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Integrated product and process system with continuous improvement in the auto parts industry

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ABSTRACT

Purpose: Quality systems (QS) update must be based on the enterprise organization to assure customer satisfaction, as Deming, Juran and Feigenbaum did in their time, to seek improvement processes to reach high quality performance. This way, the proposal of this paper is the development of quality system integration model of product and process with continuous improvement.
Design/methodology/approach: To reach this goal, a Brazilian automotive parts quality system was improved through the Computer Integrated Manufacturing (CIM), Design for Manufacturing and Assembly (DFMA) and Lean Six Sigma (LSS) methodologies.
Findings: The paper shows what the problems are during the factory quality system management. The results achieved in the studied company show the performance quality evolution through their indicators.
Research limitations/implications: The article presents quality system problems of only one Brazilian plant of an automotive industry.
Practical implications: Presented in this article should be a way to look for continuous improvement methods.
Originality/value: The paper is supported on the authors' practical experiences to improve the quality system at a Brazilian plant.
Keywords: Quality System; CIM; DFMA; Lean Six Sigma

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1. Introduction

The quality control at the beginning of the industrial era was in the hands of the craftsman. Quality changed with the beginning of that era, which occurred more than two centuries ago in England, with the invention of the steam machine, and the mechanical loom for weaving, which is known today as the first industrial revolution. But quality control and management are different now. The search for increasing quality levels turned to new methods for improving processes, such as integration with CIM (Computer Integrated Manufacturing) and Lean Manufacturing (LM) and Six Sigma (SS), called Lean Six Sigma (LSS) (see Table 1). In agreement with these points, the development of this work was directed by the following research question: How to implement the integration of CIM and LSS which are different methodologies to attain the improvement of systems performance within an implementation for this approach by involving technical and human resources?

Although this is an issue caused by the manufacturing companies, the application of LSS can also be extended to the improvement of administrative processes and services [1].

However, the choice here was to restrict the boundaries of research to exploit the conditions in which the LSS has been used in the improvement of quality systems in industrial processes to obtain more specific results.

This paper is structured as follows. Initially, section 2 presents a theoretical framework on the CIM, LM and SS methodologies. Then, a case study on the implementation of the approach of integration CIM and LSS, with its organizational aspects are addressed in Section 3. In section 4, the case is examined in the light of the research issue and finally, in section 5 the conclusions are presented.

2. CIM and Lean Six Sigma

2.1. Computer Integrated Manufacturing

The acronym CIM - Computer Integrated Manufacturing is the Computer (C) which plans, organizes and simplifies all decisions at all levels of an organization by Integrated (I) that connects all computers and systems within a comprehensive communication plan, besides integration and Manufacturing (M) establishing a manufacturing organization in its broad form, or as a strategic business unit. In CIM, the integration initially takes place with the CAD / CAM, which was subsequently developed with other methodologies, including DFMA (Design for Manufacturing and Assembly) [2]. CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) form the CAD/CAM pronounced together as an integrated system [3].

The growing need to produce better quality goods with lower costs have made companies move towards integration and industrial automation. Automation is invading areas such as trade, banking, office, education, agriculture and industry. However, the execution of that search is planned and organized. Therefore, it requires creativity at first and then, investments, requiring it to be ordered and supported by a methodology and by an action plan. The CIM should support the business strategy which, in turn, studies the behavior of the market and how the company should market the product. However, both strategies are about whether this methodology also depends on the human factor in relation to the achievement of goals through organizational structures.

The integration of the client, the product and process project design can be aided by QFD (Quality Function Deployment), which is a technique used to transmit the customer needs for engineering the product, aiming to facilitate engineering and manufacturing planning. This unfolding identifies causes, defines tasks and suggests methods to find the product "designed" by the client. The QFD is a concept similar to the DFM (Design for Manufacturing) because it also seeks to integrate communication between the product engineering, quality, marketing and customer. Still, the QFD drives the designers of the product to compare a range of technical informations as well as business data so that they can choose, together with marketing, which ones fit the need of the customer. QFD This technique reduces the total time of project, and the DFM.

