Management Assessment Tool of Lean Manufacturing and Six Sigma based on PNQ Model: A Brazilian Case Study

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Abstract

The competitiveness in the industrial environment has increased considerably and, as a direct consequence, the search for different techniques and management practices to achieve better performance in all processes have been a major concern for organizations interested in solidifying its global market presence. Companies are using models, philosophies and programs to improve their production processes, seeking to reduce wastage, time and increase profits. This paper aims to show the main results of an implementation of a tool developed to assess the integrated elements originated from Lean Manufacturing and Six Sigma, based on PNQ (*Programa Nacional da Qualidade* - Brazilian National Quality Program). Thus, some specific objectives were outlined: i) to develop constructs and elements from theory that represents this integration about Lean Manufacturing and Six Sigma, based on PNQ Quality model; ii) to apply the instrument in one manufacturing organization in Brazil; iii) to briefly analyze and discuss the results. This is an applied and qualitative research, which used basic qualitative studies and descriptive techniques as research strategies. A 5-point Likert scale was used for the evaluation of the elements and constructs. The instrument was applied in one manufacturing company located in the southern region of Brazil. The application of the instrument showed that it could be useful in the management of elements and constructs of companies that have the Lean Manufacturing and Six Sigma implemented. Among the 9 constructs, three of them need more attention: Strategy, Culture and Customer.

Keywords: Lean manufacturing; six sigma; management; PNQ.

1 Introduction

The competitiveness in the industrial environment has increased considerably and, as a direct consequence, the search for different techniques and management practices to achieve better performance in all processes have been a major concern for organizations interested in solidifying its global market presence. Companies are using models, philosophies and programs to improve their production processes, seeking to reduce wastage, time and increase profits.

Currently, one of the philosophies that have been widely used by businesses, especially in large companies, is the philosophy of Lean Manufacturing. It is a philosophy originated in Japan in the 1950s, in Toyota Corporation. This philosophy basically seeks the elimination of waste. Another program that is gaining adherents in the manufacturing world is the Six Sigma. It has emerged in the late 1980s, in Motorola Company. It has as fundamental principle the continuous reduction of variation in processes and consequently seeks to achieve the satisfaction of both customers and consumers.

This paper aims to show the main results of an implementation of a tool developed to assess the integrated elements originated from Lean Manufacturing and Six Sigma, based on PNQ Model. Thus, some specific objectives were outlined: i) to develop constructs and elements from theory that represents this integration about Lean Manufacturing and Six Sigma, based on PNQ Quality model; ii) to apply the instrument in one manufacturing organization in Brazil; iii) to briefly analyze and discuss the results.

The paper has more four sections besides this introduction. We present in section 2 the theoretical framework of the paper, presenting terms as Lean Manufacturing, Six Sigma, and the PNQ Model. The

third section presents the research's method and the management tool. The fourth section presents the results of the application and the fifth presents the conclusions.

2 Theoretical Framework

2.1 Lean Manufacturing

One of the new programs or philosophies that have been widely used by organizations, especially in large companies, is the Lean Manufacturing. It is a philosophy originated in Japan in the 1950s, in Toyota Corporation. It basically seeks the elimination of waste, loss and inefficiency. In the United States, it was popularized from the 1990s with the publication of the book "The Machine That Changed the World" by James P. Womack, Daniel T. Jones and Daniel Roos (Womack; Jones; Roos, 1990).

The book clearly illustrates the significant difference in performance achieved by implementing this concept in the Japanese auto industry in comparison with western industry. For Womack, Jones and Roos (1990) Lean Manufacturing emerges as an "antidote" to do more with less, and always with the aim of offering customers what they really want, in time they need. The goal is to make business more flexible and capable of responding effectively to customer needs and still be able to develop, produce and distribute products with less human effort, space, resources, time and overall costs.

In other words, the main objective of lean manufacturing is to produce an item based on customer specifications, in the fastest and most efficient way, and at the best possible price. According to Womack and Jones (1996) there are five underlying principles that form the basis for the concept of lean manufacturing:

a) **Specify Value**: The most efficient way to create a product is to have a complete understanding of what the end user wants before production begins. Building a product according to specifications avoids waste. Communication with the customer is the key to developing the specifications for the product. In other words, instead of building a particular car model in a designated color, that car is manufactured with each option and accessory that the customer has ordered. The end result is a proficient product for a satisfied customer with a perceived value.

b) **Identify Steps**: Once the value has been identified, a process flow is mapped out to achieve that value. By knowing exactly what steps are needed to create the specified product, unnecessary steps and parts can be eliminated from the process. This allows the product to be manufactured in the shortest amount of time with the least amount of waste.

