o.o.

Challenge of each company is to implement a good quality assurance system, assuring that all defined processes are under control and managing of those fulfil owner and customer requirements. But as many other companies our company is also daily facing with problem of weak, not properly defined and not controlled processes. Results of managing processes in such a way is pointed out in higher production costs, loosing customer's confidence and at the end, loosing also collaboration and confidence of employers.

Results of annual analysis performed by Head Quarter shows, that higher importance must be given to Non conformity process management. Flenco d.o.o. decided to improve this process using Six Sigma method as already done in previous cases.

Six Sigma project named ''6-Sigma NC Management'' started with establishment of Six Sigma Team, evolving all main process owners. We decided that members of Six Sigma Team will be responsible people, who are in charge of most important processes related to non conformities, have the knowledge and the power of changing.

In the first step of Six Sigma project named ''Define'' we had to found out what is our deficiency related to non conformities management. This task did not represent a big problem, because we were facing them day after day. We agreed that problem statement could be pointed out in three major items:

1) Our production process is composed from different production phases including different inspections, but the practice and consecutively annual analysis show that too many defects are discovered only at latest phases of production process. In our case this means that design (drawing) mistakes, non conform components and material as also other non conformities are detected only once the system is completely painted, assembled and finalised. In the worst case above mentioned non conformities are discovered by customer at final inspection. Consequences of too late non conformity

detection rise up several additional problems pointed out in insufficient time to manage a non conformity in a proper way and at the end, also in missing or non conform material at unit delivery.

2) Second problem that we are facing quite often we can call ''Problem of mixing material''. Delivery time of many components it's quite long and if we add up some unexpected troubles we came to the conclusion that in many cases components are not delivered on time. The consequence of late delivery results in unsuitable behaviour of operators: their target is to finish the work so they take and they use what is in their disposal. Deciding just on a short look, perhaps a component looks the right one, but the reason for non conformities are differences in small details that operators are not able to detect (different type, different IP protection, different material,...). The ground bases of this problem arise from not controlled storehouse management which allows the operators to take material from the storehouse without any consent.
3) The third problem represents the non conformity management itself. Once the non conform material has been detected and the reason for the non conformity can be applied to the supplier, a non conformity report to the supplier is issued by the Quality department Flenco Slovenia. Due to the fact that all material is ordered by Flenco Italy and all responsible persons for supplier contact seat in Flenco Italy, also the managing of non conformities start in their hands. A problem arise when a non conformity is vey urgent and it must be solved as soon as possible but purchasing department get lost in several non conformities received every day from different production sites. Another obstacle represents poor technical knowledge: not seeing and not knowing burning problem in all details it's hard to contact supplier and to manage the non conformity in a proper way. All listed facts represent a problem in the non conformity management system and prolong their resolution.

Above stated problems are as part of Six Sigma project represented on Figure 3. Second step of Six Sigma project named ''Measure'' represents analysis preformed on all data that Flenco has on disposal. Our analysis was based on Final inspection reports prepared by customers during Final inspections.

Problem Statement:

Non conform material detected only at latest phases of production process.
Consequence:

- No time to manage non conformities in a proper way
- Missing/ non conform material at final inspection and unit delivery

Mixing materials/components between different units
Managing non conformities lasts too long (takes too much time)

Figure 3: Problem statement.

In year 2008 Flenco Slovenia shipped out for different customers totally 81 units. During final inspections of the units below indicated non conformities have been found (Figure 4):

