1. Design for excellence – quality control & DFX

1.1. Introduction

The design and manufacturing processes as well as their quality control and operation management at the beginning of the industrial era were in the hands of a lone person, the craftsman, as a handcraft activity. Design and manufacturing and their quality control and management 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. In this sense design and manufacturing, a transformation operation process should be studied joining the aspects of materials, manufacturing and management, as postulated in the Figure 1.1. A historical evolution of this synergy between design, manufacturing and management can be seen at Table 1.1, complemented by the more recent approaches including a continuous improvement of the quality of product and processes (Figure 1.2), emphasized on the purpose of this book of a design of excellence approach for the development of product and manufacturing processes. In this sense, design and manufacturing 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 (6σ), called Lean Six Sigma ($L6\sigma$) (see Table 1.2).

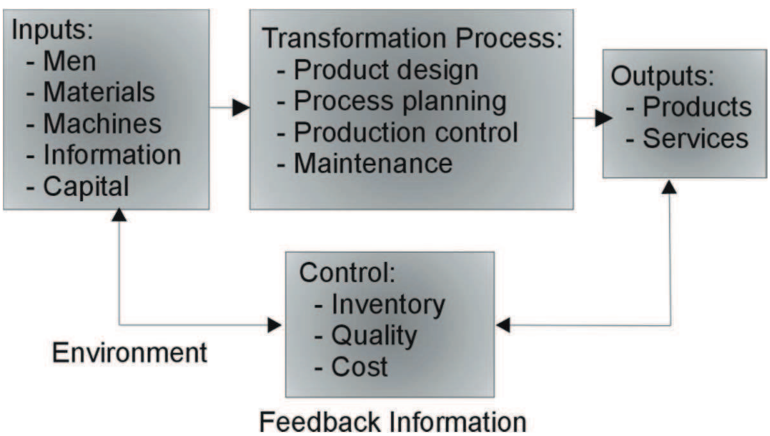

Figure 1.1. *Schematic of a production system [1]*

Table 1.1. *Historical evolution of the manufacturing & operational management (Adapted [1])*

Date	Contribution	Contributor
1776	Specialization of labour in manufacturing	Adam Smith
1799	Interchangeable parts, cost accounting	Eli Whitney & others
1832	Division of labour by skill; assignment of jobs by skill; basics of time study	Charles Babbage
1898 1900	Scientific management time study and work study Developed dividing planning and doing of work	Karol Adamiecki / Frederick W. Taylor
1900	Motion study	Frank B. Gilbreth
1901	Scheduling techniques for employees, machines jobs in manufacturing	Henry L. Gantt
1915	Economic lot sizes for inventory control	F.W. Harris
1916	General Theory of the Operational Management	K. Adamiecki/ Henri Fayol
1927	Human relations; the Hawthorne studies	Elton Mayo
1931	Statistical inference applied to product quality: quality control charts	W.A. Shewart
1935	Statistical Sampling applied to quality control: inspection sampling plans	H.F. Dodge & H. Roming
1940	Operations research applications in World War II	P.M. Blacker & others
1946	Digital Computer	John Mauchlly & J. Eckert
1947	Linear Programming	G. Dantzig, Williams & ot
1950	Mathematical programming, non-linear and stochastic processes	A. Charnes, W.W. Cooper & others
1951	Commercial digital computer: large-scale computations available	Sperry Univac
1960	Organizational behaviour: study of people at work	L. Cummings, L. Porter
1968	Metrological terminology standardization	J. Obalski & J. Oderfeld
1970	Overall strategy integrating operations - Computer integrated manufacturing (CIM), scheduling and control, Material Requirement Planning (MRP)	W. Skinner J. Orlicky & G. Wright
1980	Quality & productivity applications from Japan: robotics, CAD-CAM, Toyota quality system	W.E. Deming & J. Juran

Table 1.2. *Methodologies to support Quality System in product design and manufacturing [2]*

No	Acronym	Explanation
1.	CIM – DFMA	Computer Integrated Manufacturing & Design For Manufacturing & Assembly
2.	LM	Lean Manufacturing = Waste elimination & lead-time reduction. VSM – Value Stream Mapping , 5S's & PokaYoke
3.	Six Sigma (6σ)	Zero defects & customer satisfaction. DMAIC (Define, Measure, Analyse, Improve, Control)

The conception of a continuous improvement integrated quality control system for the management during product design and manufacturing, however a complex task, as shown by the factors illustrated on the Figure 1.2.