c) **Process Flow**: When the steps to achieve the value have been laid out, the actual process flow is ready to begin. Each step in the process should flow into the next step without hesitation. The entire process, from start to finish, should literally move like a well-oiled machine. The process should be tight and void of any unnecessary maneuvers. Since the steps are identified and mapped out, the margins of error are greatly reduced or eliminated.

d) **Pull Inventory**: Under the premise of lean manufacturing, only the exact number of parts is pulled from inventory and placed at the point of manufacture. Simply stated, if the specified product requires five two-inch screws, only five two-inch screws are pulled from stock and brought to the manufacturing line. This process is also referred to as Just-In-Time manufacturing. The objective is that you make only what you need when you need it.

e) **Continual Improvement**: As a process is repeated over and over, it can continually be monitored for possible improvements. Under the lean manufacturing concept, these improvements result from elimination of waste during the process. Waste may be defined as extra steps that can be eliminated while still achieving the same end result, or the reduction of idle time during the process. By continually improving the process, the product can be manufactured in less time and at a lower cost.

As this research seeks to present a proposal for an assessment tool that integrates management of Lean Manufacturing and Six Sigma, there were selected other researches that present the principles of Lean Manufacturing that could be analyzed and compared with key factors of Six Sigma. The papers and books selected were: Womack and Jones (1996), Jackson and Jones (1996), Karlsson and Ahlström (1996), Sánchez and Pérez (2001) and Godinho and Fernandes (2004). Table 1 shows a comparison between the principals presented in these selected researches.

Womack e Jones (1996)	**Jackson e Jones (1996)**	**Karlsson e Ahlström (1996)**	**Sánchez e Pérez (2001)**	**Godinho e Fernandes (2004)**
Specify Value (focus on the customer's perspective)	Customers's perspective			Value (focus on the customer's perspective)
Identify steps	Information architecture	Vertical information system	Flexible information system	Identify steps
Process Flow	Lean organization Lean production Lean Maintenance	Waste disposal	Elimination of activities with zero value	Process Flow
Pull Inventory	Lean Engineering	JIT and pull production	JIT	Pull production
Continual improvement	Culture of improvement	Continual improvement	Continual improvement	Continual improvement
	Leadership			
	Partnership		Integration with suppliers	
		Zero defects		Quality
				Cleanliness, order and safety
		Functional teams, integrated functions and responsibilities devolved	Functional teams	Developing and training human resources
				Visual management
				Adaptation to other areas of the company to lean thinking

Table 1: comparison between the principles of Lean.

2.2 Six Sigma

The other program studied on this paper is Six Sigma. What is now called Six Sigma has emerged in the 1980s, when Motorola began a series of studies on the concepts established by Deming on the variability of production processes, aiming to improve performance through analysis of such variations.

Some authors and researchers in the field (Basu, 2004; Blakeslee Jr. 1999; Snee 2000) define the Six Sigma as a very disciplined and quantitative management strategy. The main objective of Six Sigma is to increase the profitability of organizations by improving quality, increasing customer satisfaction. For Linderman et al (2003) the fundamental principle of Six Sigma is continuously to reduce the variation in the process and thus to eliminate the defects or defaults in products and services.

The selected papers in the literature, which present key factors for the implementation and management of Six Sigma and that can be linked with the principles of Lean Manufacturing are: Antony and Banuelas (2002), Johnson and Swisher (2003), Antony (2004) and Kwak and Anbari (2006). A comparison between these papers is presented in Table 2.

Antony e Banuelas (2002)	Johnson e Swisher (2003)	Antony (2004)	Kwak e Anbari (2006)	Santos e Martins (2008)
Involvement and top management commitment to the program	Management commitment and Leadership skill	Commitment of executive leadership and senior management	Organizational commitment and managerial involvement (with a focus on leadership)	Measurement and management of organizational performance
Prioritization and selection of projects, review and monitoring; Project Management Skills	Project selection	Selecting and prioritizing projects; Skills to manage projects; Monitoring and review of projects	Skills check, manage and control projects	Implementation and Project Management
Training Alignment with human resources Organizational infrastructure	Training and continuing education Alignment with human resources	Training and education Organizational infrastructure	Training and continuing education	Training / expertise of people
Alignment to business strategy	Alignment to business strategy	Alignment to business strategy		Strategic orientation and strategic alignment; Strategic and managerial
Customer Focus		Customer Focus		Customer Focus
Cultural change	Organization's overall commitment	Managing cultural change Organization's overall commitment	Acceptance and encouragement for cultural change	
Understanding the methodology, tools (statistics) and techniques		Understanding the methodology DMAIC		Statistical thinking
Alignment with suppliers				
		Aligning economic and financial		
				Use of information technology

Table 2: Comparison between the key factors for Six Sigma implementation.

