3rd International Conference on Industrial Engineering and Industrial Management
XIII Congreso de Ingeniería de Organización
Barcelona-Terrassa, September 2nd-4th 2009

SIPOC: A Six Sigma Tool Helping on ISO 9000 Quality Management Systems

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Keywords: SIPOC, ISO 9000, Quality Management Systems, Six Sigma.

1. Introduction

Since it was introduced, back in 1987, the popularity of quality management systems (QMS) based upon the ISO 9000 standards has widely grown around the world. According to the successive annual ISO Surveys, the number of certified organizations has increased, year after year, reaching a total of around 900 000 certificates in 170 countries by the end of 2006. More specifically, ISO 9001:2008 standard is based upon a process-model, according to which all the activities that impact customer (and not only the product) requirements, should be identified, mapped, understood, controlled and continuously improved.

Six Sigma is also a process-focused approach to achieve business improvement. The main goal here is to improve the performance of a specific core process, one project at a time. To that end, it is important to understand not only the core processes, by themselves, but also how their outputs impact on the customer's (both external and internal) requirements.

This paper discusses how a Six Sigma tool, named SIPOC, can play an important role in mapping, interrelating and managing key processes of an organization. Moreover, it is described how SIPOC diagrams can bridge the integration between an ISO 9001 quality management system and Six Sigma. A case study, covering a practical application, is also presented, to illustrate the suggested approaches.

2. Quality Management Systems Based upon ISO 9000 Family of Standards

2.1. History and evolution of the ISO 9000 standards

ISO 9000 corresponds to a family of international standards whose main aim is to assist organizations in implementing and operating effective quality systems (Hoyle, 2003). The first set of standards was published in 1987, with a similar structure to the former BS 5750 standards, published by the BSI in United Kingdom back in 1979. Their popularity grew significantly during the 1990s, first in the manufacturing sectors and in Europe, but later on in all kinds of organizations and countries.

In 2000 the scope and structure of the ISO 9000 set of standards changed significantly. Since then there is a single standard available for certification purposes (ISO 9001), whereas the ISO 9004 standard goes beyond the clauses of ISO 9001, in order to assist companies in improving their performance and in meeting the expectations of all interested parties (including, but not limited to customers). The ISO 9000 standard specifies the vocabulary and concepts concerning quality management systems and supports the good use of the other two standards. From a scope perspective, the 2000 version of the standards is strongly based upon a process-model that emphasizes the principles of quality management, contrasting with the quality assurance approach of the previous versions, based on conformity with standard requirements, which often led companies to have a rigid and limited vision of quality and sometimes complaints about too much documentation and records.

ISO 9001:2008 has been developed in order to introduce clarifications to the existing requirements of ISO 9001:2000 (Table 1) and to improve compatibility with ISO 14001:2004 (ISO, 2008b). There are no new requirements in the new ISO 9001 standard.

Table 1. Main clarifications introduced in ISO 9001:2008

Clause	Clarification in ISO 9001:2008
0.2 (Process Approach)	The text added emphasizes the importance of processes being capable to achieve the desired outputs.
1.1 (Scope)	Clarifies that the term "product" also includes intermediate product. Explains the importance of continuously identifying and updating the statutory, regulatory and legal requirements.
4.1 (General Requirements)	Clarifies that outsourced processes are still the responsibility of the organization, so they should be included in the QMS.
4.2.1 (Documentation)	Explains that QMS documentation also includes records and that documents required by the standard may be combined.
4.2.3 (Document Control)	Clarifies that only external documents relevant to the QMS need to be controlled.
5.5.2 (Management Representative)	Makes clear that the manager representative must be a member of the organization's own management.
6.2.1 (Human Resources)	Clarifies that competence requirements are relevant for any personnel who are involved in the operation of the QMS.
7.2.1 (Customer Related Processes)	Explains that post-delivery activities may include actions under warranty provisions, contractual obligations (e.g. maintenance) and supplementary services (e.g. recycling, final disposal).
7.3.1 (Design and Development Planning)	Clarifies that design and development review, verification and validation have distinct purposes.
7.3.3 (Design and Development Outputs)	Clarifies that information needed for production and service provision includes preservation of the product.
7.5.4 (Customer Property)	Explains that both intellectual property and personal data should be considered as customer property.
7.6 (Control of Monitoring and Measuring Equipment)	Renamed "Control of Monitoring and Measuring *Equipment*". Emphasizes that the ability of computer software to satisfy the intended application need to be confirmed.
8.2.1 (Customer Satisfaction)	A note was added to explain that the monitoring of customer perception may include inputs from a set of sources.
8.2.3 (Monitoring / Measuring of Process)	A note clarifies that when deciding on appropriate methods, the organization should take into account the impact on the conformity to product requirements and the effectiveness of the QMS.