The recent increase of possibilities of the information technology (IT) enables the designers and R&D managers to face the challenge to balance all these factors using a simultaneous and concurrent engineering approach. This approach is very useful, especially when it is applied to the historical evolution of the complexity and quantity of components of new products, as well as to the versatile and enhanced range of the available engineering materials and manufacturing processes (See Figure 1.3).

Chronologically increasing of the number of components as well as of the mass of the new car bodies can be justified by several new improvements likes: hybrid power trains, automatic transmission, active suspension, freely configurable inner space, on board navigation systems

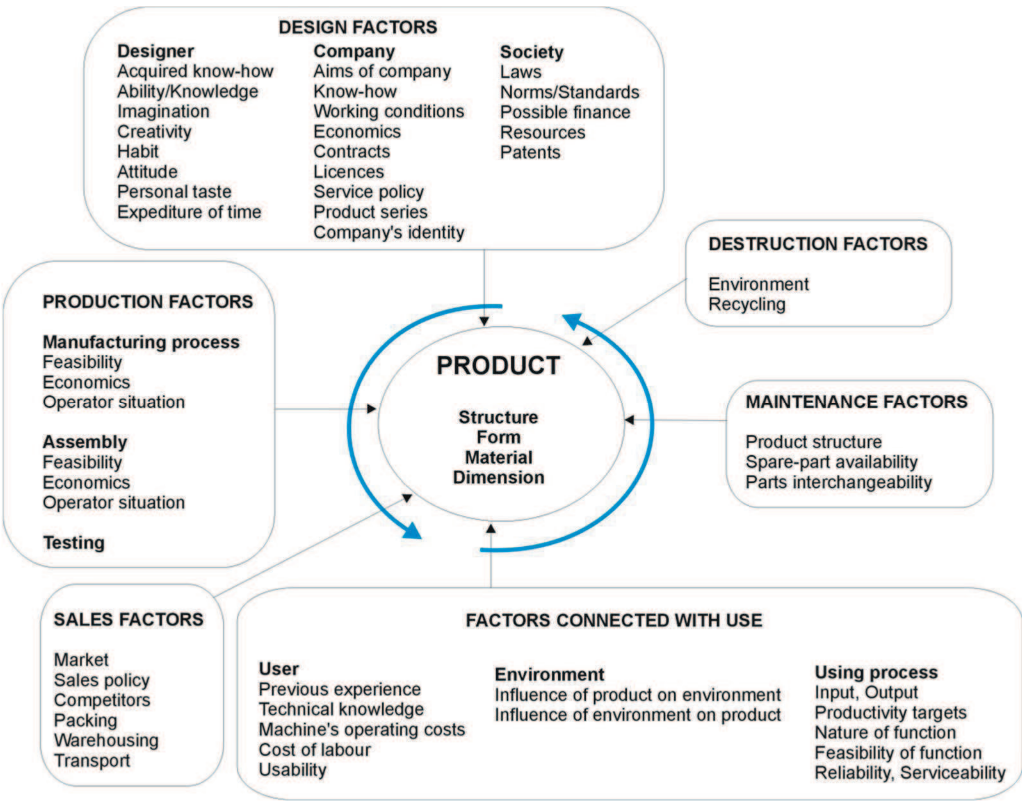

Figure 1.2. *Integrated factors influencing the product research and development [3-4]*