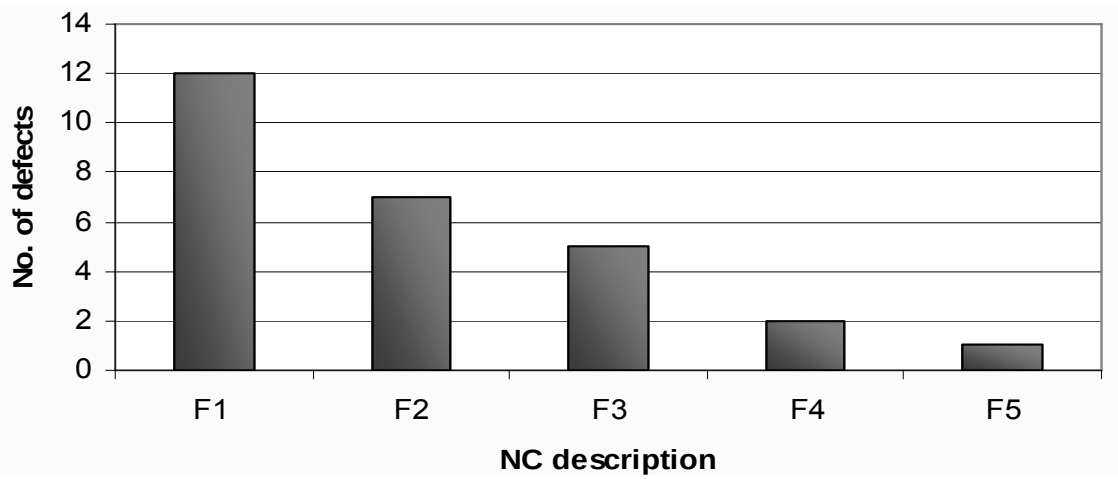
1) Material not in line with purchase order and customer request. None conform material was detected by the customer during functional test. Under this point we understand missfunction of components, wrong type of components and also wrong marking of components. The reason for this kind of fault could be wrong placed order, or wrong delivered material which doesn't match project requirements. From 81 delivered units in year 2008 we had 12 examples of non conform material found during final

inspection by the customer. This point represents the most critical point in our production process and an increased care must be paid on it.

2) Missing material at final inspection due to non conformity in progress. Each non conformity found during production process which is followed by a non conformity report, demands a certain time for the resolution. If this is not done in defined terms, it could happen very easily that non conform material is not replaced on time and an incomplete unit became a subject of an inspection. This was the case in 7 examples from 81.
3) Not completed Manufacturing data book represents the third most often fault found out during final inspections of units. Under this point we have in mind missing certification related to certain components as well wrong certification (wrong data mentioned on certificates, certification dossier not completed, unreadable copies, not approved certificates,…). Same as the previous case, also here the most important thing represents the order placement. Certification as component itself, is defined with order which must include all customer requirements. If this is not done in a proper way, we can confront many troubles including incomplete or wrong documentation. This was the case in 5 examples from 81.
4) Due to very long delivery time of many components, methodology planning ''just in time'' and some unexpected troubles that could came over, many components are not delivered on time and the system became a subject of an inspection although not completed. Fortunately this happened only twice.
5) An the last example of the non conformity found during final inspection which was noticed only once, represents problem of mixed material, as already described in above chapter under point 2).

To resume, there were totally 27 non conformities detected on 81 units and this represent quite a high portion (cca. 33%). Our performance objective is to reduce this portion to 10 %.

Major problems pointed out on Figure 3 and consequently performed analyses are not directly correlated with non conformity process management but we can find their root in an inappropriate managing of different production processes. That's the reason that Six Sigma Team decided to found out main causes for these problems. One of the most important steps of each Six Sigma Project is to define reasons for any problem and that's what we did.



Legend:
F1 - Missing material at final inspection*
F2 - Missing material at final inspection due to NC in progress
F3 - Manufacturer Data Book no completed (wrong/missing certif.)
F4 - Missing material at final inspection due to late delivery
F5 - Mixed material between different jobs

Figure 4: Project analysis.

For this purpose we took use of ''Fish bone'' diagram or in other words, ''Cause Effect Diagram'', as shown on Figure 5. Generally we call this step of Six Sigma project ''Analyse''.

