UNIVERSITÀ DEGLI STUDI DI PADOVA

Head Office: Università degli Studi di Padova

Department of Management Engineering

Ph.D. COURSE IN MANAGEMENT ENGINEERING AND REAL ESTATE ECONOMICS

CYCLE XXX

DEVELOPMENT OF AN ASSESSMENT TOOL FOR THE EVALUATION OF LEAN PRACTICES IMPLEMENTATION IN SMALL AND MEDIUM-SIZED ENTERPRISES

Coordinator: Prof. Cipriano Forza

Supervisor: Prof. Roberto Panizzolo

Ph.D. Student: Alberto Maria de Crescenzo

"I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I…
I took the one less travelled by,
And that has made all the difference."

Robert Frost, The Road Not Taken

Abstract

Companies of different dimensions and various business have invested in the implementation of lean practices inspired by the principles belonging to “Toyota Production System”. Thanks to Toyota success, consisting in becoming one of the biggest automaker in the world, lean manufacturing emerged as one of the most popular topics in business and manufacturing literature.

Despite this success, the implementation level of various lean manufacturing practices and measures could vary not only between companies, but also within a company over time. Lean manufacturing implementation elements are evident across different sectors, but the pace of change is dramatically different and outcomes vary company by company. On the one hand, the LM practices have been defined thanks to various studies during last thirty years but the outcomes of their implementation have not been sufficiently assessed in regards to small and medium-sized enterprises. On the other hand, the need to assess the overall status of lean implementation derived directly from the lean principle of pursuing the perfection.

The emerging gaps highlight the lack of assessment techniques capable of assess the outcomes of lean manufacturing implementation based on certain firm-specific inputs. Moreover, the importance to investigate the relationship between organizational characteristics (product vs. process focus, volume, variety, firm peculiarity and so on) and the implementation of lean practices has largely been ignored in research. Therefore, the current gaps address the development of an effective methodology to assess the level of LM practices implementation according to firm characteristics

Therefore, the aim of this paper is to propose a contingent assessment tool able to identify priority practices and relevant performances in line with production system characteristics and firm’s strategic priorities. Therefore, the proposed tool has two main objectives: the first one consists in assessing the degree of LM practices implementation considering the organizational/production context, the second one lies in defining improvement paths in line with strategic objective of the company.

Keywords: Lean Manufacturing, Assessment Tool, Lean Practice, Small and Medium-Sized Enterprises.

Sommario

Aziende di diverse dimensioni e differenti settori di attività hanno investito considerevolmente nell'attuazione di pratiche Lean ispirate ai principi del "Toyota Production System". Grazie al successo Toyota, che è diventata uno dei più grandi produttori mondiali di automobili, il Lean manufacturing è emerso come uno dei temi più diffusi nella letteratura inerente sia gli aspetti produttivi produzione che le attività manageriali.

Nonostante questo successo, il livello di implementazione delle diverse pratiche di Lean manufacturing e delle relative misure variano non solo tra aziende dello stesso settore, ma anche all'interno della stessa azienda. Elementi di implementazione del Lean manufacturing sono evidenti in diversi settori, ma il ritmo del cambiamento è considerevolmente disomogeneo e gli esiti di tale cambiamento variano da azienda ad azienda. Da un lato, le pratiche di Lean manufacturing sono state definite negli ultimi trent'anni grazie a innumerevoli studi accademici, ma i risultati della loro attuazione non sono stati sufficientemente valutati per quanto riguarda le piccole e medie imprese. D'altro canto, la necessità di valutare lo stato complessivo di implementazione della Lean deriva direttamente da uno dei principi cardini di questa filosofia: il perseguimento della perfezione.

I gap emergenti evidenziano la mancanza di tecniche di valutazione capaci di determinare i risultati dell'implementazione del Lean manufacturing basandosi su determinati input aziendali specifici. Inoltre, l'importanza di investigare la relazione tra le caratteristiche organizzative (ad esempio focus sul prodotto o sui processi, volumi produttivi, varietà del mix, specificità aziendali ed etc.) e l'attuazione di pratiche Lean è stata ampiamente ignorata nella ricerca. Pertanto, i gap attuali in letteratura evidenziano la mancanza dello sviluppo di metodologie efficaci per valutare il livello delle implementazioni delle pratiche di Lean manufacturing in base alle caratteristiche aziendali. Pertanto, l'obiettivo di questo tesi è quello di proporre uno strumento contingente di assessment in grado di identificare le pratiche primarie e le prestazioni rilevanti in linea con le caratteristiche del sistema di produzione e le priorità strategiche dell'impresa. Dunque, lo strumento proposto ha due obiettivi principali: il primo consiste nel valutare il grado di attuazione delle pratiche di Lean manufacturing in considerazione del contesto organizzativo / produttivo, il secondo nella definizione dei percorsi di miglioramento in linea con gli obiettivi strategici dell'azienda.

Parole Chiave: Lean Manufacturing, Strumento di Assessment, Pratiche Lean, Piccole e Medie Imprese.

TABLE OF CONTENTS

Chapter 1: Introduction

Due to the persistence of economic recession in the first decade of twenty-first century many organizations were forced to reduce cost and to be more reactive to customer demands. In order to face the fierce completion in the global market, manufacturing organizations primarily deal with challenges from two different directions (Jasti and Kodali, 2015):

- Firstly, traditional existing production paradigm and methods show their obsolescence while advanced manufacturing philosophies are intensely emerging.
- Secondly, the customer behaviour is changed: they have become more demanding for innovative products and services in shorter period and cheaper products at same time.

Other authors describe this phenomena with a broad prospective, defining the twenty-fist century as the century characterized by the hyper –competition (Hu et al.,2015). However, the implication of this analysis on the demand side is the same: customers are characterized by a resolute assertiveness in searching and looking for better and worth values selecting products and services (Bhamu and Sangwan, 2014).

In this context, Lean Manufacturing (LM) has been extensively perceived by different industrial sectors as a suitable reaction to these necessities because one of the main purpose of LM is to reduce waste without additional requirements of resources. In fact, application of LM is not limited exclusively to the automotive sector, it has been implemented in a wide range of manufacturing industries in western countries (Shah and Ward, 2003) and all over the world (Cua et al., 2001; Anand and Kodali, 2008); moreover LM is being applied in small as well as large organizations (Hu et al., 2015).

Therefore, although a huge variety of tools and methodologies has been developed to increase competitive advantages, LM principles and methods have been shown to be one of the most effective for manufacturing sector (Pakdil and Leonard, 2014; Womack et al, 1990; Liker, 1997; Hino 2006; Li 2013). In fact, the main aim of LM is to be highly responsive to customers' demand by reducing waste.

On one hand, this led researchers and practitioners in LM field to formulate an overabundance of LM definitions in terms of objectives, performance indicators, tools/techniques/methodologies (Bhamu and Sangwan, 2014). On the other hand, despite the diffusion of LM, practitioners and especially managers have difficulty in assessing how their production system inspired by the LM principles can contribute to improve the organization's performance. This fact implies also the need to have more control on overall production processes and LM tools/techniques/methodologies applied (Cezar et al., 2014).

For this reason, managers need, aside from lean procedures that help them to plan and implement LM activities, answering to the question "*how to become leaner*", also integrated frameworks that help them to determine "*how lean is"* their production system according to firm's strategic objectives and production process characteristics.

1.1 Scope and research objectives

In conducting the research, firstly it is essential to set the boundaries of the research itself; therefore this section plays a key role in the entire thesis because it defines and describe in details the initial assumptions and ideas underlying the research (Yin, 1994).

Ghosh (2012) proposes that "LM is viewed by the scholarly community primarily at three levels", this classification is useful in order to determine the level of abstraction in the literature and identify at which level this research thesis is located:

- First Level or Philosophical Level: at the first level, the conceptualization of "waste" elimination from the production system is provided. Waste, called in Japanese *muda,* are in total seven and defined as: over production, unnecessary motion, excess inventory, excess transportation, rework, waiting, and over processing (Ohno, 1988; Shingo, 1989; Womack et al., 1990; Womack and Jones, 1996). For instance, Shingo (1989) states that nearly 80 percent of production time are waste; only a minimal part represents value added activities. Apparently at that level, elimination of these waste looks simple and straightforward, nevertheless their identification is often difficult in most organizations.