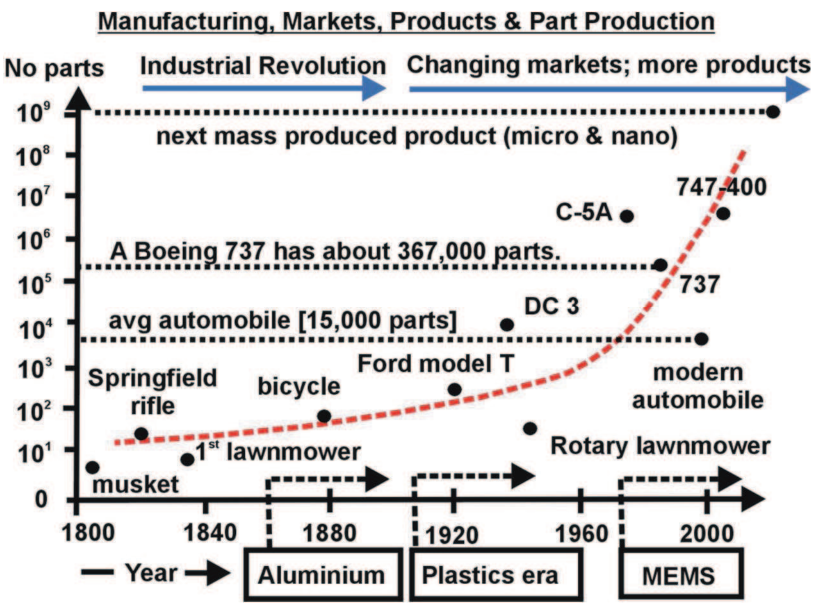

Figure 1.3. *The increase in complexity of parts from the industrial revolution onward (After[5])*

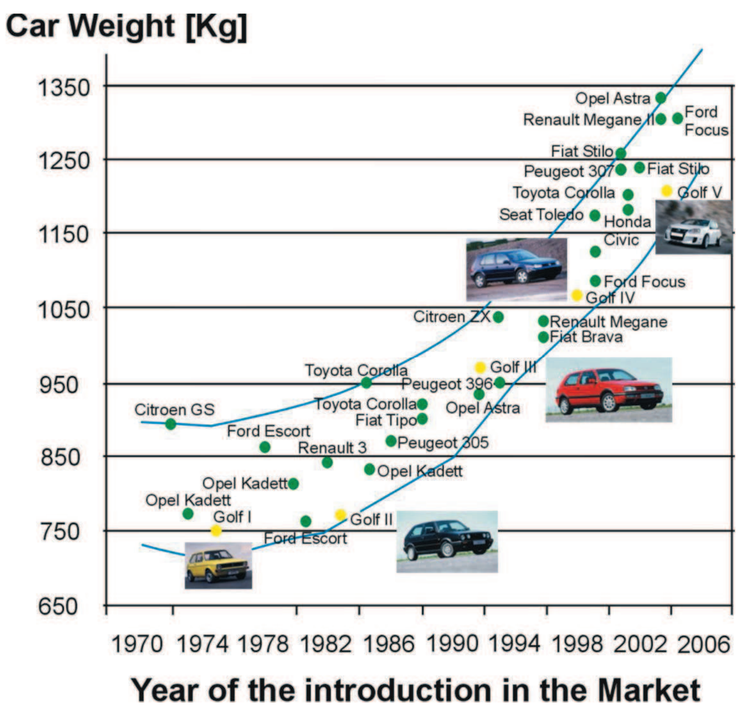

Figure 1.4. *Chronologically increasing weight of cars introduced in the market. Adapted from Automobil industrie, 9, 2009, [6-7]*

(GPS & multimedia), pre-crash sensors, active curve lights (headlamps), pedestrian protection, night vision and field recognition, car to car communication, etc. (see Figure 1.4)

In agreement with these points, the development of this book was directed by the following research question: how to implement the integration of CIM and L6σ which are different methodologies to attain the improvement of systems performance within an implementation for this approach by involving technical and human resources and approaches of design for excellence (DFX)? Although this is an issue caused by the manufacturing companies, the application of L6σ can also be extended to the improvement of administrative processes and services [8]. However, the choice here was to restrict the boundaries of research to exploit the conditions in which the L6σ has been used in the improvement of quality systems in industrial processes to obtain more specific results.