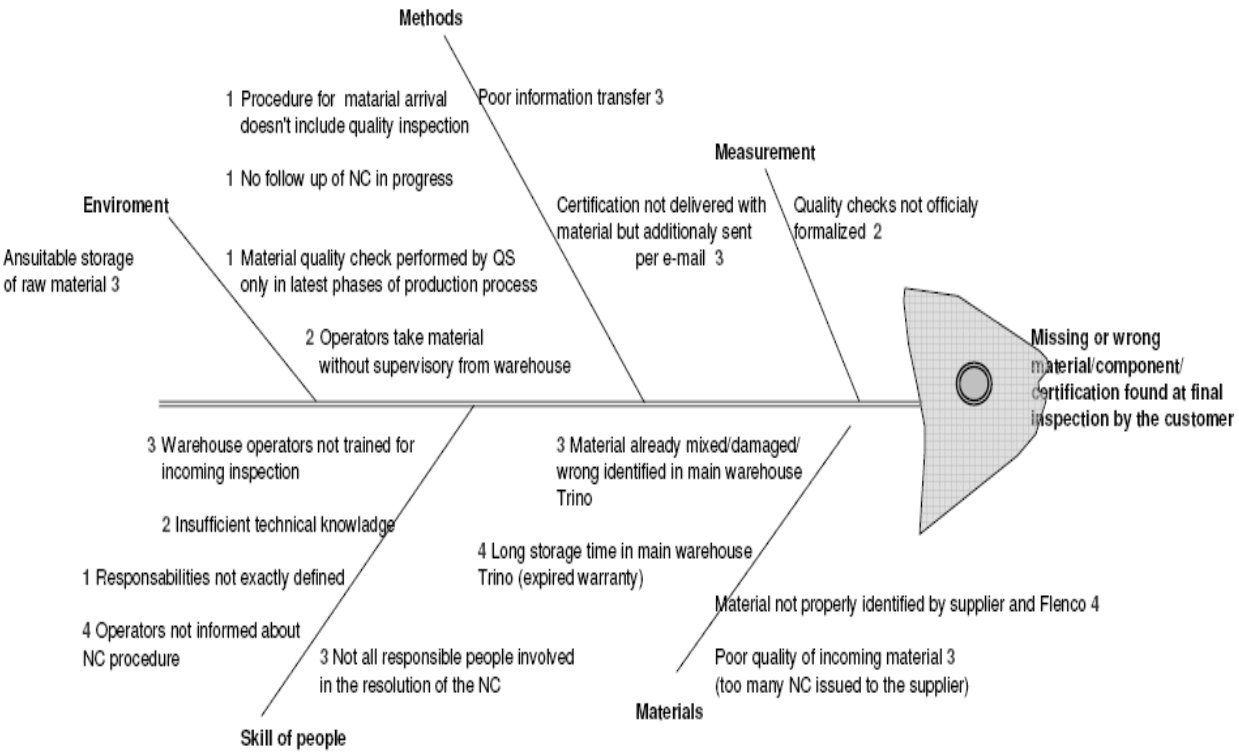


Figure 5: Cause effect diagram.

We think that root causes for our problems could be divided in five major groups: Measurements, Methods, Environment, Skill of people and Materials. Each defined cause has been evaluated according to impact and implementation, estimated from 1 to 4:

1 = easy implementation, high impact
2 = easy implementation, low impact
3 = hard implementation, high impact
4 = hard implementation, low impact

Using this tool gave us opportunity to think in a larger sense and to found out also these less important causes that we would never thought about but in a certain sense they could became very important for our process. Finishing with ''Cause Effect Diagram'' we all agreed that our current process for managing non conformities is not appropriate and it doesn't assure satisfactory follow up and in time resolution of non conformities.

Root causes evaluated with no. 1 represent the most critical characteristics, because their impact on process capability is high, but on the other hand, implementation of corrective action is estimated as easy.

Results of our ''Cause Effect Diagram'' show, that there are four vital characteristics (Xi) relevant for our non conformity management process:

1) Procedure for material arrival does not include quality inspection
2) Responsibilities concerning managing with non conform material are not exactly defined
3) Material quality and certification check performed only in latest phases of production process
4) No follow up of non conformities in progress

Once above indicated vital characteristics were defined, all further efforts have been directed to find appropriate Corrective and Preventive actions. This task represents the fourth step of Six Sigma Project, named also ''Improve'' step.

We analysed in all details each vital Xi and we tried to found out the most effective corrective action to improve these characteristics and consequently also our process. Our improvement plan is shown in table II. It is composed of corrective action description related to Xi, defining responsibility and target.