2.2. ISO 9001:2008

Figure 1 shows the process-model of ISO 9001:2008, the same of its previous version. This standard is organized under 8 sections and 23 requirements, with 2 of them being general requirements (Section 4) and the remaining 21 allocated into one of the sections illustrated:

Management Responsibility (Section 5), Resource Management (Section 6), Product Realization (Section 7) and Measurement, Analysis and Improvement (Section 8).

The ISO 9000:2008 standard presents in detail 8 principles of quality management that should be used in order to achieve a better performance in the quality systems: 1) Customer focus, 2) Leadership, 3) Involvement of people, 4) Process approach, 5) Systems approach, 6) Continuous improvement, 7) Factual approach, 8) Supplier relationship.

Under the context of this paper principles 4 and 5 are especially relevant.

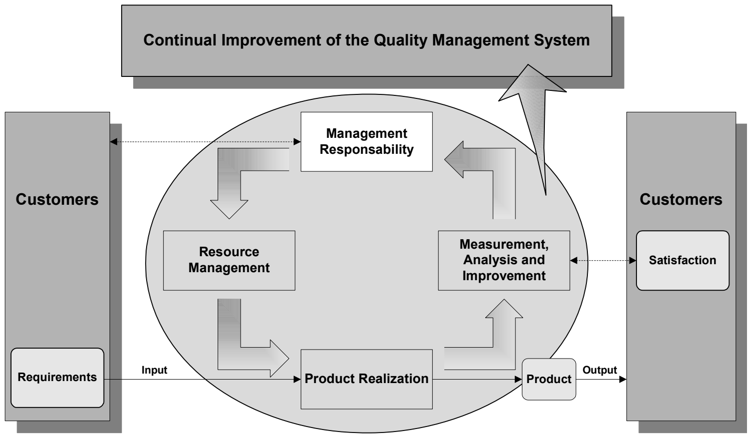

Figure 1. Process-model of the ISO 9001:2008 standard

2.3. Process management, systems approach and ISO 9001:2008

A process can be defined as a set of interrelated activities that use necessary resources to transform inputs into outputs, thus creating added value. A process should be operated under controlled conditions and its performance against requirements should be permanently monitored by key process indicators (KPIs) which have one or more metrics associated with them.

Three main types of processes can thus be considered:

– Processes for management~~,~~ that involve issues such as strategic planning, establishment of policies, setting of objectives and providing communication.

– Realization processes~~,~~ that directly add value to the intended outputs (products) of the organization. In other words, all these processes are associated with the life cycle of the intended outputs of the organization, such as is the case of product design, customer orders, operational execution procedures, invoicing, etc.

– Support processes, in spite of not directly adding value to the intended outputs, help the realization processes to perform well. Human resources management and information management are two typical examples of this type of processes.

All these processes, regardless of the organization they belong to, are related to each other in some way. Therefore, each process should not be viewed alone, but rather integrated into a net of interconnected processes (systems approach), that together impact customer (and eventually other stakeholders) satisfaction, and ultimately also business results.

The main advantage of adopting a process approach is the ability that it provides to manage organizations across different areas, as opposed to looking at them as a set of closed walls departments. Other subsequent advantages, resulting from process approach, are:

– Cost reduction since resources are used more efficiently.

– Identification of improvement opportunities is stimulated.

- Cross-functional communication is encouraged.
- Roles and responsibilities become clearer.
- Strategic indicators can be more easily linked to key process indicators.
- Targets for processes in terms of efficiency and effectiveness becomes more realistic.