This chapter is structured as follows. Initially, section 1.2 presents a theoretical framework on the CIM, LM and 6σ methodologies.

Then, a case study on the implementation of the approach of integration CIM and LSS, with its organizational aspects are addressed in Section 1.3. In section 1.4, the case is examined in the light of the research issue and finally, in section 1.5 the conclusions are presented.

1.2. CIM and Lean Six Sigma

1.2.1. 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 the Integration activity (I) and Manufacturing (M) that establishes 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) [9]. CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) form the CAD/CAM pronounced together as an integrated system [10]. Figure 1.5 illustrates the different methodologies that can be integrated under the acronym "CIM".

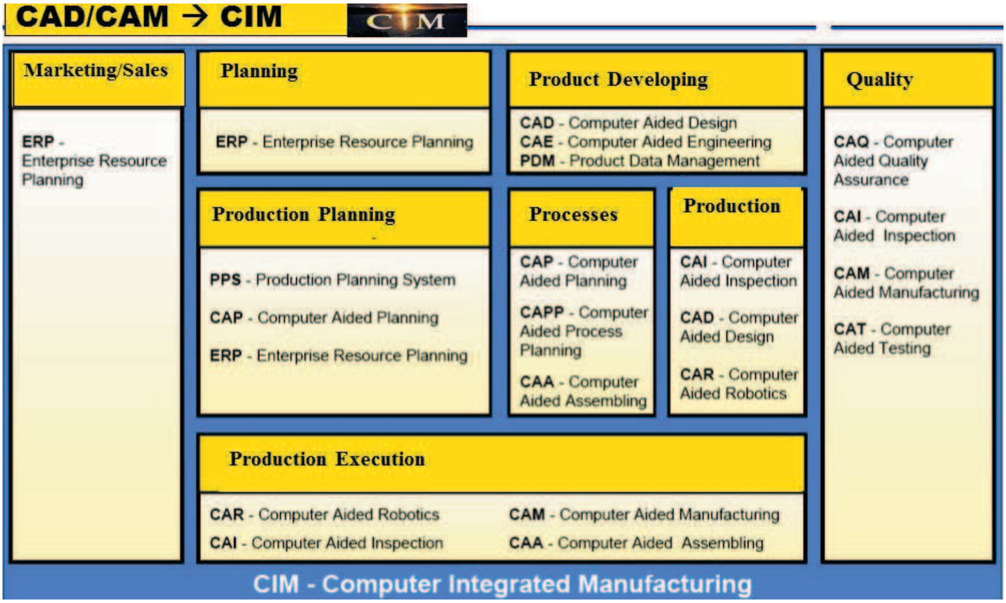

Figure 1.5. *The different components of a computer integrated manufacturing approach, (adapted from sparse notes from RWTH lectures [10])*

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 behaviour 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 information as well as business data so that they can choose, together with marketing, which ones fit the need of the customer. The QFD technique reduces the total time of project, and the DFM.

The **DFM, also included in the approach as SE - Simultaneous Engineering, or CE – Concurrent 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. Applying this techniques yields feasibility 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 [9]. 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 aims first 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, may establish a roadmap for 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 [9]. 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 – connecting them to the co-workers of the "workshop's groups" at the plant, reducing the total cycle time of developing a product, and implements product quality, in full compliance with the customer [9].

1.2.2. Lean Manufacturing (LM)

The principles of LM gained publicity 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 [11].

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 [12] 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 [13], 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 [14]. 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.

1.2.3. Six Sigma (6σ)

The 6σ 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 [15]. 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 [16]. 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. 6σ 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 (**D**efine, **M**easure, **A**nalyze, **I**mprove, and **C**ontrol) [15-16] or DCDOV (**D**efine, **C**oncept Development, **D**esign Development, **O**ptimize Design **V**erify Capability), see Table 1.3.