The DFM, also known as SE - Simultaneous Engineering, is the concomitant development of the project functions of the product and process, which aims to reduce cost and time to launch the product in the market. The result of applying this technique is feasible to obtain a quality product that can be introduced with enhanced productivity and manufacturing, since it takes into account the entire production system during the development of this project [2]. DFM means increased joint work of product and processes engineers with the staff of the "factory shop-floor" and provides more communication, cooperation and integration. In many traditional organizations, the engineering of the product first aims at terminating the project, drawings, calculations and prototypes, and only then releasing all the engineering drawings for the process, which once being in possession of drawings of products, establish a roadmap manufacturing, specifying the machines, choosing the tools and work stations. During this phase, analysis of cost and feasibility often create the need to request changes in the product but, at this point, the analysis of these changes becomes difficult and sometimes impossible, leading to an additional product, an increase in manufacturing time and the need for certain operations in the process that could have been avoided [2]. As a result, simultaneous engineering aims to develop the design of product / process avoiding all instances mentioned above. Thus, QFD and DFM promote integration between engineering, manufacturing and marketing - "ground-to-factory" reducing the total cycle time of developing a product, and implements product quality, in full compliance with the customer [2].

Table 1.
Methodologies to support Quality System

No	Item	Explanation
1.	CIM - DFMA	CIM – Computer Integrated Manufacturing and DFMA – Design For Manufacturing and Assembly
2.	Lean Manufacturing (LM)	Waste eliminated and lead-time reduction. VSM – Value Stream Mapping , 5S’s and PokaYoke
3.	Six Sigma (SS)	Zero defects and customer satisfaction. DMAIC (Define, Measure, Analyse, Improve, Control)

2.2. Lean Manufacturing (LM)

The principles of LM gained notoriety in the 1980s with the results of a research project conducted by MIT (Massachusetts Institute of Technology) who studied the management practices and programs for improvements adopted by market leaders in the automotive supply chain and found that the adoption of these principles very much contributed to their competitiveness [4].

The central motivation of the LM method is to reduce the time between the request of the customer and delivery through the elimination of waste. It promotes the identification of what adds value (and not added) in the customer's perspective, the interconnection of the steps needed to produce goods in the flow of value, so that it moves without interruption, detours, returns, or rejects waiting, and operation of the flow driven by demand.

So as to plan the implementation of LM practices, Rother & Shook [5] recommend the application of Value Stream Mapping (VSM - Value Stream Mapping), a planning tool that facilitates the visualization of information and materials flows. The VSM demands a comprehensive portrayal of the production system and aims to build maps that represent the same page for the information flow (from the customer's request to the planning of production) and the materials flow (from raw press to the finished product).

The LM action tools most commonly applied in production systems are listed below: Five, Poka Yoke, Just-in-Time, Continuous Flow Manufacturing, Standard Work, Quick Setup, and Total Productive Maintenance.

It is worth noting that authors such as Lewis [6], who developed drawing on the practices of LM, which have been effectively implemented by companies in manufacturing, identified much of what is highlighted here about teamwork, multi-functionality, decentralized structure, removal of bottlenecks, streamlining production and training base and the suppliers' base.

The most effective method for implementing LM is the implementation of kaizen workshops; the results achieved should be monitored on a daily basis by means of visual controls that promote the principle of management to Vista [7]. A given area, the level achieved in the implementation and application of LM for each tool can be compared with the other tools in a "radar" plot facilitating their monitoring.

2.3. Six Sigma (SS)

The SS method was introduced in the 1980s by Motorola, aiming to increase the quality levels of the common level of 3σ to 6σ through a systematic application of statistical tools oriented to the optimization of manufacturing processes [8]. It is a methodology that has been signing as a means of establishing a discipline of statistical thinking objective use to improve processes and products [9]. The central point of this methodology is to reduce the variations that cause defects by using vision, application of well defined metrics, the use of benchmark and support through a structure for managing projects.

SS is a project conducted in a structured way following a string divided into five phases. When the project aims to improve an existing process, the sequence adopted is the DMAIC (Define, Measure, Analyze, Improve, and Control) [8-9].