Based on such a process management approach, the ISO 9001:2008 standard requires organizations to identify, classify and map key processes, and to establish their mutual relationships, normally through a net of interlinked processes. Control and continual improvement activities, for those processes, must also be defined, as well as responsibilities for process management (usually a Process Owner) and execution. Key process indicators (KPIs) are established to evaluate performance and its evolution against assumed targets.

3. Six Sigma

Six Sigma is a customer-centric system developed initially by Motorola, in the mid-1980s, to produce almost defect free products by minimizing variability on their respective processes.

In the beginning, Six Sigma was viewed essentially as a quality improvement methodology, but as a concept it has evolved considerably along the years, in a very interesting way. Six Sigma can actually be viewed from three different perspectives:

1. As a metric.
2. As a methodology.
3. As a business initiative.

Harry and Schroeder (2000) classify these perspectives respectively into three levels: operational level, tactical level and strategic level.

3.1. Metric perspective – Operational level

Six Sigma can be seen as a statistical measure of process performance. In the field of statistics, sigma (σ) is a Greek letter that usually represents standard deviation, which is a measure of variation. Figure 2 shows the statistical concept behind Six Sigma for a process with two-side specification limits under the assumption of a normally distributed measurable critical to quality (CTQ) characteristic.

A process with a six sigma level of performance is at a distance of six standard deviations (6σ) from both specification limits when its mean value equals the target value. In this case, the number of defects will be of about 0,00189 parts per million (ppm), so that can be stated to be an almost defect free process. In the long term, such a process is robust enough to also accommodate shifts of up to $\pm$ 1,5σ in the central tendency location, because the measured critical characteristic will not fall out of the specification limits, even if that happens, more than 3,4 times over each million of opportunities.

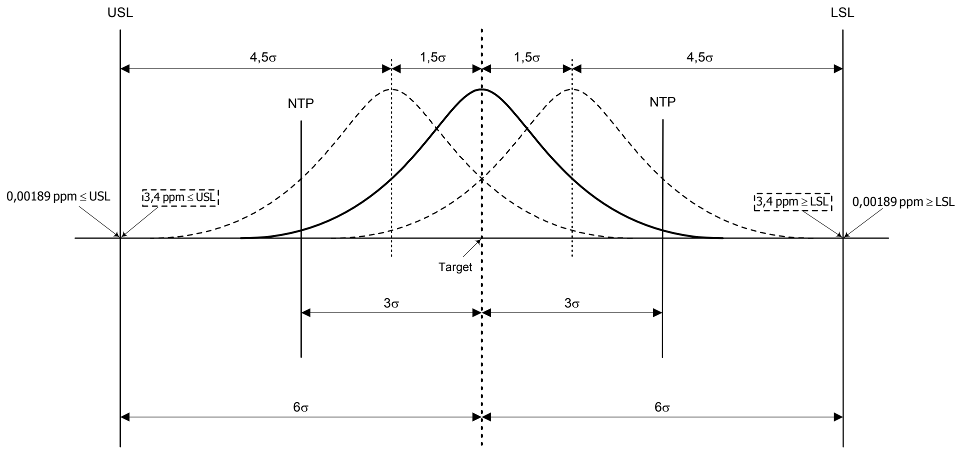

Figure 2. Statistical concept behind Six Sigma

3.2. Methodology perspective – Tactical level

Six Sigma projects are executed through a well defined sequence of phases, using appropriate statistical tools in each of them. There are two main methodological approaches through which Six Sigma teams conduct their projects:

- DMAIC, standing for Define-Measure-Analyze-Improve-Control. This roadmap intends to improve the capability of as process in a certain CTQ characteristic. The main idea is to minimize variability over the most significant inputs (with regard to the desired output) of the process, in order to optimize performance over the CTQ characteristic.
- Design for Six Sigma (DFSS). This approach is used not to improve an existing process, but rather to redesign or reengineer, as well as to design a new one. DFSS can also be employed to design or redesign products/services. A roadmap named ICOV (Identify requirements – Characterize the design – Optimize the design –Validate the design) is usually used to conduct DFSS projects, although it is easy to find other acronyms that basically have the same intent, and do share a similar set of tools and sequence of steps.