- Second Level or Normative Level: at this level scholars define lean as a rule driven system. Spear and Bowen (1999) in their research studied 40 plants in Europe, Japan and USA. In their findings, they define that Toyota utilizes three main rules for the production system design and one more rule for a structured approach to the problem solving. The first rule prescribes that all activities should be defined in terms of timing, sequence and content/outcome. The second one proposes that all interaction/ connection with customer and supplier should be straight and unambiguous. The third rule braces simple and direct pathways for any product/service provided. The last one, referred to the problem solving, recommends that incremental improvement should be performed with a structured and well defined approach at the lowest level possible.
- Third Level or Operative-Functional Level: at this level lean is established as a aggregation of tools/practices/techniques. In this study, the term lean practices (LP) refers merely to this kind of aggregations. Many scholars investigated the lean at this level proposing the application of these aggregations. For instance, Karim and Arif-Uz-Zaman, (2013) propose an integrated methodology for implementing LM in a firm. Their model identifies different waste by production time study and process. Starting from these *muda*, an improved process map is developed in manufacturing area; process efficiency and effectiveness are evaluated by using performance measurement thanks to the application of selected LPs. Moreover, various scholars investigate the relationships between different LP and production performance (Karlsson and Åhlström, 1996; Agus and Hajinoor, 2012), or financial and non-financial measures (Fullerton and Wampe, 2009). Soriano-Meier and Forrester (2002) analyse the degree of adoption of 9 LPs in relation to the management commitment to lean transformation program and changes made in this direction. In addition, others scholars investigate the application of LPs and propose a categorization of them: for instance Shah and Ward (2013) identify 22 LPs and classify them in four bundles: just-in-time (JIT), total quality

management (TQM), total productive management (TPM), and human resource management (HRM). Moreover, Sanchez and Perez (2001) develop a check-list of 36 lean indicators in six groups to assess the changes towards LM.

In summary, the first level of the classification proposed by Ghosh (2012) provides the highest level of abstraction according to a philosophical perspective and the rule driven system provides the second level of abstraction; the third level composed namely by lean LPs defines the least level of abstraction. Therefore, relevant for the purposes of this thesis is the fact that at third level of abstraction are located the LPs extensively utilized for the implementation of LM in industry (Shah et al., 2008).

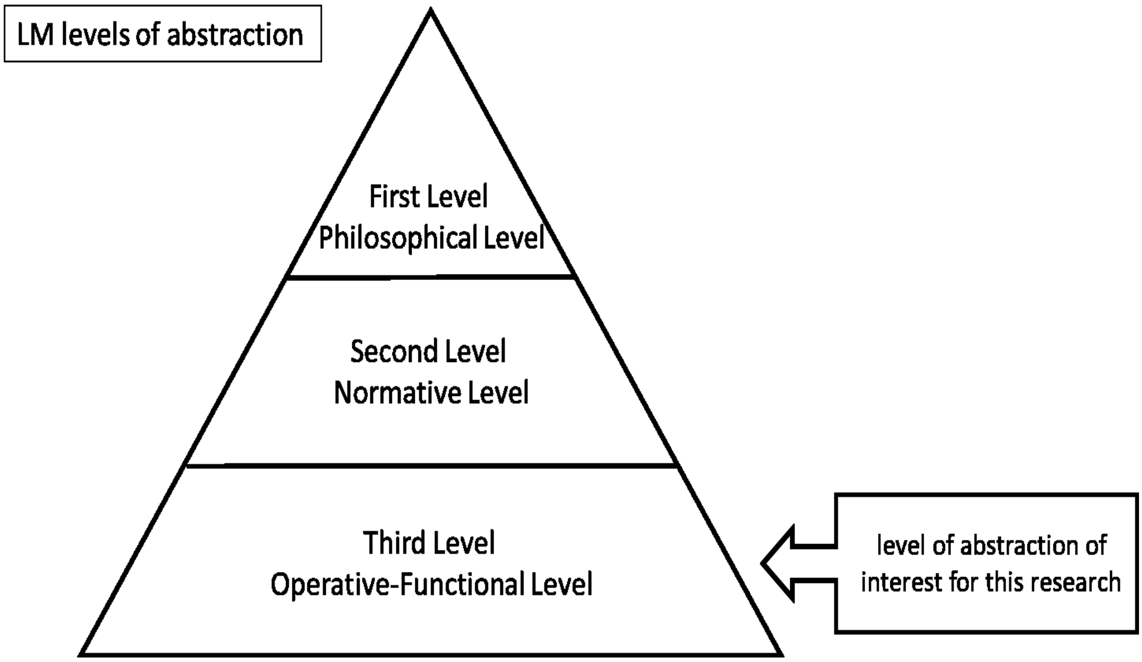


Figure 1.1 Level of abstraction of interest for this research

Identified the level of abstraction of interest for this research (Figure 1.1), another relevant definition of the focus of this research is provided as follow: small- and medium-sized enterprises (SMEs) play a remarkable role in industrial manufacturing sector in term of production volume and employment generation. Economic globalization and emerging technologies have a tremendous impact on SMEs, therefore these kinds of firms are hardly trying to adopt new methodologies and principles like LM to achieve decisive performance improvement (Bhamu and Sangwan, 2014). While several scholars address the lean implementation in general (e.g. Hines et al., 2004; Moyano-Fuentes and Sacristan-Diaz, 2012) or focus on large enterprises (LEs) rather than SMEs (Gnanaraj et al., 2010), there is a deficiency of research that focuses on LP implementation within SMEs (Hu et al.,2015)

Before to delineate the scope of this research, three interesting themes that are ***not*** the main focus of this study are briefly introduced for the sake of clarity. In the most recent literature on LM and SME, the first theme that arises is the application of lean on external operations, generally logistics and supply chain management. SMEs are expected to be more focused on internal operation (production and operation processes) rather than the external ones, the approach to implement Lean is commonly viewed as an "operational practice" (Pettersen, 2009). Hu et al. (2015) highlight the difference whit "what is observed in the literature for Lean in LEs, in which LM applicability on external operations is more likely to be defined as a strategic philosophy". Stuart and Boyle (2007) point out that Lean adoption outside the SMEs' factory floor can be hardly found. Although Karlsson and Ahlstrom (1997) state that even if Lean applicability is extendable to the SMEs' logistics and supply chain, there is still a slight evidence in literature of this applicability. In fact, Hu et al. (2015) in their literature review on Lean implementation within SMEs argue that there is a lack of knowledge about "how Lean can be implemented at the supply chain level by SMEs".

A second relevant theme is the integration of LM with other systems/philosophies. For instance, Hu et al. (2015) focus on how the Lean in SMEs approach can be combined with Six Sigma. This approach integrates quality control and continuous improvement using rigorous statistical analysis and data collection methodologies (Nabhani and Shokri, 2009). Another important topic in this research stream is the integration with IT solutions. IT is now pervasive in manufacturing firms. In all modern organisations, IT solutions are widely implemented and the more widespread systems such are: Material Requirements Planning (MRP) and Enterprise Resource Planning (ERP) (Hu et al.,2015). Moreover, others integration of LM with systems/philosophies are evident in the manufacturing sector: discrete event simulation software, Theory of Constrains (TOC), Quality Function Deployment (QFD) and accounting method as ABC.

The third theme is the investigation of critical success factors (CSFs) for Lean implementation in SMEs. In particular, this stream of research concerns the identification of inhibiting and enabling factors in favour of SMEs when implementing Lean. Typically, inhibiting factors for SMEs are identified in two main categories, external and internal ones. One of the key inhibitors on the external side is the issue of supply chain power. Due to the typical small volumes for SMEs, it is difficult for them to negotiate with larger suppliers (Wilson and Roy, 2009). Moreover, SMEs usually compete on the market characterized by a variable demand and the difficulty to receive materials from suppliers in the right quantity at the right time. For these reason, SMEs focus more on JIT production rather to JIT integration with suppliers (Panizzolo et al., 2012). On the internal side, taking into account the financial aspect, the literature emphasizes the lack of appropriate resources and infrastructure/facilities in implementing Lean. Furthermore, SME organisations are characterized by poor processes and quality control systems, they represent barriers to Lean implementation at operational level. Moreover, Panizzolo et al. (2012) highlight that in SMEs, workforce is deployed in day to day operations without considering *"strategic organisational factors, such as developing employee empowerment and participation in decision making and ensuring a supportive organisational culture for Lean"*. Focusing now on enabling factors, SMEs are characterized by easy and fast internal communication thanks to the small size of the organization; it clearly may help the process of Lean implementation in such organizations. In addition, SMEs production systems are more flexible and able to produce small lot sizes to satisfy different customer requirements. In conclusion, SMEs are often privately owned, this trait helps in providing commitment to develope and sustain business (Hu et al., 2015).

At this point, we end up with the relevant theme in this research: the lack of clear LM implementation process and dedicated framework within SMEs. Bhamu and Sangwan (2014) investigate extensively this theme. In a temporal prospective, they have identified three phases: LM pre-implementation, implementation and post-implementation. At pre-implementation phase a firm may define lean awareness programs and clear objectives for all employees. In particular for line operators and supervisors, these activities are supported with dedicated training programs. Bhamu and Sangwan (2014) state that this phase *"creates a platform for lean implementation and at the same time eliminates the scepticism surrounding its implementation and benefits"*. The implementation phase is mainly focused on identification and elimination of waste through the application of selected lean tools and techniques in order to obtain for instance: quality improvements, process stability, inventory control and etc. At this phase is crucial an effective customer-supplier relationship for a successful LM implementation (Bhamu and Sangwan, 2014). The LM post-implementation phase is the most critical phase of lean transformation program. In fact, even if the majority of firms obtain impressive initial gains they are not able to sustain and to spread these gains to the entire organization. A specific research stream in this field emphasises the impact of Lean initiatives within SMEs in terms of efficiency or performance; e.g. reductions in inventory, space, time or improvements of changeover time, delivery time, lead time and throughput time (Hu et al., 2015). Therefore, if on one hand this phase involves the observation of outcomes and process analysis; on the other hands, the organization needs to hold-up in order to observe positive results after implementing lean (Bhamu and Sangwan, 2014) and to act in-line with the strategic objectives of the company and customer value at same time (Srinivasaraghavan and Allada, 2006). For this reason, SMEs should call for reviewing their Lean transformation program in order to create opportunities og improvement concerning LPs implemented, monitoring the path took and the direction to follow.