Total quality, TQM, makes each executive responsible for the quality they produce, making it "right the first time", i.e., the inspection should be on job for each stage of the process, not only at the end. The search of "zero-loss" is due to: the constant improvement, implementing the self, using the Poka-Yoke, and using the CEP audit quality. The TQM is a program in which quality is focused within the company as a method. This program aims to satisfy the customer, but also product performance above the expectation, or the quality of the company's relationship with customers and employees, creating quality of life at work and in relation to society [10].

When the purpose of the project involves the development of a new product and / or a new process, it is a case of DFSS (Design for Six Sigma) which implies the adoption of a sequence known as secondary DMADV (Define, Measure, Analyze, Design, Verify). It starts with the definition phase (D) in which the goal of the project are defined in association with the customer's requirements (internal and / or external). Then, during the measurement (M), the customer's specifications are determined and should be a benchmarking study. At Analysis (A), the alternatives to meet the customer needs are examined. Advancing to the stage of development (D), the process to meet these needs should be thoroughly designed. Finally, during verification (V), it should make sure that the performance of the designed solution meets the customer's requirements.

2.4. Lean Six Sigma (LSS)

The integration between LS and SS discussed in this work has been called Lean Six Sigma (LSS) and in theory can provide better results than the conduct of two programs by separate organizations. The integration is different from company to company in how to manage them separately and jointly [11].

3. Quality System Case

3.1. Methodology

The methodology applied in this work is the case study, which according to Yin [12] investigates contemporary phenomena, considering their real context. This empirical research is generally applied when the boundaries between context and phenomenon are not well defined, similar to the system. Thus, this research method usually involves a small number of cases, yet establishes relationships and understanding on the subject studied.

The Quality System Final (QSF) was implemented in a multinational company's supply chain in the automotive industry. The group has one hundred years of existence, approximately 80,000 employees, is present in different cities in Brazil and in the world, is distributed in 150 countries and has sales in the order of 14 billion US dollars a year. This study was conducted in the State of Sao Paulo, Brazil, at a plant with 2,500 employees.

3.2. Quality System

The Initial Quality System (QSI) was described in terms of key business processes of a business and ISO 9001:1994. In this view, the quality system receives its input to quality policy and its output presents the product or service. During its processing, interacting parts are organized and the quality efforts are coordinated throughout the company. Finally, its feedback characterizes the continuous development process.

However, the QSI, instead of presenting continuous improvement and meeting an acceptable quality level, shows to be below the level projected, so that the connections have more trees (little retroaction). This degeneration of QSI is transformed into QSi (Initial Quality System "Real") (see Figure 1). Thus, the QSi undergoes a major transformation, changing first to the Quality System (QS). This transformation is based on integration and CIM LSS. The Quality System (QS) was modeled to achieve better levels of quality, however, noting the QSi (Initial Quality System "Real") is considering revisions to meet its continuous improvement processes and the ISO 9001:2000 (see Figure 1).
Despite having a better quality level, the QS have undergone a new redesign, through greater integration of their subsystems, making it finally Quality System Final (QSF) (see Figure 1).

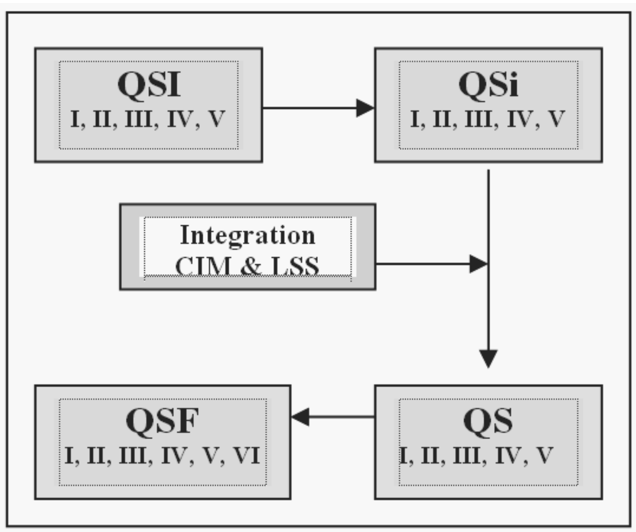

Fig. 1. Quality System Evolution (QSF)

These quality systems have five subsystems, namely: quality management (I), product and process project development (II), manufacturing (III), supply (IV) and post-sale (V), which are described in Figures 2 to 6. QSF has increased from five to six subsystems. It incorporated a new system called continuous improvement (QSF VI), described in Figure 7. The function of this subsystem is to integrate all the improvement processes of other subsystems.