3.3. Business initiative perspective – Strategic level

Six Sigma builds on leadership to become an organization wide initiative. By the hand of leaders such as Bob Galvin, of Motorola, or Jack Welch, of GE, among others, many organizations successfully implemented a Six Sigma system directly linked to their business strategy, involving all of the organization in a broad implementation scope. Such a global and wide implementation of Six Sigma demands the allocation of human resources at different levels of qualification and knowledge (Black Belts, Green Belts, etc.).

A key feature of Six Sigma is that improvement actions are developed on a project by project basis. The selection of Six Sigma projects depends on the analysis of how their potential benefits can better contribute to meet strategic objectives of the organization, such as business growth and customer satisfaction.

4. SIPOC Diagrams

SIPOC diagrams are usually used across the DMAIC roadmap for problem solving, especially during the Define phase. They are a powerful mapping tool, whose name corresponds to the following five elements: **S**upplier, **I**nput, **P**rocess, **O**utput, **C**ustomer (Figure 3).

A simple example of a SIPOC diagram, corresponding to the high-level operational process of a graphics company that produces packages in compact cardboard, is shown in Figure 4.

As mentioned by Pyzdek (2003), a SIPOC diagram is usually drawn to map a process at a high-level. However, it can also be used to map a process at increasing levels of detail (macro-processes, but also processes and sub-processes). Figure 5 represents the use of SIPOC diagrams to map a process at different levels of detail.

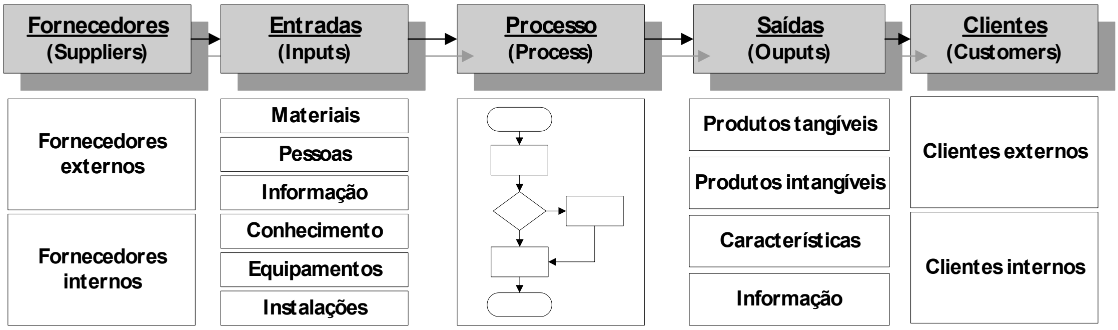

Figure 3. Layout and general content of a SIPOC diagram

Suppliers	Inputs	Process	Outputs	Customers
- Final customer - Equipment and software supplier	- Geometric or graphical models - Specifications - Pre-printing equipment and software	Pre-printing	- Structural design	- Printing area of Production Department
- Pre-printing Department - Raw materials suppliers - Equipment supplier	- Structural design - Tints - Cardboards - Printing equipment	Printing	- Printed cardboards	- Cutting and creasing area of Production Department
- Printing area of Production Department - Pre-printing Department - Equipment, tool and material suppliers	- Printed cardboards - Structural design - Cutting and creasing equipment and tools - Special glue	Finishing	- Finished product	- Shipping area / Logistics Department
- Shipping area / Logistics Department	- Finished product - Order packaging	Shipment	- Finished product shipped to the final customer	- Final customer

Figure 4. SIPOC diagram for the production process of packages in compact cardboard

5. Linking ISO 9001:2008 and Six Sigma through SIPOC

By analyzing clause 4.1 of the ISO 9001:2008 standard it is possible to identify five main steps (Figure 6) to be followed in order to develop a quality management system based on both process and systems approach principles.

SIPOC diagrams can play an important role in the practical implementation of steps 3 and 4. By using the layout reported in Figure 7, or similar ones, SIPOC diagrams can be easily integrated into process maps used for quality management systems based upon the ISO 9000 family of standards.