This latter aspect is the main of this thesis: to formulate and propose an assessment tool for the evaluation of LPs implementation within SMEs, that have already started a lean transformation program, in order to identify the most urgent area to enhance according to firm's characteristics and strategy and to provide clear initiatives of improvement. In fact, the measure of LPs implementation and the selection of right measuring metrics with appropriate implementation method is very crucial (Arif-Uz-Zaman, 2013). A clear understanding of this aspect will close the gap between theory and practice and will provide an effective solution for SMEs manufacturing sector.

Lastly, the current research is financed by the by the Italian Law N. 170, July 11th, 2013, for the improvement of advanced manufacturing systems relevant for the

"Made in Italy" industry. The "Made in Italy" is a merchandise mark regulated by the Italian Law N. 135, September 25th, 2009; the Law states that only products totally made in Italy (planning, manufacturing and packaging) are allowed to use the labels "Made in Italy, 100% Made in Italy, 100% Italia, Tutto Italiano" in every language. Each abuse is punished by the Italian Law.

1.2 Structure of the Thesis

The research starts with a brief description of the origins and evolution of lean manufacturing; it is proposed in the Chapter 2 in order to provide an introduction to LM fundamental concepts. It may help the reader to better understand to topic of this thesis. In the Chapter 3, the literature review on existent Lean Assessment Tools (LATs) is proposed in line with the methodology proposed by Tranfield et al. (2003). The literature review allows to formulate a critical categorization and evaluation of previous works and contributions within the research domain. The review also highlights the analytical observations on research gaps not currently addressed. Moreover, the highlighted research gaps provide the basic guidance in the research design of the following chapters. The Chapter 4 is fundamental for defining the development of this study: there the research questions are formulated and the research methodology adopted is described. In the Chapter 5, the development process and the evolving ideas about the proposed assessment tool are described. The Chapter 6 describes the results of the application of the proposed tool within the sample of firms, practical and theoretical contributions are evaluated in order to assess the quality and validity of the research. Lastly, in the Chapter 7 the research question's answers are proposed and limitation and issues for further research discussed.

Chapter 2: Origins and evolution of Lean Manufacturing

Before to describe the literature review that is the basis of this research, in this chapter a brief description of the origins and evolution of lean manufacturing is proposed in order to provide an introduction to LM fundamental concepts. The chapter firstly describes the Japanese historical and cultural background, then it continues with a description of Toyota Production System (TPS) and it ends with a depiction of LM evolution introducing the key principles universally accepted by academia and practitioners.

2.1 The Japanese historical and cultural background

To better understand how Japanese management and production systems cannot be reduced to mere techniques to import directly into the West-countries' economies, it is necessary to briefly investigate the values underlying them. These values have their roots in a ancient history and culture that has permeated the entire Japanese society at all levels even before business sector.

Taiichi Ohno (1988), founder of the Toyota Production System (TPS), used to repeat: "This production system was born in Japan because it probably would not be able to arise elsewhere". The ethical values expressed by the ancient "way of the warrior", *the bushido*, have been the fertile ground on which the principles and methods of Japanese industrial system have grown.

Perhaps, the best metaphor representing the ideal for a Japanese firm or plant is the tea ceremony for its austerity and simplicity: during this ceremony, nothing is superfluous in order to express the high aesthetic values that it must inspire and cause. In the course of the ceremony, there is a master who allows other participants to ponder and act autonomously. It is reported that when a problem occurred in a department, Ohno himself called the head of that department and placed him in the centre of a circle. He marked it with a chalk directly on the floor to let the employee to reflect, find out the issue details and propose a solution. In the same way, Ando Naotsugu (1564-1635), the son's guardian of Edo Shogunate founder (1603), acted in the same way: to whom asked him for an opinion or a decision on a specific matter, he simply answered with an "all right" or "not all right" without adding anything else. Furthermore, who pointed out that it would be more useful to suggest how to behave, he replied that if he had given precise instructions no one would have thought to find the best solution, and therefore, everyone would have done nothing but following just his words.

If we take in consideration the Japanese geographical context, many centuries of rice cultivation in a hostile environment, have taught the Japanese to work together, to be diligent, to see the work not as a punishment but as a duty to accomplish. In a context of scarce resources and numerous workers, the Japanese population has learned to live with parsimony and frugality, to have a strong bond between generations with a subdivision of the various tasks needed to survive in the community. At that time, frugality was a virtue while flaunting luxury was considered as a crime (Farris, 2006).

The Japanese population has learned to bend to the will of nature, not to dominate it, like the *typhoon that cut down the oak but saves bamboo*. They recognized that flexibility is the indispensable element to survive, in the same way firms know how to adapt quickly to changes. Examples of this culture pervasively widespread in the society are flexibility in work conditions, salary, job-position reallocation and performing multiple functions.

In a homogenous culture, there is no need for many speeches to understand each other: the use of senses in Japanese factories such as colors' utilization, lights and sounds, visualization of problems and information indicate the use of simple solutions, often more effective than sophisticated ones.

2.2 The Toyota Production System (TPS)

The scholars that have schematized and categorized the lean concepts to apply in business sector, have referred to the distinctive principles and features of production systems developed in Japanese companies and in particular in Toyota. Starting from the need to maximize the value for the customer and to minimize waste, especially where products and services are created, the lean thinking scholars have begun to broaden the scope of application: from manufacturing context to non-industrial one, to the tertiary sector and, then, to the financial sector, healthcare, education, public administration, etc.

Very often, the so-called lean system resumes and incorporates previous organizational and management models such as TQM, TPM, Business Process Reengineering (BPR) and others, proposing mostly techniques and tools used in Japanese industry (Dahlgaard and Dahlgaard-Park,2006; Motwani, 2003).

The advantages of LM approach, especially in the factory, are evident: low inventory levels are in place; abnormalities are quickly detected and eliminated; relationship of trust with suppliers facilitates the procurement processes; the training of multifunctional staff increases motivation as well as contributes to the improvement of quality and efficiency. However, equally evident are the weak points that the implementation of a lean system implies: the risk of having to stop a whole line for lack of stocks, if defects occur during the production process; significant increase in costs for training workers; excessive dependence on firm's employees (Philips, 2002).

Starting from the methods utilized in the North American mass production automotive industry and referring to traditions and practices of Japanese organizations, Toyota has spent more than fifty years in developing an evolving an industrial production and management structure. This structure has leaded Toyota at the top of automotive world industry.

The underlying philosophy that drives the Toyota company has been well-defined by its founder Taiichi Ohno (1988): the two pillars of TPS are represented by Just in Time (JIT) and Jidoka.

Just in Time

According to TPS, operations must be structured to respond quickly to customer requests with a pull system, contradicting traditional batch-and-queue production approaches.

In a pull system, JIT refers to a philosophy that wants to reduce production's waste producing the right piece in the right place at the right time (Slack & Al, 2013). It means to produce only the components needed to complete finished products and to synchronize their arrival on production line. Following customers' requests, parts and work-in-progress (WIP) are pulled from the work stations that require them using the *Kanban* cards. They are utilized to make the JIT an effective production system that optimizes material movement and WIP levels.

Through the JIT application, profits increase and return on investment are expected to increase by reducing the production and the delivery lead time as well as WIP levels. Such results are particularly achieved in the case of repetitive production processes, stabilizing and balancing the production flow between different work centers, pursuing ideally single lots: the so-called *one-piece-flow production*.

The main requirements for establishing a JIT production can be summarized as follows: (El-Haik, 2006)

- create a production system that ensures a balanced and uniform flow between all stations;
- reduce the time needed for machine set-ups;
- reduce the size of production orders and batches;
- reduce of production and supply lead time;
- implement a program to reduce defect in production;
- use a pull production logic;
- have a cellular layout that allows minimal movements.

Jidoka

The meaning of Jidoka is to equip each machine with a stand-alone system that stops production automatically as soon as a malfunction is detected and to train workers to behave in the same way.

This clearly leads to an interruption in the production flow; in some cases, it can implicate major losses and/or delays, but it aims to identify and correct the problem immediately, to "build in quality" at every stage of the production process. The main objective of Jidoka is to create a process that minimizes malfunctions and quality problems, without producing defects, and align processes to defined standards. Long-term benefits are expected to be much higher than the costs incurred for breaks in the production flow. With this approach, the quality built on the production line is *"considerably more effective and less costly"* than the one built by tests and controls.