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

Table 1.3. *The Design For Six Sigma Approach*

DCDOV	Goals	Tools
Define	Obtain customers' needs and wants Translate customers' needs and wants to VOC list	Market/Customer Research, Kano analysis, stakeholders analysis, operation cross walk
Concept Development	Develop Design Feature/functional requirements based on VOC	QFD. TRIZ, Axiomatic Design
Design Development	Identify engineering and process parameters based on the design features/functional requirements	CTX, DFX, DOE, Taguchi methods
Optimize Design	Identify optimal settings for the engineering and process parameters based on the performance, robustness, production and other requirements	RSM, FMEA update, sensitivity analysis, Taguchi Methods
Verify Capability	Check if the designed product/process is capable of meeting the design target and requirements	Verification/qualification tests, validation tests, simulation, statistical analysis

Acronyms:
TRIZ – *Teoriya Resheniya Izobretatelskikh Zadatch*
(теория решения изобретательских задач)
TIPS – Theory of Inventive Problem Solving (English acronym for the TRIZ approach)
QFD – Quality Function Deployment
VOC – Voice Of the Customer
CTX – Committed To eXcellence
DFX – Design For eXcellence
DOE – Design Of Experiments
RSM – Response Surface Modelling
FMEA – Failure Modes and Effects Analysis

only at the end. The search of "zero-loss" is due to: the constant improvement, implementing the self, using the Poka-Yoke (Figure 1.6) [10], 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 [17].

When the purpose of the project involves the development of a new product and/or a new process, it is a case of DF6σ (Design for Six Sigma) which implies the adoption of a sequence known as secondary DMADV (**D**efine, **M**easure, **A**nalyse, **D**esign, **V**erify). 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.

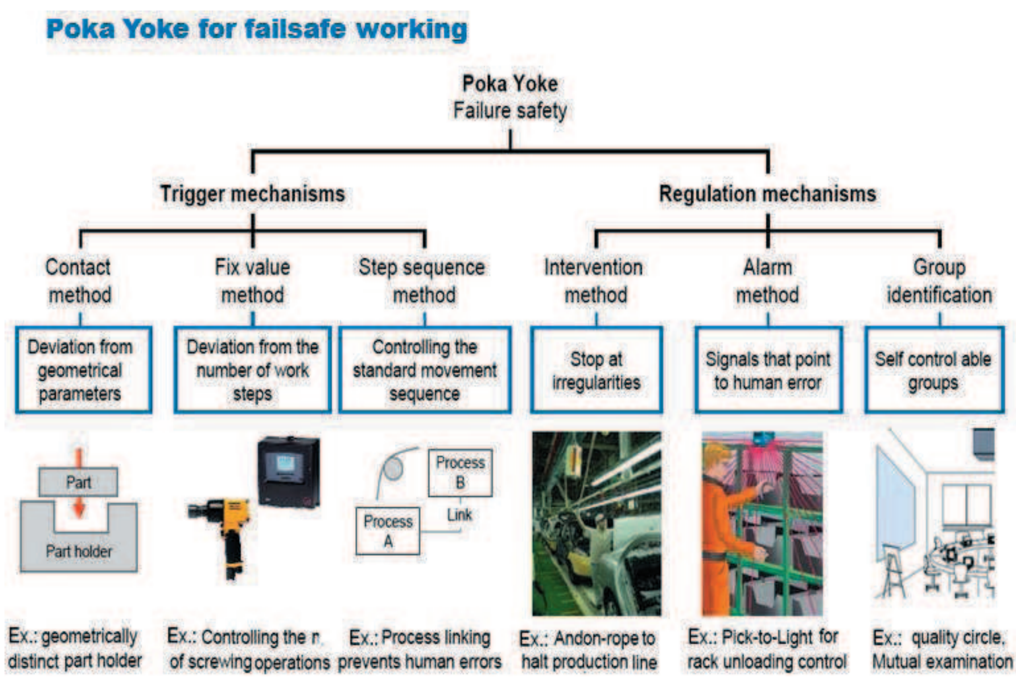

Figure 1.6. *Continuous Improvement (KAIZEN) and DFX approach trough fail safe devices and operation control (POKA-YOKE) [10]*

Finally, during verification (V), it should make sure that the performance of the designed solution meets the customer's requirements.