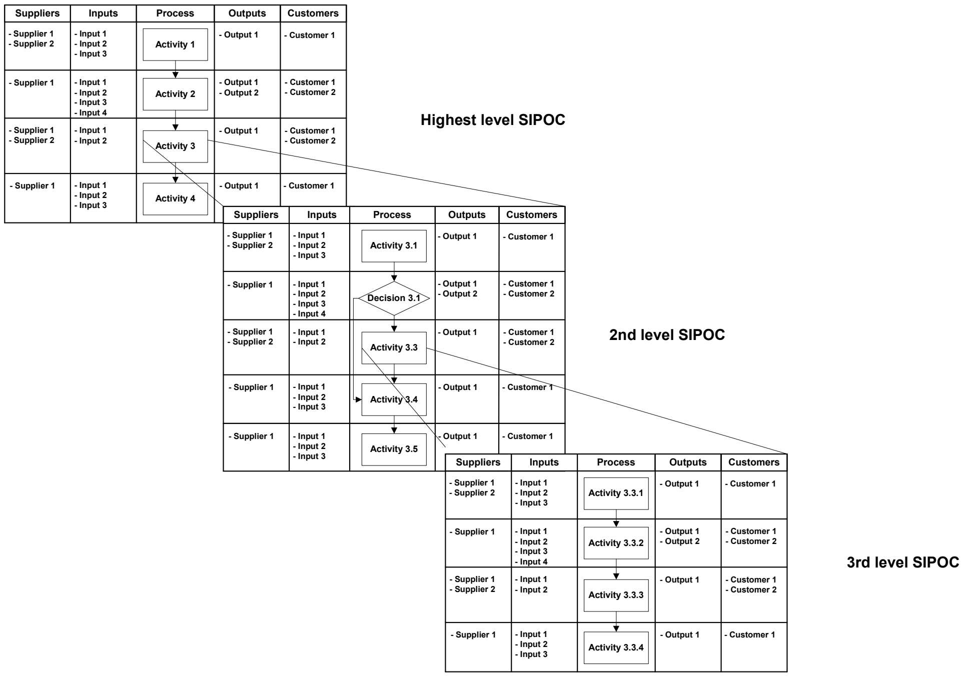

Figure 5. The use of SIPOC diagrams to map processes at different levels of detail

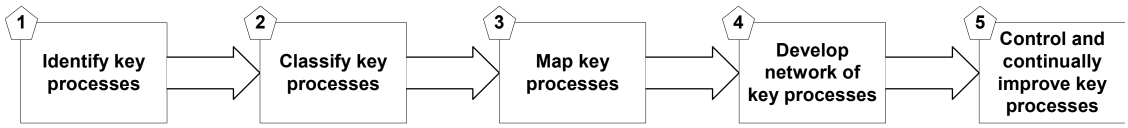

Figure 6. Five steps to develop a quality management system based on ISO 9001:2008.

Applicable ISO 9001 requirements/clauses	Process Owner	KPIs	KPIs measurement frequency

Suppliers	Inputs	Process	Outputs	Customers	Responsibilities	Documents

Figure 7. Structure of a process map under ISO 9001:2008 context derived from a SIPOC diagram

The grey section corresponds to the SIPOC format, while the other fields are needed under the context of an ISO 9001:2008 quality management system and include the KPIs description, as well as their monitoring frequencies, the process owner, the requirements which are relevant for the process, the responsibilities for each activity of the process and the relevant documents to be used (which may include written procedures, records and/or work instructions).

A network of processes is a diagram that represents the relationship between all of the key processes, with arrows showing that the output of one process may also be the input of other processes. Individual process maps, with a SIPOC structure (Figure 8), can easily represent the relationships with other processes, in terms of inputs, outputs, suppliers and customers. This capability will be demonstrated in the case study.

6. Case Study

The case study presented in this section is based on the implementation of a quality management system in an organization that provides engineering services in the construction and maintenance of energy infrastructures.

During the implementation of a ISO 9001:2008 quality management system, a total of seven key processes were identified: four of them were classified as realization processes, two as support processes and one as a process for management.

One of the processes is the innovation process, that describes the set of activities for new service development. This process is the first of the four realization processes, which altogether represent the service life cycle. A partial description of the innovation process map, which was coded as SIPOC-R-01, is represented in Figure 8.