The phases of *Jidoka* application can be summarized as follows (Lights, 2017):

1. Identify problems

It consists in highlighting and reporting anomalies. It can be done automatically by machine or operator trained in recognizing production failures.

2. Stopping the line

This stage consisting in interrupting production line, as soon as an anomaly occurs, can be automated or not. It is based on the idea that in order to understand why the process creates defects, it is necessary to intervene, and not simply to mark the problem and postpone its resolution later.

3. Resolve the situation

Solving the detected issues requires an activity that may last in proportion to the severity of the anomaly. It may be performed by the operator himself or may require someone else to assist him. However, the speed of this activity is fundamental, indeed it is necessary to restart the process as quickly as possible, but it is even more important to create the awareness aimed at avoiding to perpetrate again the identified error.

4. Clarify the causes of the problem

It is important to implement a corrective action to ensure that this anomaly does not occur over time again. In this case, analysis is performed using tools like the *5 Why* and dedicating *Kaizen* sessions on this purpose.

Therefore, Toyota's strength lies on the limited inventory level with it operates, on the mechanisms that foster problem highlighting within employees, on increasing productivity and improving quality. As production system improves and seems to be a problem-free context, Toyota personnel is looking for new problems, apparently of lesser importance, persuaded that most of them and especially their real causes are still hidden. Toyota's strength may be found in this persistent research of problem’s solution by thousands of its employees. The secret of their competitiveness, therefore, is not based on specific methods or techniques, but on the underlying principles on which it is based and on the direction of continuous improvement. Certainly, in Toyota factories, like in other Japanese companies, many practical methods are widely utilized. Taking advantage of the potential offered by these tools, Japanese companies try to meet customer desires and requests, reducing costs and making sustainable profit.

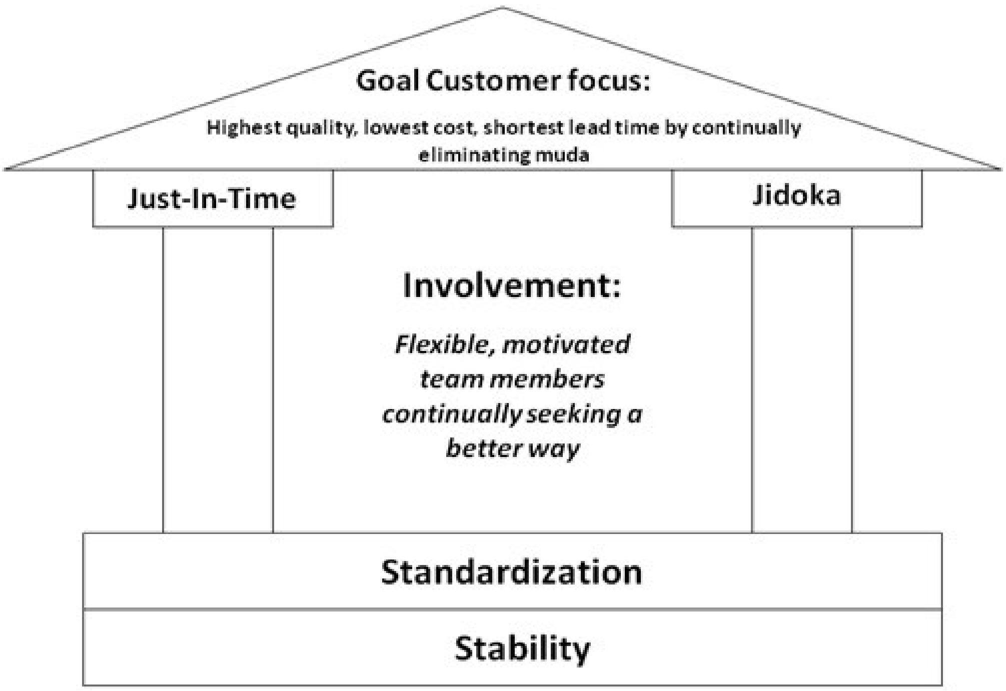


Figure 2.1 – The TPS temple

The practical tools and the techniques used to implement "pull" systems, wastes elimination (muda), production excessiveness (muri) and unbalanced workloads (mura) are therefore very useful to improve the production system, to have reliable long-term relationships with suppliers, etc. For instance: implementing the Plan-Do-Check-Act (PDCA) cycle to achieve zero defects, zero errors and zero failures or maximizing human resources and using in the best way the capital invested, it is indisputable to way to pursue the path of excellence. In fact, when an organization tries to incorporate the TPS key factors within a lean transformation program, this organization recognizes the importance of tools to be implemented (such as Value Stream Mapping, 5S, Poka-yoke, kanban and so on) in order to reduce costs, increase efficiency, and improve quality to increase the value offered to the customer. It is certainly correct to highlight the importance of these tools and techniques, but this organization is still far from TPS mindset, a mentality that puts man at the centre of every activity and concern. In the Figure 2.1, the TPS is represented as a temple, JIT and Jidoka are the two pillars and their foundation sets up a successful implementation of TPS, resulting in improved quality, delivery, and customer satisfaction thanks to a continue effort aiming to seek the better way.

Only with the activity of *hitozukuri* (creation, formation, personal growth) it is possible to obtain the *monosukury* (manufacture, production). Only personnel can make production and every business process ever more fluent, can level and synchronize production and only employees are able to assure success and paybacks for the company, for customers and for society as a whole.

2.3 Lean Manufacturing

Outside Toyota context, TPS is universally recognized as Lean Production. The term “lean” war firstly used in scientific field by Krafcik (1988) within the research conducted by the Massachusetts Institute of Technology's on the International Motor Vehicle Program, under the supervision of James P. Womack. At that time, the significant performance gaps between Western and Japanese automotive industries was evident and the aim of that study was to investigate these gaps. Krafcik analysed data from various automotive companies in different countries, this analysis became the basis of book published by Womack in 1990: “The Machine that Changed the World”, where the superiority of Japanese production facilities was clearly and unequivocally demonstrated.

Until the 1980s, Japanese growth was justified by west-country scholars through "Country Specific" factors (Fuss and Waverman, 1985; Dunning, 1979), these factors can be summarized as follow:

- cost benefit due to low wages, favourable exchange rate and low capital costs;
- production of cars characterized by low fuel consumption during the oil shock;
- extensive utilization of automation technology in production plants;
- economic subsides from Japanese government in order to rebuild the national industry after the second world war through the MITI – Japanese Ministry of International Trade and Industry;
- intrinsic value of Japanese culture.

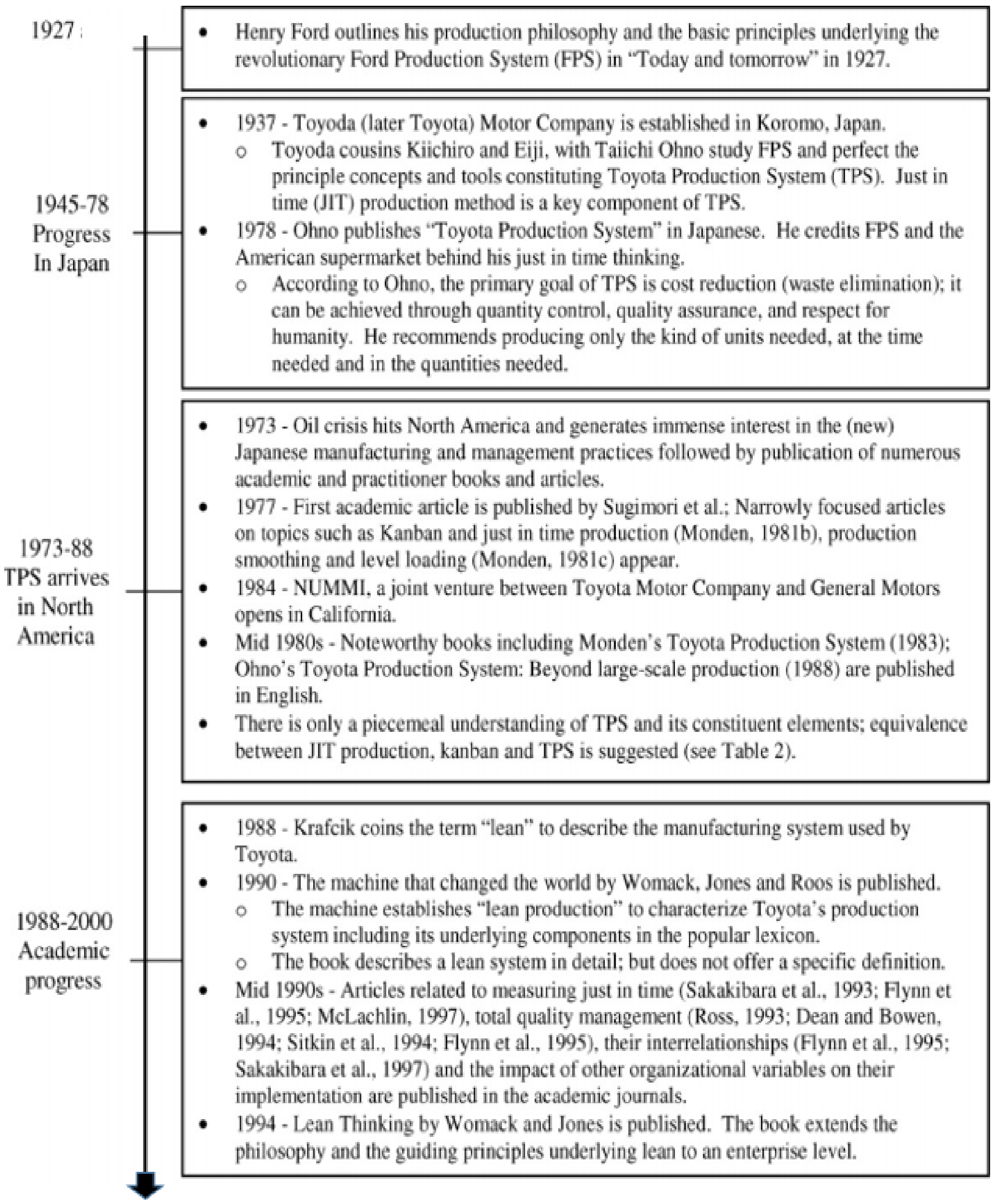
These factors were partly true and largely false (such as extensive automation) and were utilized essentially as a palliative to avoid more thorough analysis. Nevertheless, no automotive manufacturers, North American especially, could understand Toyota's paradigm shift through TPS.