Table II: Improvements.

Xs	Corrective & Preventive action	Responsible department	Resolution status
1	Revise operative norm NO25 ''Warehouse Management'': - Including material quality check - Including procedure for managing non conformities Flenco d.o.o – Flenco Firenze - Update Check Cards	Quality Dep.	May,09
2	Revise general operative procedure PO-8.3-01 ''Non conformities Management''exactly defining responsabilities related to Flenco d.o.o. Translate and update NC flow chart in Slovene language and instruct all in NC process flow involved people.	Quality Dep.	May,09
3	Introduce material quality and certification check performed by QS department at preassembly phase. Include this inspection step for all units in standard QCP.	Quality Dep.	Finished
4	Introduce weekly meetings between Flenco d.o.o. and Flenco Firenze purchasing department responsible for NC resolution. Enable the access to NC log published on Flenco portal to all persons involved in NC process flow. Improve collaboration with suppliers (make them sensible for occuring foults)	Purch. Dep	Finished

We focused on actions that are easy to implement and they have a big impact on process management. Some of them are already implemented, the others will be implemented in the near future. In few wards we can resume that our goal is to improve our process introducing the following corrective actions:

1) All documentation related to the non conformity management process (operative norm Warehouse management, operative procedure Non conformities management, forms,…) will be revised adding missing inspection points and clearly identifying responsibilities. Involved people will be appropriately trained.
2) Enable access to Non conformity tracking log published on Flenco Intranet to all responsible people involved in non conformity management process.
3) Introduce weekly meetings between Flenco Slovenia and Flenco Italy purchasing department. This corrective action is very important to assure follow up of the non conformities in progress and in time resolution.

4) Improve collaboration with suppliers make them more sensible for accruing faults.

The last step of Six Sigma project named ''Control'' consists of monitoring and evaluating what we defined and established in previous steps. It's not enough to know that something is wrong with our process; it's also not enough to know what is wrong and how to improve it. The only real and right indicator showing us how successful we were improving our process, are the results. We were obliged to make some measurements and to define the capability of our process. Those measurements were useful to found our root causes and establish a corrective and preventive action plan. Once all corrective and preventive actions are implemented, additional measurements must be performed giving us information about actual status of process capability.

As shown in Table III Six Sigma Team decided to control following points:

1) Number of non conformities arises during production process divided per unit, customer and supplier.
2) Number of non conformities found at final inspection by the customer.
3) Manufacturing data book not completed at final inspection (missing certification)

Table III: Control chart.

Item	Control	Method	Responsible
1	No. of non conformities per unit and per supplier	Quartely NC analysis (follow up trend)	Quality Dep. Purch. Dep.
2	No. of non conformities found at final inspection by customer	Quartely Punch list analysis related to non conform and missing material (follow up trend)	Quality Dep.
3	Missing certification at final inspection	Quartely analysis of MDR delivered completed and on time	Quality Dep.

These are indicators that have been already discussed in previous chapter. Methods to control defined indicators will include detailed analysis based on non conformity reports issued to the supplier, internal non conformity reports and punch lists prepared by customers during final inspections.

5. CONCLUSION

Although Six sigma has wider acceptance in organizations today there is still a lack of detailed case studies. This paper presents a real case study illustrating the effective use of Six sigma methodology to reduce waste in individual production. It illustrates in detail how the project was selected, and how the define, measure, analyse, improve and control phases of the Six sigma DMAIC methodology were carried out.

The company decided to reduce detected non conformities at final inspection from 33% to 10%. In Six Sigma terminology that would mean to move from 1σ to about 3σ.

Although all corrective and preventive actions have been defined and performed in details we still don't have the final results of our intervention. For the moment we can not say that trend of non conformities is decreasing because till now no further analysis have been performed. But we can assure that this management tool has also many other benefits beside results that we are all impatiently looking for. It rouse up collaboration spirit, we were forced to share our opinions and ideas and also to accept other's kind of thinking. And that's the benefit that Six Sigma is giving us.

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