2.3 Lean Six Sigma based on PNQ Model

According to Smith (2003), Upton and Cox (2004), Arnheiter and Maleyeff (2005) and Snee (2005) the both programs, Lean Manufacturing and Six Sigma, have been designed to be used by companies in an isolated and independent way. However, it is observed in recent years, a greater tendency for the implementation and management of both in an integrated way. For companies, to implement and manage both programs together can bring some advantages, such as to enjoy the strengths of both jointly and in a complementary way, and also overcoming the limitations of each one separately (Connor, 2003; Arnheiter; Maleyeff, 2005). One of the major advantages is related to the rational use of human and financial resources in those programs. So, if companies do not manage properly, in a systemic way, the common elements between Lean and Six Sigma, they will be wasting time and money. But, how the organizations can evaluate integrated elements from Lean Manufacturing and Six Sigma? In other words, how they can manage these elements or manage the Lean Sigma?

Based on the fact that both, the Lean Manufacturing and Six Sigma, are more focused on operational aspects of managing the organization, this paper proposes to use the PNQ Quality Model as the basis for a integration of Lean Manufacturing and Six Sigma. The PNQ Quality Model (also know in Brazil as Management Excellence Model - MEG) is a systemic model of organizational management, with strong results orientation, based on eleven grounds that are put into practice by means of the eight criteria of excellence.

The PNQ/MEG is a model that sees organizational management in a systematic way, an organic system, adaptable to the external environment (FNQ, 2009). The model emerged from the experience of FNQ - National Quality Foundation with the PNQ - National Quality Award. The award has existed since 1992 and was awarded companies like IBM Brazil, Xerox Brazil, Citibank, Alcoa, Bahia Sul Celulose, Gerdau, among others.

The Model provides an integrated and interdependent orientation to manage an organization. Considers that the various elements of the organization and stakeholders interact in a harmonious and balanced strategies and results. Thus, the PNQ/MEG allows the various elements of an organization can be implemented and evaluated together interdependently and complement (MEG, 2008).

According to Miguel (2006), the PNQ/MEG is today in Brazil an important tool for encouraging competitiveness in the form of assessment of companies seeking to achieve excellence in recognition of what they produce and / or marketing, are products, or services. It is based on eleven pleas and eight criteria. The FNQ sets the pleas as the pillars, the theoretical basis for good management. They are: systems thinking, organizational learning, culture of innovation, leadership and constancy of purpose, guidance and information processes; vision of the future, value creation, valuing people, knowledge of the customer and the market, development of partnerships and social responsibility (MEG, 2008).

These pleas are put in place by means of the eight criteria of excellence, which correspond to a scoring system, whose maximum sum is 1,000 points. Each of the eight criteria has a different weight, as shown in Table 3.

Table 3: Distribution of points and weights for the MRG/PNQ criteria.

Critérios	Points	Weights	Criteria items
Leadership	100	10%	1.1 System leadership 1.2 Culture of excellence 1.3 Analysis of organizational performance
Strategies and plans	90	9%	2.1 Formulation of strategies 2.2 Implementation of strategies
Clients	60	6%	3.1 Picture and market knowledge 3.2 Relationship with customers
Society	60	6%	4.1 Social and environmental responsibility 4.2 Ethics and Social Development
Information and Knowledge	60	6%	5.1 Organization Information 5.2 Information comparative 5.3 Intangible Assets
People	90	9%	6.1 Systems work 6.2 Training and development 6.3 Quality of Life
Process	90	9%	7.1 core business processes and support processes 7.2 Processes of relationship with suppliers 7.3 Processes economic and financial
Results	450	45%	8.1 Economic and financial results 8.2 Results for the customers and the market 8.3 Results related to society 8.4 Results for persons

			8.5 Results of core business processes and support processes 8.6 Results for the suppliers
TOTAL	1.000	100%	

Source: Adapted from MEG (2008)

Carvalho (2008) highlights the strong orientation of model results, which represents (for the model) the excellence of the organization in various aspects related to customers and markets, the financial situation, people, suppliers, society and the processes. It also emphasizes the systemic view is very present in the model, since it suggests interaction between the criteria, represented in Figure 1 by blanks. As noted in this context, the criteria are subdivided into 24 items. Items 1.1 to 7.3 are named in Items Process Management model and ask, specifically, some requirements related to the management of the organization without prescribing tools or working methods. The so-called Items Organizational Outcomes (8.1 to 8.6) require the submission of performance indicators that indicate the areas of important results.