	General Motors	Toyota	NUMMI
Assembly Hours per Car	31	16	19
Assembly Defects per 100 Cars	130	45	45
Assembly Space per Car	0.75	0.45	0.65
Inventories of Parts (Average)	2 weeks	2 hours	2 days
Space used for Rework	15%	None	7%
Absenteeism	15%	None	1.5%
Assembly Hours per Car	31	16	19

Table 2.1- Comparison of three different production plants (Womack and Jones, 1990)

The Krafcik's study allowed the formulation of several tables of comparison between various plants between different companies. A well-known example is shown in Table 2.1, where one North American plant (General Motors), one

Japanese plant (Toyota) and the Toyota plant in North America (NUMMI), with local manpower managed by Japanese managers, were compared thanks to significant parameters. NUMMI - New United Motor Manufacturing – is a plant founded by General Motors and Toyota in 1984 thanks to a joint venture, today it is owned by Tesla. The differences arisen from this study and others, definitively dissolved all the dogmas on the specific country factors revealing at that time the inadequacy of US production system.



1927	• Henry Ford outlines his production philosophy and the basic principles underlying the revolutionary Ford Production System (FPS) in "Today and tomorrow" in 1927.
1945-78 Progress In Japan	• 1937 - Toyoda (later Toyota) Motor Company is established in Koromo, Japan. o Toyoda cousins Kiichiro and Eiji, with Taiichi Ohno study FPS and perfect the principle concepts and tools constituting Toyota Production System (TPS). Just in time (JIT) production method is a key component of TPS. • 1978 - Ohno publishes "Toyota Production System" in Japanese. He credits FPS and the American supermarket behind his just in time thinking. o According to Ohno, the primary goal of TPS is cost reduction (waste elimination); it can be achieved through quantity control, quality assurance, and respect for humanity. He recommends producing only the kind of units needed, at the time needed and in the quantities needed.
1973-88 TPS arrives in North America	• 1973 - Oil crisis hits North America and generates immense interest in the (new) Japanese manufacturing and management practices followed by publication of numerous academic and practitioner books and articles. • 1977 - First academic article is published by Sugimori et al.; Narrowly focused articles on topics such as Kanban and just in time production (Monden, 1981b), production smoothing and level loading (Monden, 1981c) appear. • 1984 - NUMMI, a joint venture between Toyota Motor Company and General Motors opens in California. • Mid 1980s - Noteworthy books including Monden's Toyota Production System (1983); Ohno's Toyota Production System: Beyond large-scale production (1988) are published in English. • There is only a piecemeal understanding of TPS and its constituent elements; equivalence between JIT production, kanban and TPS is suggested (see Table 2).
1988-2000 Academic progress	• 1988 - Krafcik coins the term "lean" to describe the manufacturing system used by Toyota. • 1990 - The machine that changed the world by Womack, Jones and Roos is published. o The machine establishes "lean production" to characterize Toyota's production system including its underlying components in the popular lexicon. o The book describes a lean system in detail; but does not offer a specific definition. • Mid 1990s - Articles related to measuring just in time (Sakakibara et al., 1993; Flynn et al., 1995; McLachlin, 1997), total quality management (Ross, 1993; Dean and Bowen, 1994; Sitkin et al., 1994; Flynn et al., 1995), their interrelationships (Flynn et al., 1995; Sakakibara et al., 1997) and the impact of other organizational variables on their implementation are published in the academic journals. • 1994 - Lean Thinking by Womack and Jones is published. The book extends the philosophy and the guiding principles underlying lean to an enterprise level.

Table 2.2 - Critical phases in LM evolution (Shah and Ward, 2007)

Womack et al. (1990) thanks to the book “The Machine that Changed the World” descanted on "lean production", or lean manufacturing as a synonymous. The study of this production model and related tools and techniques, promoted the application to non-automotive and non-Japanese industries of this methodology, relying on the premise that problems in manufacturing industries are universal problems in business management as stated by the authors Womack et al. (1990).

In the Table 2.2 the key phases that have contributed to our current understanding of lean production are highlighted. Shah and Ward (2007) formulate the Table 2.2 in their research, it provides the lean milestones until the year 2000 at a glance.

Different authors propose a definition for the lean production, for instance Emiliani (2000) stated as follows: ‘‘*to be lean is to cut fat’’*. Author explains that ‘‘*the opposite of lean behaviour is called ‘fat behaviour’, which is defined as any activity or action that creates or perpetuates behavioural waste*’’. Even if this statement is characterized by intrinsic tautology, it captures in a simply a direct way the aim of lean production. Another interesting definition is provide by Wilson (2010) that perceives lean as an ongoing drive toward perfection: *‘‘At the heart of lean is its philosophy, which is a long-term philosophy of growth by generating value for the customer, society, and the economy with the objectives of reducing costs, improving delivery times, and improving quality through the total elimination of waste – muda*‘‘.

Womack et al. (1990) as the first authors that introduced the concept of lean production whit a research group at MIT, after studied the TPS in the 1980s, emphasizing both input and output dimensions of manufacturing lean:

‘‘Lean production . . . is ‘lean’ because it uses less of everything compared with mass production—half the human effort in factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products’’.

Moreover, the same authors, considering the broad philosophical dimension of lean thinking, define the universally accepted five key principles of lean production (Womack and Jones, 1996):

- *Identify Customers and Specify Value from their perspective*
- *Identify and Map the Value Stream*
- *Make the process flow*
- *Pull from the Demand*
- *Continuously strive to improve*

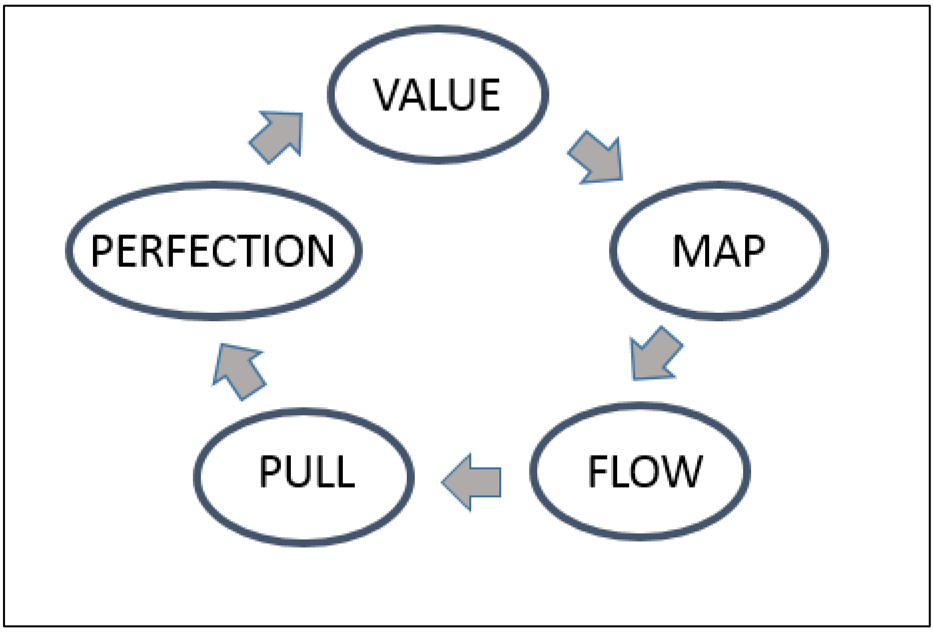


Figure 2.2 – The five lean principles

- *Identify Customers and Specify Value from their perspective*

Value needs to be specified from the standpoint of the final customer. If the customer does not pay for an activity, it is considered as non-value-added and it should be eliminated. Therefore, the starting point is to identify the product attributes and the service that the customer recognizes and are willing to pay for, that is the *value*. This must become the main goal to be pursued because the more the company will focus on this result, the more the company's value will grow. It requires an analysis of firm's structure in order to distinguish between value-added actions and the ones that do not create value, which should be eliminated as a source of waste. Therefore, it is necessary to overcome the traditional vertical vision for functions and to get a new horizontal vision for processes; in fact, business processes, transversal to different functions, contribute to generating and increasing the value of each product/service. Moreover, firms need to strive for the optimization of the total flow; it almost never coincides with the optimization of the individual functional compartments. There is the need of a different point of view, focused on the customer. In order to avoid waste from the outset, it is useful to analyse and understand accurately which are the customer's actual needs and how much he/she is willing to pay to meet his/her needs. Providing to customer something that he/she does not perceive, is a non-value-added activity as well. The way to define value for the customer is not a simple and predictable path, often it is overlooked by companies that focus primarily on optimizing individual internal processes. Firstly, it is necessary to remember that the customer is not an abstract entity; and creating value means being useful not only through a product, but with a complete service. These principles are not only valid between company and external customer but also between supplier and customer within the organization itself.