1.2.4. Lean Six Sigma (L6σ)

The integration between LS and 6σ discussed in this work has been called Lean Six Sigma (L6σ) 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 [18].

1.3. Quality System case

1.3.1. Methodology

The methodology applied in this chapter is one case study, which according to Yin [19] 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.

1.3.2. 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

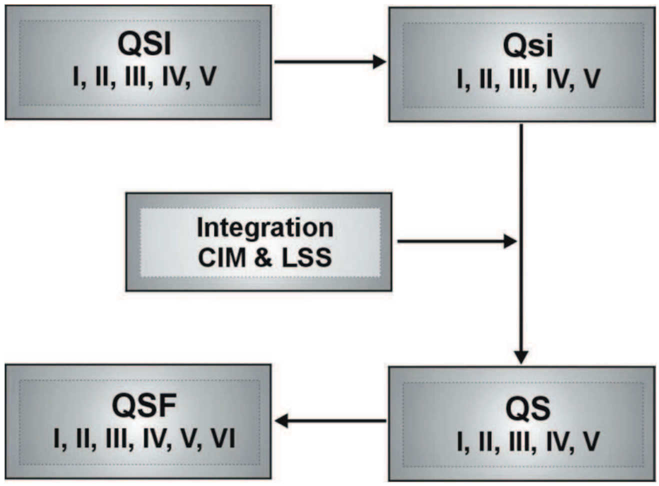

Figure 1.7. *Quality System Evolution (QSF)*

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") (Figure 1.7). Thus, the QSi undergoes a major transformation, changing first to the Quality System (QS). This transformation is based on integration and CIM L6σ. The Quality System (QS) was modelled 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 1.7). 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 1.7).

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 1.8 to 1.12. QSF has increased from five to six subsystems. It incorporated a new system called continuous improvement (QSF VI), described in Figure 1.13. The function of this subsystem is to integrate all the improvement processes of other subsystems. The quality management subsystem (I), described in Figure 1.8, establishes an organization focused on customer satisfaction. Employees are motivated to the extent of their involvement and consequent commitment. The customer's satisfaction and co-workers' commitment integrate and join the quality management with the project development. The description of each subsystem is presented below.

Figure 1.8. *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 analysing the failures of the product, periodically examine the system and quality administration, monitor the cost, develop and integrate the planning within the business, analyse 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 analysing 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 1.9 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.

Figure 1.9. *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, analyses 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 analyse 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: stablish, 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), seen in the Figure 1.10, 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.

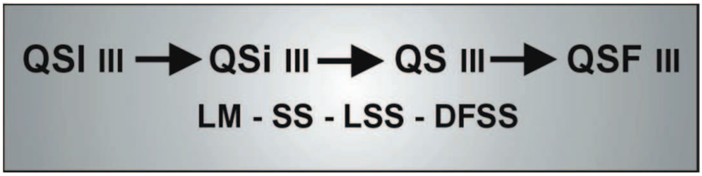

Figure 1.10. *Manufacturing (III)*

- **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 analyse 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 1.11, manages the acquisition of SCM (Supply Chain Management). The description of each subsystem is presented below.

- **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. The QFD technique reduces the total time of project, and

Figure 1.11. *Supplier (IV)*

and improve the DFM approach. 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 1.12, 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** → 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.