3 The Method and Management Tool

Table 4 presents the proposal for the integration of lean principles and key factors of Six Sigma through 9 constructs (from PNQ/MEG). This table was made from the literature and it was the basis for the development of the tool that was applied in a Brazilian company.

Construct	***Principals of* Lean Manufacturing**	***References***	**Critical Factors of Six Sigma**	**References**
Leadership	Leadership	Jackson; Jones (1996) Womack; Jones (1996)	Commitment and Leadership skills	Antony; Banuelas (2002) Johnson; Swisher (2003) Antony (2004) Kwak; Anbari (2006)
Culture	Continuous Improvement Culture	Womack; Jones (1996) Jackson; Jones (1996) Karlsson; Ahlström (1996) Sánchez; Pérez (2001)	Culture (change)	Antony; Banuelas (2002) Antony (2004) Kwak; Anbari (2006)
Strategy	Strategy Alignment	Jackson; Jones (1996) Womack; Jones (1996)	Strategy Alignment Economic Alignment Economic-financial Alignment	Antony; Banuelas (2002) Johnson; Swisher (2003) Antony (2004)
Costumer	Value (Costumer focus)	Womack; Jones (1996) Jackson; Jones (1996)	Costumer focus	Antony; Banuelas (2002) Antony (2004)
Human Sources Management	Development and Human Sources Training	Womack; Jones (1996) Jackson; Jones (1996) Karlsson; Ahlström (1996) Sánchez; Pérez (2001)	Human Sources Management	Antony; Banuelas (2002) Johnson; Swisher (2003) Antony (2004) Kwak; Anbari (2006)
Flow Management Process	Identification of the value stream Flow Pull production Information systems	Womack; Jones (1996) Jackson; Jones (1996) Karlsson; Ahlström (1996) Sánchez; Pérez (2001)		
Continuous Improvement	Continuous Improvement Waste disposal	Womack; Jones (1996) Jackson; Jones (1996) Karlsson; Ahlström	Implementation and Project Management	Antony; Banuelas (2002) Johnson; Swisher (2003) Antony (2004)

		(1996) Sánchez; Pérez (2001)		Kwak; Anbari (2006)
Partnership and Society	Partnership with stakeholders	Jackson; Jones (1996)	Alignment with suppliers	Antony; Banuelas (2002)
Quality	Focus in Quality Zero defects	Jackson; Jones (1996)	Quality (Focus in Statistic)	Antony; Banuelas (2002) Antony (2004)

Table 4: Framework for the relationship between Lean Manufacturing and Sis Sigma, based on constructs of PNQ.

The instrument developed in this research aims to assist in the management of integrated elements and constructs from the principles of Lean Manufacturing and the critical factors of Six Sigma. The instrument has 9 constructs and 45 elements that represent the integration, according to Table 5.

Construct	***Elements***
Leadership	1.1 Leadership system (commitment and ability) 1.2 Dissemination of company values 1.3 Internal communication strategies 1.4 Analysis of overall performance
Culture	2.1 Spreading the culture of excellence 2.2 Dissemination the culture of continuous improvement 2.3 Resource allocation for cultural adaptation
Strategy	3.1 Formulating strategies 3.2 Implementing strategies 3.3 Deployment of action plans 3.4 Balancing of needs
Costumer	4.1 Knowledge of customer characteristics 4.2 Knowledge of decision factors of customers 4.3 Knowledge of what adds value to the client's vision 4.4 Closer customer relationships 4.5 Knowledge about current market 4.6 Knowledge about potential market
Human Sources Management	5.1 Existence of training programs for leaders 5.2 Existence of training programs for others employees 5.3 Focus on capacity building of multifunctional teams 5.4 Existence of motivation programs for employees 5.5 Existence of motivation programs for leaders 5.6 Concern about quality of life of employees
Flow Management Process	6.1 Dissemination of the concept of loss 6.2 Mechanisms to identify losses, 6.3 Mechanisms to classify losses 6.4 Focus on the elimination of losses in the production chain 6.5 Presence of pull production 6.6 Mechanisms of reducing process variability; 6.7 Setup reducing 6.8 Preventive maintenance 6.9 Presence of information systems 6.10 Mechanisms of information analysis
Continuous Improvement	7.1 Dissemination of the concept of continuous improvement throughout the organization 7.2 Concern with the choice of projects 7.3 Concern with the management of projects 7.4 Presence of performance measurement systems 7.5 Feedback about information
Partnership and Society	8.1 Environmental management programs 8.2Health and safety programs 8.3 Social responsibility programs