The quality management subsystem (I), described in Figure 2, establishes an organization focused on customer satisfaction. Employees are motivated to the extent of their involvement and consequent commitment. The customer's satisfaction and coworkers' commitment integrate and join the quality management with the project development. The description of each subsystem is presented below.

QSI I → QSi I → QS I → QSF I
Political Quality – Quality System

Fig. 2 – Quality Management (I)

QSI I → Establishes the government responsibility , defines the quality policy, establishing the quality system and maintains the quality of information, controls documents, audits quality, proposes corrective actions and critical analysis of quality, to establish the general quality planning , customer service, care of the training, maintaining the technical quality and establishing quality planning indicators.

QSi I → The QSi I runs all activities of the QSI I, but it does not control the documents or plans the training.

QS I The high level management must issue, publish and review the quality policy, develop the quality system, manage information, ensure the control of documents and data, internal audit, implement preventive and corrective actions, reporting and analyzing the failures of the product, periodically examine the system and quality administration , monitor the cost, develop and integrate the planning within the business, analyze the market, reporting needs and expectations of the client, follow the law of product, plan education and training of those involved, select and implement statistical techniques to improve, develop and implement programs to improve quality, using the technical solutions of problems and plan performance indicators for analyzing the quality system.

QSF I → The QSF I runs all the activities of the QS and additionally has: Strategic Planning the quality of benchmarking in the analysis of competitors, customer focus, ensures an appropriate form of communication, emphasizing the motivation to establish the integration company -employee, hiring new employees with secondary level education, using techniques of flexibility in applying Lean Six Sigma techniques.

The subsystem of the project development of the product and process (II) shown in Figure 3 is the quality control in which the product is designed according to the customer's requirements. This subsystem defines the manufacturing process in accordance with the characteristics of the product. The description of each subsystem is presented below.

QSI II → QSi II → QS II→ QSF II
QFD – FMEA – DFMA – DFSS

Fig. 3 – Design for Product and Process (II)

QSI II → Establishes the project and changes in product and process concept, manages, review and approves the design of product and process quality indicators and establishes the project.

QSi II → QSi II performs all the activities of QSI II, but does not review the design of the product.

QS II → From customer requirements (voice of the consumer-QFD-Quality Function Deployment) designing the product (voice of engineering-FMEA-Failure Mode and Effects analysis) according to the marketing requirements, analyzes the project from a perspective of attraction, considering its feasibility, sends the reports to the customer and the engineering of the initial sample, administers the project in its entirety, monitors both existing and new product and process projects, continuously reviewing the project, develops the process from the product requirements , ensures the use of the roadmap process, releases the tooling and equipment design of the process, approves the product and the process through testing, considering the domestic manufacturers and suppliers, to critically analyze contracts, ensuring the ability to meet the agreed items, identify and assess risks to quality, ensuring the administration of changes in product and process, assesses the equipment and often the tools and establishes / reviews indicators in product / process design.

QSF II → The QSF II performs all the activities of the QS II and additionally has: to establish, plan and implement a business strategy for the development of the project, ensuring the parameterization and the standardization of product and process, monitor the discipline to meet the characteristics of the product, applying project techniques CAD / CAM, SE, DFMA and DFSS. The subsystem fabrication (III), see Figure 4, is responsible for managing the quality of implementation of the project and the production of the product through TQM and Lean Six Sigma techniques. The description of each subsystem is presented below.

QSI III → QSi III → QS III→ QSF III
LM – SS – LSS– DFSS

Fig. 4 – Manufacturing (III)

QSI III → Establishes a quality assurance in manufacturing, controls the production and measurement equipment, the use of control plans and instructions for production, controls the handling, storage and tracking of the product.