INNOVATION PROCESS		SIPOC-R-01
ISO 9001:2008 requirements	**Process Owner**	**KPIs and measurement frequency**
7.3	James Morgan	Mean Time to Market of new service development projects *Calculation updated after each project completion*

Objectives of the process	Interrelated processes
Design of a new service or redesign of an existing one, from opportunity identification to service launch	(1) Commercial, (2) Operational, (3) Purchase Order Management and Logistics, (4) Human Resources

Suppliers	Inputs	Process	Outputs	Customers	Responsibilities	Documents of support
- Commercial Dpt. - Technical Dpt.	- New customer needs - New legal requirements - New technical requirements	Commercial Operational	- Commercial and technical opportunity communicated	- Innovation Dpt.	- Commercial Manager - Operational Manager	
- Commercial Dpt. - Technical Dpt. - Marketing Dpt.	- Commercial and/or technical opportunity - Market research	Opportunity identification	- Opportunity identified - New project opened and numbered	- Innovation Dpt.	- Marketing Manager	- Innovation project front record
- Innovation Dpt.	- Opportunity identified - Project objectivea	Elaboration of Innovation Project Plan	- Team memebrs nominated - List of activities defined - Due dates defined - Members roles defined	- Project team	- Project Leader	- Project Plan
- Marketing Dpt. - Technical Dpt - Customers - Other stakeholders	- Voices of the customers	Identification of service requirements	- Service requirements identified	- Project team	- Project Leader	- Service requirements list

Figure 8. Structure of a process map under ISO 9001:2008 context derived from a SIPOC diagram

All processes were mapped using a layout similar to the one exhibited in Figure 8, and coded as SIPOC-T-SS, where:

– SIPOC stands for a reference common to all processes.
– T stands for the type of process, and can be R, S or M (R = Realization processes, S = Support processes, M = Processes for management).
– SS is the sequential number attributed to the process of one given type (01, 02, 03, …).

One can see from Figure 8 how SIPOC diagrams show the relationship with other processes, so that all the SIPOC diagrams, each one corresponding to a specific process, are usually closely interrelated. Based upon such interrelationships, it was possible to develop a network of processes, such as the one shown in Figure 9.

The integration of SIPOC diagrams with more traditional process maps has proven to be very useful for this particular organization. Among others, the main advantages thus found are:

– Greater capability to focus on customer requirements than if conventional process maps were used.

– Ability to identify potential Six Sigma improvement projects and define where their scope was enhanced.

– SIPOC diagrams provided a single common language within the organization to control, manage and improve key processes.

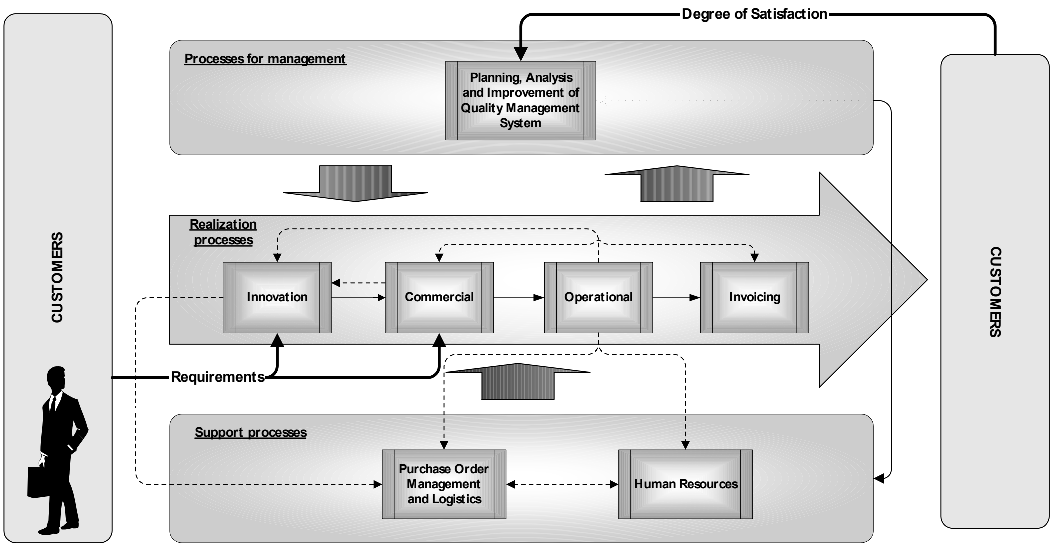

Figure 9. Network of processes, showing the relationship between the seven key processes that were mapped using the SIPOC diagrams