Once, the firm has fully understood this change in its mission, it faces the difficulty of translating the desire to maximize that value in concrete aspects: products, technologies and services. On one hand, the value expected by the customer is not immediately translatable in concrete and measurable factors; it is sometime a perception or a desire, or just an idea. On the other hand, the customer may not be able to explicitly explain their own needs and sometimes they are unaware of what exactly are them. In order to meet expectations, the company must be able to grasp this perception and make it tangible and pragmatic, guiding the customer in determining the value, accompanying him in finding the best choice for him. The task of the company is therefore to satisfy evident needs, but also to help the customer to understand and define the latent needs in order to propose the right value. Only after the customer has defined the specifications of the product or service, the company will derive the technical and production specifications.

- *Identify and Map the Value Stream*

The value stream is the set of all the specific actions required to produce a specific product or service. All steps in the value stream should be identified for the given product family. In fact, after identifying the products and services that build up the value for the customer, it is necessary to identify the value stream, namely the ordered of all processes and activities that contribute to create the value. For this purpose, it is necessary to map the physical flows and information across the company by creating the *value stream map*. Once the value chain is represented (current state), waste and corrective actions need to be defined by building the *future state*.

The flow analysis shows that three types of activity can be identified:

- value-added activities, they generate value perceived by the customer;
- non-value-added but necessary activities, activities that, while not generate value for the customer, are currently needed (e.g. set-up time);
- non-value-added activities, they can be eliminated from the start as they are not necessary

To construct the map of the value stream and identify what are the non-value-added activities, distinguishing them in the required and not, multiple tools are present such as *value stream mapping, spaghetti chart* and *work sampling*.

- *Make the process flow*

The materials should flow through the system with minimum interruption and waiting. Accurately defined the value, mapped the flow and eliminated the wastes, the remaining value-added activities should form a fast and smooth flow. It means that these activities flow without interruption, avoiding waiting, scrap, and anything that can result in waste.

To do this, it is necessary to eliminate the internal barriers to the company, both physical and logical, and to develop an organization focused on product/process that may radically reduce lead time. Often, this involves changing from a traditional factory divided in department, through a batch production, to a continuous flow organization that allows to reduce WIP, develop multifunctional operators, and reduce lead time. Again, there are various specific and effective tools, such as *5S initiative* and the *Rapid Tool Setting* (RTS).

- *Pull from the Demand*:

The customer should pull the product from the source as needed, rather than the source process pushing products onto the customer. In other words, no upstream function or department should produce a good or service until the customer downstream asks for it. Therefore, firm does not produce and move according to its internal optimization logic, but only when required by the customer. In the "pull" system, the flow of value is activated only for a real need for the downstream phase. This principle contrasts with the "push" logic, typical of mass production, where the offer pushes the market.

Production, and all business processes, must adapt to the pace of the market (*takt time*). Takt time (the term derived from the German word Takt Zeit, meaning "clock cycle") represents the rhythm that a finished product must be produced in order to meet the demand from the market. It is calculated by dividing the total production time available by the number of product request by the market. It is used to synchronize the production pace with the market one. If the firm produces faster than takt time, it means that is producing for the warehouse, with obvious repercussions in terms of WIP, finished products, space used and resources involved in stock management. On the other hand, producing at a slower pace means that firm is not able to meet market demand.

In a lean production context, the rhythm is set equal to the takt time, but it should not be taken as a static figure: it is an evolving parameter to deal with in order to adapt production speed to the market. When the company, identifying the value stream and determining its takt time, is about to activate, according to the fourth lean principle, a continuous flow from raw materials to the finished product. In doing that, company faces enormous difficulties associated with physical and technological constrains (long set-up time, batch processing cycle time, lead time different from takt time). To get closer to the target, it is therefore necessary to introduce in first instance a series of intermediate buffers that allow to control and level the production upstream of the flow-managed processes.

An essential condition for achieving this principle is the establishment of the flow and a particularly suitable instrument is the use of the *kanban* that allows visual management of the production flow as it signals to upstream processes the moment in which to produce or provide certain parts for the downstream.

- *Continuously strive to improve*:

After implementing the abovementioned activities, the managers and teams of employees should eliminate further waste and pursue perfection through continuous improvement. In fact, one of the fundamental principles of lean production is the awareness to work towards perfection through the continuous improvement. It does not mean to benchmark against standards competitors or their performances, because it is always possible to reduce time, waste, cost, and increase the value for the customers.

Lean journey steps are a circle: when an improvement cycle is finished, firm should go back to the first step of the journey, getting even closer to customer's needs by finding further value to maximize. In the lean processes, this virtuous circle PDCA is composed by four phases, namely:

- *plan*: define a goal and make an improvement plan;
- *do*: analyse the current situation and find solutions;
- *check*: check the results and decide on recovery actions;
- *act*: activate the plan and arrange the next steps.

In a company that follows lean principles, the propensity to change never stops, and this explains the fundamental and indispensable importance of the human resources involvement and motivation, because they become the creators of improvement.

A fundamental concept of TPS is the *Kaizen*: is a method of continuous improvement, step by step, which involves the whole corporate structure. The term *Kaizen*, in fact, is the composition of two Japanese terms: *kai* (change) and *zen* (better). There is always room for improvement, and the more a company is *lean* and transparent, the more mistakes and wasting become evident, transforming themselves into opportunities for improvement.

2.4 Muda: the seven forms of waste

Muda is the Japanese word that indicates the activities that are waste and do not add value. It is a key concept of TPS and is one of the three types of waste that must be avoided and eliminated together with *Mura*, which can be translated as "irregularities", and *Muri*, which indicates excesses, laborious or slowed down tasks.

It can be defined lean, not the enterprise that cuts costs in a systematic and indiscriminate manner, but the one that, having clearly identified its own goals, focuses on products, processes, resources and organization in such a way to implement only effective actions and investments, eliminating those that do not create added value. One of the key steps in TPS is identifying what adds value and what does not. Dividing all the activities in these two categories, it allows to take action to improve the first and eliminate the second.

According to Shoichiro Toyoda: *"Waste is all that exceeds the minimum contribution of plants, materials, components, space, workforce, which are absolutely essential to add value to the product/service provided".*

Therefore, the first step towards applying the TPS is to clearly identify what are the factors of loss that can be identified by the following phenomena (Ohno, 1978):

- Transport;
- Inventory;
- Motion;
- Waiting;
- Overproduction;
- Processing;
- Defects.

The abovementioned phenomena are described in detail to provide a better understanding of these main factors of loss in the production:

- *Transport*

All material transport within the company can be seen as waste, as only physical processing and transformation of the product creates value. In fact, neither transformation takes place during the period of transport, nor added value to the product itself. To create flow, however, the movement of the products is necessary, so the aim is to reduce it to the minimum necessary, considering that the more a product is transported, the greater the likelihood that it will be damaged. Moreover, each transport will help to lengthen the total crossing time.

- *Inventory*

All the raw materials, semi-finished products, finished products that, being in excess of market demand, lie in the firm's warehouse, buffers and storage areas. WIP, which lies between the various phases of a production process, should also be considered as stocks and, therefore, eliminated. This kind of waste do not only add value to the finished product but consumes considerable resources such as space, equipment, personnel dedicated to their handling and capital immobilization. In addition, warehouse material is subject to obsolescence, especially if the product has a high level of technology and is subject to the risk of damage. The main cause of this type of *muda* is another waste itself, the *Over-production*, which in turn is caused by a lack of synchronization between processes in the production flow.

- *Motion*

These are movements made by operators that do not add value to the product. Any movement of a person's body that is not directly related to adding value to the product is to be considered unproductive; for instance, walking to pick up tools in distant places or go far looking for instructions. Any action that requires excessive physical effort by the operator should be avoided; the reason is not only because it is difficulty for the operator but also because it is a risk to his health. These movements that lengthen unnecessarily the lead time can be eliminated or avoided through an appropriate design of line layout and ergonomic workstations.