QSi III → The QSi III performs all the activities of the QSI III, but does not control storage.

QS III → Implements the project planning process, ensuring that production equipment keeps operating and available, through corrective maintenance, prevention and prediction and rapid information exchange system, planning inspections and testing, controls equipment for measurement, ensuring that the frequency and knowledge of the uncertainties in the measurements, ensure the capacity of the process, ensure that the documentation required for manufacturing the product is used, ensures the organization and order of tools, ensures the control plan, ensuring that tracking is maintained during the product processing, identifies and segregates non-conforming materials at each stage of the process, thus ensuring that they are not used, ensures the protection of product during handling and storage, creates a system to support the development of quality and to establish and analyze quality performance indicators .

QSF III → The QSF III performs all the activities of the QS III and the following: ensuring the group meetings , using participation techniques CCQ (Circle of Quality Control), supports facilitators, establishes control of the automated process, implements new processes, implements Lean Six Sigma.

The subsystem supplier (IV) described in Figure 5, manages the acquisition of SCM (Supply Chain Management). The description of each subsystem is presented below.

QSI IV → QSi IV → QS IV→ QSF IV
LM – SS – LSS– DFSS

Fig. 5 – Supplier (IV)

QSI IV → Establishes quality assurance for the supplier evaluates and selects the supplier.

QSi IV → The QSi IV performs all the activities of QSI IV, but does not assess the vendor.

QS IV → evaluates suppliers on the quality assurance and capability of their systems, plans and fit the need of the customer. QFD This technique reduces the total time of project, and the DFM. implements the inspection of receipt (if necessary because the quality is assured), selects the suppliers, the suppliers send the data needed to purchase the product, validate the processes of suppliers, ensuring that the quality of the purchased items is maintained during the delivery, making the supplier take responsibility for the loss of control, monitor changes, provide corrective action with the supplier; the supplier periodically audits and establishes / reviews the performance indicators of the system of material purchased.

QSF IV → The QS IV performs all the activities of the QS IV and additionally has: to encourage the supplier to use all cases that showed good results in the company, such as Lean Six Sigma.

The subsystem post-sale (V), shown in Figure 6, is the quality assured, at the sale and after-sales, with total assurance to the customer through the evaluation of product performance and service. The description of each subsystem is presented below.

QSI V → QSi V → QS V→ QSF V
Quality Assurance

Fig. 6 – After-Marketing (V)

QSI V → Establishes quality assurance in post-sales, maintain customer satisfaction and meet the field service with warranty.

QSi V → The QSi V runs all the activities of the QSI V, but there is no in field warranty service.

QS V → Ensures the quality of the replacement piece from the source to the receiving client, ensuring proper guidance and assistance to the customer through regular contact, ensuring customer assistance in accordance with the supplier/customer relationship, guarantees components supply, updates the policy to ensure security, provides assistance plan, disseminating the failure data and returning information to customers, manages the inventory (the one which comes first, the first coming out), establishes / reviews the performance quality indicators in post-sale and get client satisfaction, ensuring the delivery.

QSF V → performs all the activities of the QS V and the QSF V, plus: meets the characteristics attributed to the services, namely intangibility and simultaneity.

Finally, the continuous improvement subsystem (VI), see Figure 7, is a subsystem of quality that, through involvement, communication and trust, always seeks to achieve a better quality level than the competitors. Involvement with people is the motivation of Quality System Final. The Commission integrates engagement and trust. In turn, confidence leads to decision and action which is shared between the working groups and managers. This subsystem detaches success through people as a continuous improvement and integration system, a relationship of the intra- and inter-company environment. It is the key to the organization success. Modern systems and machines to qualify the workforce create control mechanisms of employees and suppliers' involvement has become key priority as well as optimizing quality standards. Companies are expected to be increasingly flexible and their labor is able to absorb new technologies and can adapt to modern quality management systems. People are the key to the success of new businesses; with the greater degree of automation in industry, the human element is always the one to take decisions, actions and guarantee quality. The description of this subsystem is presented below.