	8.4 Alignment and partnership with suppliers
Quality	9.1 Use of statics tools in the process with focus on reducing variability 9.2 Use of statics tools in the process with focus on reducing losses 9.3 Certification of quality programs (such as ISO 9001)

Table 5: Constructs and Elements of the instrument

For each element of analysis, the respondents chose a grade between 1 and 5 (Likert scale) according to the scale shown in Table 6. This scale represents the degree of implementation of each element in the company. Once answered and returned, the data analysis was made. 15 questionnaires were returned. Respondents were 02 managers (Quality and Operations), 05 technicians and 08 people working on the production line.

Degree	Situation
1	Do not apply/it is improperly applied/does not exist in the company
2	Exists in the company but in isolated areas/exists but was not continued
3	It is implemented but not so systemically
4	Implemented throughout the organization, but needs to consolidate
5	Implement in a systemic and consolidated way

Table 6: Scale for the degree of implementation

4 Results

The company in which this case study was conducted began its operations in 1978 and it is located in southern region in Brazil. It has about 4,000 employees and is considered a large company. It manufactures electronic fuel injection systems for diesel engines. Its main customers are the automotive industry, from Brazil, the United States, Europe and Asia.

In 1996 the company received its first ISO 9001 certified. In 2000, they received the first certification of ISO/TS 16949, and in 2003, the first ISO 14001 certification. The company does not have the certification of OHSAS 18001, but has a system to manage health and safety implemented. They use lean manufacturing since the 1990s and they have been improving its fundamentals. They also work with the Six Sigma program, since the beginning of 2000.

After the application of the instrument in the company, it is observed through the Table 7 that the company presents a construct (Partnerships and society) with 4.5 degree of application. Five of the nine constructs (Leadership, Human resources management, Flow management processes, Continuous improvement and Quality) present level of implementation closer to 4. And three of the nine constructs (Culture, Strategy and Client) are closer to the implementation level 3.

	Constructs	**Grade**
1	Leadership	3,75
2	Culture	3,00
3	Strategy	2,75
4	Costumer	3,33
5	Human Sources Management	3,83
6	Flow Management Process	4,10
7	Continuous Improvement	3,80
8	Partnership and Society	4,50
9	Quality	4,33

Table 7: Results of the constructs

The construct **Strategy** had the lowest score (2.75). The element about the consequences of the action plans was the element that had the worst level of application (grade 2). It means that it has already been implemented in isolated areas, but there was no continuity. The second worst was **Culture**. In this case,

the company introduced the element of resource allocation for cultural adaptation rated as the worst (grade 2). It also means that it has been implemented in isolated areas, but no continuity.

The next is the construct **Costumer** who obtained a degree of application 3.33. In this case, the element of knowledge of the decision factors of customers was that had the worst rating (grade 2).

The remaining six constructs, as well as its elements, everyone had a rating equal to or above level 3. The construct of **Leadership** was rated the sixth best, with 3.75 degree. Then came the **Continuous Improvement** construct, with 3.8 degree. And fourth, the construct of **Human Sources Management**, with 3.83 degree. The third construct with best evaluation was **Flow Management Process**, with only one of its elements with grade 3 (focus on eliminating losses in the production chain) and all others with grades 4 or 5.

The construct **Quality** also had a good assessment in relation to your application, getting 4.33 degree, although the degree 3 for the element of use of statistical tools in the process, focusing on reducing losses. The construct better evaluated by the company was **Partnership and Society**, with 4.5 degree.

5 Conclusion

The objective of this paper was to show a proposal of an instrument or tool developed to assess the integrated elements originated from Lean Manufacturing and Six Sigma and an application of this instrument in a Brazilian company. In this case study, the constructs that need greater attention are the constructs of Strategy, Culture and Customer. Considering the proposal behind this instrument, that is to help the organization management, all of them need close attention, because they are very important to the spread of excellence.

Regarding the elements, three of the 45 evaluated need attention, because they have grade 2 (it means they are implemented in isolated areas and without continuity), they are: allocation of resources for cultural adaptation, deployment of action plans, and knowledge of the factors decision of the customers.

We believe that this first attempt to develop an assessment tool built form the principles of Lean Manufacturing and the key factors of Six Sigma, and also the application in a large company brought us some new ideas that can improve this research in the future.

As recommendation for further work and continuation of this research, one possibility would be to increase the number of companies in which the instrument can be implemented by, for example, a survey research. In this case, the idea is to make another type of analysis, not only qualitative but also quantitative, using statistical methods.

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