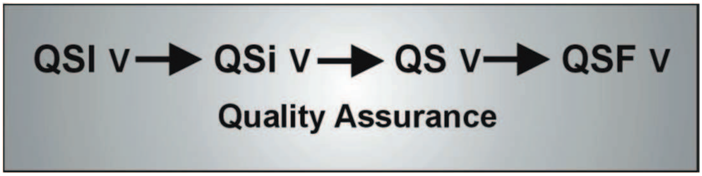

Figure 1.12. *After-Marketing (V)*

Figure 1.13. *Continuous Improvement (VI)*

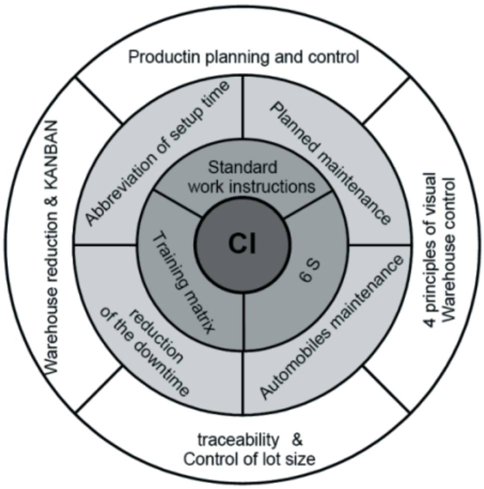

Figure 1.14. *Continuous Improvement integrated approach – KAIZEN [10]*

Finally, the continuous improvement subsystem (VI), see Figure 1.13, 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 Industrial management and organization Integrated product and process system with continuous improvement in the auto parts industry action which is shared between the working groups and managers.