- *Waiting*

The waste linked to wait is manifested whenever an operator does not perform tasks or activities, while he is waiting for a subsequent event or for incoming resources. The main possible causes can be the lack of levelled production between the various phases, the failure of a machine in production, the lack of organization among employees, the shortage of resources that forces to share tools and workstations. To eliminate this kind of waste, it is necessary to minimize the expectations, improving the work organization, preferring small batch production and reducing set up time.

- *Overproduction*:

It happens whenever production does not follow the market demand; for instance, when a firm decides to produce products that are not required by the market, in higher quantities, or in periods where there is no demand, or when production is higher than market retail level. It is a very common waste that derives from the traditional production system in which each stream process (or each department) operates independently of the others, according to a push logic; for example, pushing a production defined by a production plan developed according to a local optimization logic and not according to the real needs of the downstream process. This results in increased material accumulation between processes, inventory level, resources utilized and lead time; resulting in a worsening customer service aggravated by increased costs.

- *Processing*

This kind of waste happens whenever complex solutions to the production process instead of simple ones are implemented. In turn, these complex solutions generate other waste (expectations, overproduction, etc.). In the production context, too long ramp up, the wrong disposition of material, approximate calculations, etc. are all examples of process waste. For instance, in order to avoid this type of inefficiency, it is useful to perform regular preventive maintenance that ensures that the machines can perform properly and it also helps and facilitates the operators' tasks.

- *Defects*:

This type of waste refers to components, materials and products that have defects (e.g. they do not reach the level of quality required by the customer and therefore they need to be changed, reworked or discarded and scraped). From this, defects inevitably slow down production and greatly increase costs. In fact, defects, in order to be repaired, require appropriate and, sometimes, dedicated resources and equipment. If the piece is discarded, it generates additional costs in terms of work performed and components that are lost.

In conclusion, it can be said that tackling waste is one of the foundations of the lean approach. First of all, this purpose must be a cultural factor and, only secondly, a set of techniques and methodologies.

2.5 Chapter Conclusions

In this chapter a brief description of the origins and evolution of lean manufacturing has been proposed to provide an introduction to LM fundamental concepts. The TPS, the five lean key principles and the *muda* have been described to provide to the inexpert reader the necessary information to better understand the following chapters of this thesis. In the next chapter, the literature review on lean assessment tools is provided according to the methodology proposed by Tranfield et al. (2003), it allows to define the current gaps in the actual body of knowledge and formulate the next phases of the research in order to fulfil them.

Chapter 3: Literature Review

In this chapter a literature review on existent Lean Assessment Tools (LATs) is proposed in line with the methodology proposed by Tranfield et al. (2003). The chapter is structured as follows: the first section introduces the concept of LAT and related definition and evolution. The second section proposes the literature review developed according to the selected methodology and the last section summarizes the emerging gaps from the literature review.

Before to describe the concept of LAT and to facilitate the introduction to this topic, some aspects need to be clarified in regards of key characteristics of manufacturing small- and medium-sized enterprises (SMEs) and the development of LPs according to the Lean principles described in Chapter 2.

Generally, organisations can be simply categorised into two groups: large enterprises (LEs) and SMEs. Moreover, the main key characteristics of manufacturing SMEs are listed as follow in order to shed light on this kind of organizations in regard to the scope of this research:

- *Insufficient human resources*: SMEs companies lack both the time and skills needed to handle extraordinary activities, which are not part of the typical activities associated with the company's operation management (Hadjjimanois, 2000; Romano, 1990). People are requested to cover multifunctional roles and, at the same, entrepreneur often deals with operational activities, ignoring the ones related to management and management control. The delay in involving production staff is particularly critical (Woodcock et al., 2000), as it delays the identification of product quality problems. It brings to a consequent increase in costs and inefficiencies. Lack of internal expertise is also often accompanied by a reduced use of external supports, due to a reduced trust in available external services and a shortage of contribution from regional agencies (Cawood, 1997).
- *Reduced financial resources*: The incidence of financial resources required is proportionally more burdensome for SMEs than large companies and it

is one of the main barriers to implement improvement activities. The study of March-Chorda et al. (2002) describes the cost of improvement projects as one of the most common obstacles to innovation in SMEs; Freel (2000) points to the need for greater venture capital to finance long-term projects.

- *Emphasis on technological aspects*: A production orientation prevails in SMEs: technical product excellence and production processes are often defined by management as the key factor in determining the success of the organization. Literature recognizes the key role of production approaches not only by adopting advanced technologies and innovative manufacturing paradigms, but also by defining and managing the product strategy and marketing activities adequately (Freel, 2000; Huang et al., 2002; March-Chordà et al., 2002). A study by Millaward and Lewis (2005) shows that the scarcity of resources, as mentioned in the previous point, focuses attention on saving time and costs by neglecting more sophisticated organizational aspects. This inadequate context analysis compromises not only the ability of SMEs to capture market needs (Romano, 1990) but, as Woodcock et al. (2000) point out, it also hampers comparison of company performance with competitors.
- *Lack of information.* The literature shows a strong lack of internal communication (Brown et al., 1996) as well as insufficient level of information to support radical improvement activities. Collecting certain types of information is objectively very complex and often involves high costs; this activity is further complicated due to the lack of tools for gathering information and insufficient knowledge to analyse them; the introduction of a systematic approach to develop effective mechanisms is therefore recognized as indispensable (Woodcock et al., 2000).
- *Role of the "owner manager":* Numerous researches highlight the key role of top management in the success of LM activities (Chiva and Alegre, 2004; Gomes et al., 2000). The results of a study conducted by Salavou and Lioukas (2003) highlight how entrepreneurial orientation is one of the major determinants in lean transformation programs within SMEs. The SME entrepreneur on the one hand frequently adopts an autocratic, egocentric, impulsive and unpredictable management style that hampers integration between LPs adaptation and business strategy adopted (Filson

and Lewis, 2000); on the other side he has often lacked adequate experience and training to manage such activities (Millward and Lewis, 2005).

- *Short-term orientation*: In SMEs there is a tendency to adopt mainly short-term management logic and poor use of planning tools. Numerous authors point out the tendency of small businesses is to not define an explicit strategy and to use management and control techniques inadequate (Marchini, 1995). This approach determines the obvious difficulty of integrating LPs adaptation into a long-term strategic vision (Filson and Lewis, 2000) and it impacts negatively on the results of transformations programs (Huang et al., 2002).

Considering now the development of LPs according to the Lean principles, some preliminary useful considerations are here proposed. While the key principles of lean thinking, as described in Chapter 2, are well defined and universally accepted, Bhamu and Singh Sangwan (2014) point that there is no lean standard implementation framework and the crux of this is the lack of dedicated implementation tools, techniques, or methodologies. The authors identify 18 tools and practices "*integrated in system composed of highly inter-related elements and a wide variety of management practices*", including 5S, JIT, work teams, cellular manufacturing, TPM, Kanban, etc. In the Table 1, above mentioned tools and lean practices (LPs) are integrated with element identified in other relevant works (Karlsson and Ahlstrom, 1996; Feld, 2000; Hines and Rich, 1997; Mann, 2014; Pavnaskar et al., 2003). Just by way of explanation, these elements are listed in Table 1 according to the main pursued objective deriving from lean manufacturing principles and they will be described more in details in the next paragraphs; for instance, the Value Stream Mapping (VSM) is the tool applied for the implementation of the second principle, analysing the current state and designing a future state for the series of specific actions required from the suppliers to the customer. The VSM tool has been introduced by Rother and Shook (1998) providing a practical guiding tool for lean implementation at initial stage. Thanks to its simplicity and effectiveness, VSM becomes a crucial activity for most lean projects and practitioners (Wan and Chen, 2008). Moreover, due to the fact that, the tools/practices developed according to the precepts of *Make the* *process flow* and *Pull from the Demand* are often designed to support both these objectives, in the Table 1 these tools/practices are associated equally to both.

The majority of existing LPs and tools focus on '*how to become leaner*' instead of '*how lean it is*' and only few of them address the latter aspect as the VSM (Wan and Chen, 2008). These lean practices and tools are widely used in every step of an entire production process in a large range of companies. As stated by James-Moore and Gibbons (1997), the level of implementation of various LPs and measures could vary not only between companies, but also within any company over time. Most of these firms have obtained impressive results; however, many companies are struggling to apply the lean practices, furthermore they are not able to perceive and recognize the implementation level of these to tools/practices and principle.