QSF VI
5 S's – PDCA – Kaizen - Involvement

Fig. 7 – Continuous Improvement (VI)

QSF VI → Applies these five (5 S's), PDCA cycle and Kaizen. Ensures the monitoring of technical and cultural changes occurring in the organization, ensures the new profile of human resources, and ensures the commitment involved in development, the creation of working groups, using techniques of self: "zero-loss" and discipline to ensure the simplification of quality cost: internal and external faults, prevention and evaluation to ensure continuous improvement in the review of the product design, engineering and in the down-to-factory process, continuously improving quality indicators. Thus, it establishes success through the peoples collaboration and integration.

4. Results and discussions

Table 2 shows the evolution of the client quality level. In the first year, the QSI (Quality System Initial) presented 3300 ppm; in the following year, with the degeneration of its system, it became a QSi ("Real" Initial Quality System) of 4500 ppm. Following the introduction of the first improvement integrations as from the third year, it attained QS (Quality System) with 2,200 ppm. The continuous improvement process continued raising the quality level in the QS, reaching 1200 ppm in the fourth year.

Hence, with the reorientation of QS and continuous improvement of the subsystem (QSM VI), the QSF (Final Quality System) reached 650 ppm in the fifth year. Process management gather allied with people with greater involvement led to the QSF client quality indicator, 350 ppm, in the sixth year of quality systems monitoring. Thus, quality evolution has evolved approximately 50% every year. Developments in the QSF (sixth year, 350 ppm) from SQi (second year, 4,500 ppm) were 92%.

The quality cost was also evaluated, but only in QS systems (fourth year) and QSF (sixth year). It was substantially reduced both in the internal and external failures issues, but has maintained the investment in prevention and assessment. The quality cost rose from 4.5% of net sales to 2.8% (improvement of 61%).

Table 2.
Quality evolution in the customer

QS	Year	PPM	Cost
QSI	1º	3,300	-
QSi	2º	4,500	-
QS	3º	2,200	-
QS	4º	1,200	4.5%
QSF	5º	650	-
QSF	6º	350	2.8%

Table 3 shows the reorientation of the quality systems developed from ISO 9001:1994 to ISO 9001:2000.

The QSI is more oriented towards TQC (Total Quality Control), which focuses more on process, while the QS focuses more on the TQM (Total Quality Management) and QSF than the TQM, applying the TQS (Total Quality System) concepts, which focuses on the integration process with the business through its human resources.

The subsystem continuous improvement (QSM VI) was developed especially for the QSF, so that the processes management together with the relationship with the more involved people and therefore, more committed, led to QSF client quality indicator (see Table 2).

Table 3.
Quality evolution in the systems

QS	Year	ISO 9000	System	Subsystems
QSI	1º	1994	TQC	I, II, III, IV, V
QSi	2º			
QS	3º	2000	TQM	
QS	4º			
QSF	5º		TQM TQS	
QSF	6º			I, II, III, IV, V, VI

5. Conclusions

Finally, it is presented the findings on the modeling method developed in this work and its implementation.

In the implementation in the company studied, the Quality System Final (QSF) had its results compared with the Initial Quality System "Real" (QSi) and we found that there was an improvement, a92% quality increase in customer satisfaction. The improvement of this indicator was a change in the organization work pattern of, enhancing the recognition of customers and the market. The QSF quality cost developed by 61% of net sales compared to the QS, maintaining the investment in prevention and assessment.

The complexity can only express the inability to define easily, which is complex cannot be summarized in a law or a simple idea. Thus, the passage of the SQI, more focused on TQC, the QSF, which applies the concepts of the TQS makes it more integrated and there is more feedback.

Furthermore, the QSF (Quality System Final) produced not only a "correction of problems", but an elimination of the "root causes" to ensure the discipline requirements of the system with emphasis on continuous improvement to achieve quality assurance in the supply chain.

Therefore, the subsystems of the QSF in the development of this work presented the aspects of the integration of CIM and LSS that led to the development of the indicators of a quality system supported by technical personnel.

Finally, the possible paths lead to a reflection on the role of business processes, continuous improvement, quality assured and systemic integration. They are applications of science and knowledge to quality systems, evolving from inspection to improvement and more and more incorporating value to the product and service.

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