The quality management system was designed to enable additional beneficial synergies between the ISO 9001:2008 model and the Six Sigma program of the organization. As depicted in Figure 10, gap analysis between the Quality Objectives and the actual processes performance (measured through the use of KPIs), as well as internal and external auditing results, are sources for the identification of potential Six Sigma projects, in which the best one(s) will be selected, based on a set of criteria. The successful execution of relevant and well scoped Six Sigma projects contributes to the overall continuous improvement of the quality management system of the organization.

Table 2 describes the results of two Six Sigma projects which were developed to improve the performance of two realization processes of the quality management system.

Table 2. Six Sigma projects developed that contributed to improve the quality management system performance

Process	**Source of the Six Sigma project**	**CTQ**	**Short Term Sigma Level (before)**	**Short Term Sigma Level (after)**
Invoicing	Complaints	% of correct invoices	2,7	3,6
Operational	Internal auditing	% of correct technical reports	2,2	2,9

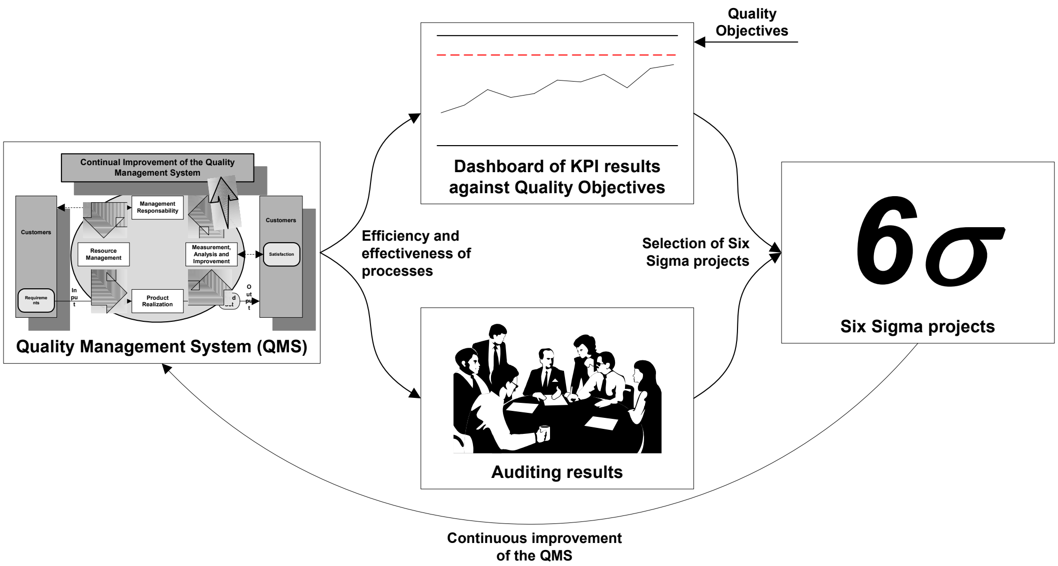

Figure 10. Synergies between the ISO 9001:2008 Quality Management System and the Six Sigma program

7. Conclusions

In this paper the use of a Six Sigma related tool, called SIPOC, was suggested under the context of development and implementation of ISO 9001:2008 quality management systems. It was described how SIPOC diagrams can be used to map, interrelate and help one to manage key processes from a customer-centric perspective. It has also been shown how SIPOC can facilitate an integration of Six Sigma systems within the ISO 9000 family of standards.

A case study was presented and it allowed us to reach some important conclusions about the practical benefits of using SIPOC diagrams in order to conceive and manage ISO 9001:2008 quality systems. In addition it was demonstrated that there are beneficial synergies that may be explored between the ISO 9001:2008 model and Six Sigma programs.

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