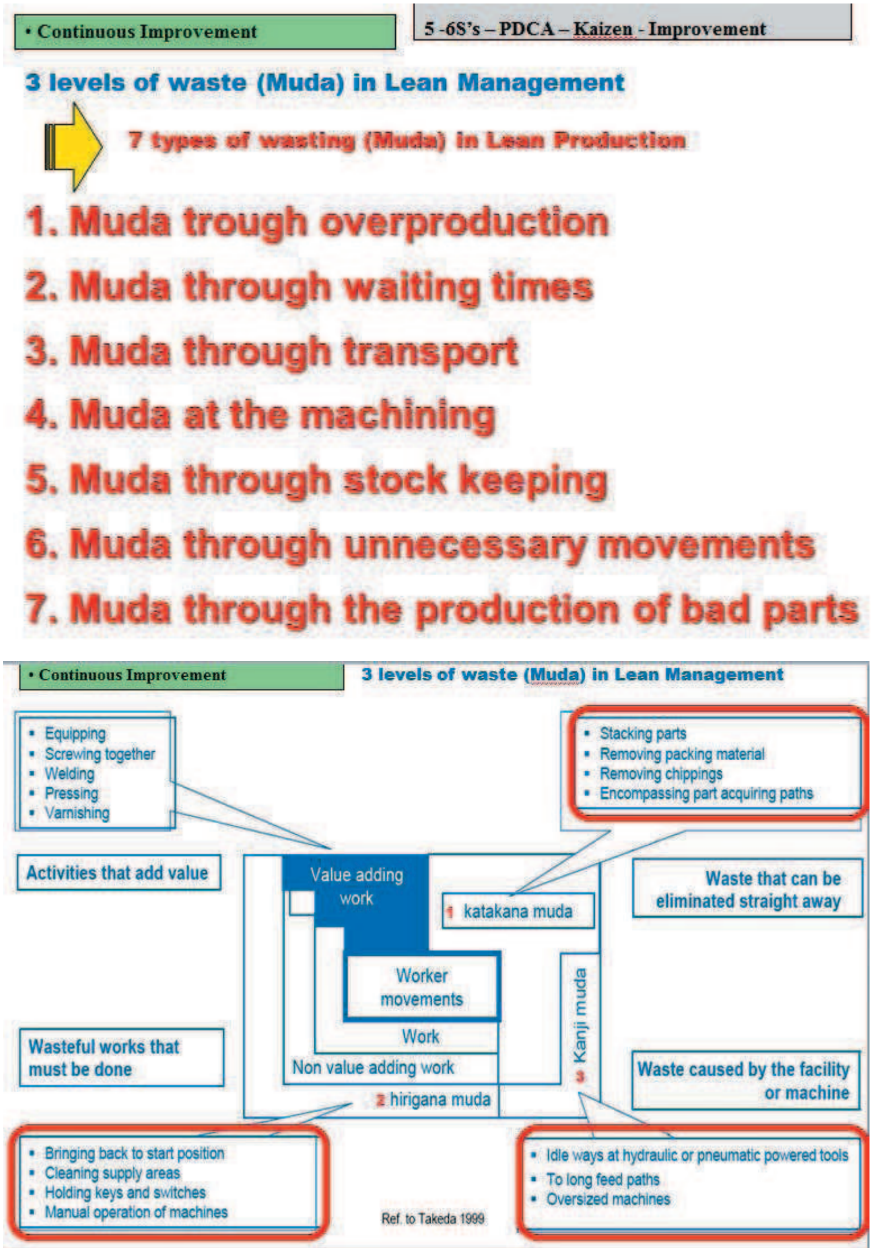

Figure 1.15. *Continuous improvement (KAISEN) by reduction of the waste (MUDA) – The three levels and seven types of waste. Adapted after Takeda [20]*

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 labour 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 in the following item.

- **QSF VI** → Applies these five (5 S's), PDCA cycle and Kaizen (Continuum Improvement – CI) (see Figures 1.14-1.16). Ensures 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-control for "zero-loss" and discipline to ensure the reduction of the internal and external

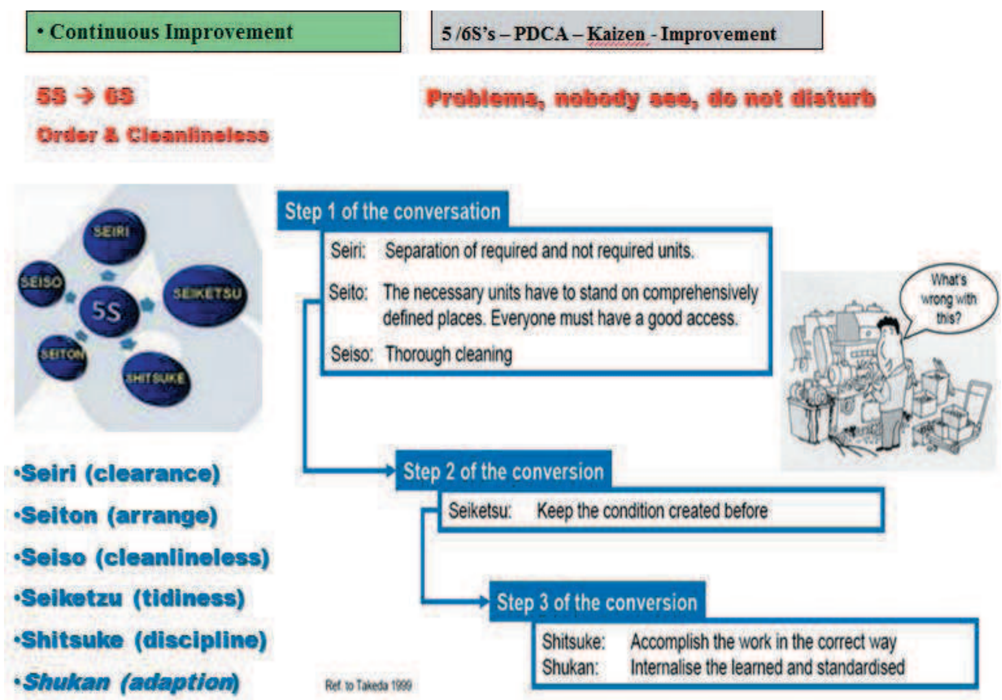

Figure 1.16. *Continuous improvement (KAISEN) through the 5S/6S approach. Adapted from Takeda, 1999 [20]*

quality cost for the 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 people's collaboration and integration.

1.4. Results and discussions

Table 1.4 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 downgrading 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 (QSMVI), 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 1.5 shows the reorientation of the quality systems developed from ISO 9001:1994 to ISO 9001:2000.

Table 1.4. *Quality evolution as evaluated at the final customer*

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

Table 1.5. *Quality evolution in the systems*

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

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 1.5).

1.5. Summary

The following conclusion can be stated about the findings on the modelling 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, a 92% 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 of such a quality system, results on the apparent difficulty to define it can easily through a summarized law or even through 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.