Objectives	Tools and Practices
Identify Customers and Specify Value from their perspective	FAST, Kano Model, QFD (Quality Function deployment)
Identify and Map the Value Stream	VSM (Value Stream Mapping) in order to identify the Current state and Future State
Make the process flow	5S, Automation (Jidoka), Group Technology and Cellular Manufacturing, Kanban, Mixed Model Production, Multifunctional teams/employee involvement, Poke Yoke, Standardized work, Production smoothing (Heijunka), SMED, Spaghetti Chart, Takt Time Analysis, Time Study Analysis, TPM
Pull from the Demand	
Continuously strive to improve	Continuous Improvement, Kaizen, Six-Sigma, TQM

Table 3.1 - Lean Tool/Practices and Related Objectives

Moreover, elements representing the implementation of lean manufacturing are evident across different sectors, but the pace of change is dramatically different and the specific outcomes vary company by company (Kochan et al., 1997). On one hand, the LM practices have been defined thanks to various studies during last thirty years but the outcomes of their implementation have not been assessed in sufficient details in regard to SME (Hu et al., 2015). On the other hand, the need to assess the overall status of lean implementation derived directly from one of lean principle defined by Womack and Jones in 1996: the pursuit the perfection (Mann, 2014). Moreover, to be successful in terms of competitive advantage lean implementation requires to apply LPs in the all organization functions, including accounting, sales and marketing, and human resources (Pakdil and Leonard, 2014). All the above considerations emphasize an increasing interest in the topic of lean implementations (Saurin, et al., 2011) and, consequently, in the topic of the evaluation of lean implementation level itself (Biazzo et al, 2016).

If we expand our point of view, in the current economic conditions, companies strive to search ways to improve their efficiencies, in order to maintain a sustainable profitability and a competitive advantage. In fact, as stated by Edwards (2009) "*this effort should be to perform an operational assessment to identify the strengths and key deficiencies within the manufacturing process. The assessment would include a detailed review and analysis of manufacturing areas such as service and quality, management and personnel abilities, reporting metrics and systems, inventory management and plant physical layout. The assessment exposes areas within the manufacturing process that can be used to initiate and concentrate improvement efforts and cost reduction strategies. Cutting costs prior to performing an operational assessment might not result in improved efficiency or profitability*".

Therefore, the aim of his chapter is to investigate trough a structured literature review the current tools/frameworks to assess the lean implementation level and to propose an analysis of them thanks to the chosen methodology.

3.1 Introduction to Lean Assessment Tool (LAT)

Before to describe in detail the literature review performed, in this section an introduction to the LATs is provided. To better understand these kinds of tools and their evolution, it is necessary to clarify the *leanness* concept. At the beginning this concept was interpreted diversely in the literature, Naylor et al. (1999) propose the term leanness to describe the process of realizing lean principles while introducing the concept of 'leagility'. Comm and Mathaisel (2000) describe leanness as a relative measure for defining if a company is lean or not. They also stated that "leanness is a philosophy intended to significantly reduce cost and cycle time throughout the entire value chain while continuing to improve product performance". McIvor (2001) introduces the term 'total leanness' that implies a perfectly lean state with several key dimensions of lean supply. Soriano-Meier and Forrester (2002) evaluate the degree of leanness utilizing nine variables derived by the model of Karlsson and Ahlstrom (1996). Radnor and Boaden (2004) propose some novel interpretations of leanness, including an *ideal state* of lean as context-dependent process. Wan and Chen (2008) propose a unit-invariant leanness measure with a self-contained benchmark to quantify the leanness level of manufacturing systems. Vinodh and Balaji (2011) develop a leanness evaluation based on fuzzy logic; in another study leanness was evaluated using a multi-grade fuzzy approach (Vinodh and Chintha, 2011a). Moreover, the authors examined the application of fuzzy quality function development (QFD) for enabling leanness in a manufacturing organization (Vinodh and Chintha, 2011a) and using fuzzy logic approach to quantify leanness level (Vinodh and Vimal, 2011). Anvari et al. (2011, 2013) attempted to outline the concept of leanness by reviewing the previous uses of the word and to measure the influence of selected lean attributes (lead time, cost, defects and value) on leanness.

For these scholars, leanness refers with a benchmarking approach to the value stream performances compared with perfection. For this reason, a leanness measure shows '*how lean'* the system is in comparison with best-in-class without taking into account the contingent characteristics of the firm's production system and its strategic priority and objectives.

Therefore, according to the purposes of this research, we go beyond the mere concept of leanness. In fact, Wan and Chen (2008) state that three are the main categories that concern the measure of the level of leanness:

- the value stream mapping (VSM) techniques;
- lean metrics;
- Lean Assessment Tools (LATs).

The first element, VSM techniques, has been briefly introduced in the previous paragraph. Current state maps and future state maps show the value streams flow in combination with time-based performance indicating improvement opportunities. In this method, the current-state map will graphically show the level of leanness of the current situation, and the future state map will be used as a benchmark. By comparing these two maps, the leanness of a system can be easily graphically evaluated (Behrouzi and Wong,2013).

Lean metrics are the performance measures that are used to track the effectiveness of lean implementation. (Anvari et al, 2013). The reason why these metrics have been developed may be found in the fact that the performance measurement is one of the most important issues in manufacturing and service systems. Most managers are interested to know these measures in order to have more control over production processes (Azadeh et al., 2015). Many scholars have provided a definition of performances set in order to assess the level of leanness: Allen et al. (2001) proposed a pool of lean metrics categorized in four main categories: Productivity, Quality, Cost, and Safety. Seyed Hosseini et al. (2011) have investigated the leanness assessment in the automotive sector utilizing the Balance Scorecard approach and identifying criteria in the direction of lean principles. The authors have defined five different perspectives: financial, process, customer, employees, and suppliers; and extracted more than 50 criteria for being lean. Analogously, Vinodh and Vimal (2011) have proposed a leanness assessment model based on 30 criteria. Dennis (2016), in his model to oriented to leanness considered three main factors: shortest lead time, lowest cost, and the highest quality to the customer. Wan and Chen (2005, 2008) proposed a methodology to measure the overall leanness level considering three prospective: cost, time and value. Slack (1999) pointed at customer value based on four attributes: functional and performance (quality), degree of excellence (defects level), lead time and development time (time), costs for acquisition, developing, operating, and etc. (cost).

Therefore, a benchmark for each lean metric or for the underlying synthesized measure is needed if the level of leanness is measured using lean metrics, in order to show the impact of each criterion on the leanness level. In summary, cost, time, defects, and value are measures for leanness largely utilized in the literature (Anvari et al, 2013).

In contrast, the LATs are more pertinent in terms of measuring the level of lean implementation due to the fact that they represent a comprehensive approach that evaluate the lean practices and principles implementation throughout an entire organization trying to mitigate the ambiguity and the uncertainty that permeate real systems. In the first instance, many scholars agree in categorizing the LATs as qualitative or quantitative perspective (Behrouzi and Wong, 2013; Pakdil and Leonard, 2014; Wong et al., 2014; Azadeh et al., 2015).

3.1.1 Qualitative LAT

Qualitative tools are typically lean assessment based on surveys and judgments. Survey has been arisen as a common tool to assess leanness and their complexity ranges from a simple LM practices assessment until the degree of adoption of lean principles. Various authors, such as Feld (2000), Jordan and Micheal (2001), Connor (2001) and Mann (2014), proposed tools to help practitioners in implementing and assessing their lean system. For instance, the survey developed by Jordan and Micheal (2001) has different versions for various stakeholders (employees, executives, suppliers, and customers). The survey addressed tools and LPs such as waste reduction, continuous improvement, VSM, and human resource issues such as employee development/empowerment and leadership. The outcome of these kind of tools is usually a score that represent the gaps between the current state of the system and the ideal conditions of several lean indicators predefined in the survey (Wan and Chen, 2008). One of the first attempt in the literature to propose a qualitative LAT is the model developed by Karlsson and Ahlstrom (1996), this model aims at assessing the changes towards LM using nine groups of “measurable determinants”. Sanchez and Perez (2001) developed a check-list of 36 lean indicators in six groups to assess the changes towards lean. Soriano-Meier and Forrester (2002) extended the model of Karlsson and Ahlstrom (1996), to assess the degree of leanness of ceramic tableware manufacturing firms in a sample of 30 companies in UK. Their model assesses the degree of adoption of nine variables of leanness (elimination of waste, continuous improvement, zero defects, JIT deliveries, pull system of materials, multifunctional teams, decentralization, integration of functions, and vertical information systems). Shah and Ward (2007) conducted a survey among various manufacturing firms incorporating three main indicators (suppliers, customers and internal processes). Pavnaskar et al. (2003) organize 101 LPs and tools in order to match manufacturing wastes with appropriate tools; however this matrix provides only the problem-tool connection without providing a measure of lean implementation level. Doolen and Hacker (2005) assessed leanness level based on average score given by the respondents, incorporating six areas into their study, similarly to Goodson (2002) with is tool for a rapid recognition of lean implementation level within a plant. In a very different format, Bhasin (2011) defined 104 sub-indicators and categorised them into 12 main groups, rated by respondents thanks to a a five-point Likert scale. James-Moore and Gibbons (1997) verified five key lean components: flexibility, waste elimination, optimisation, process control and people utilisation through close-ended questions ending (yes/no) survey. One of the popular tool among qualitative LATs and utilized in the aerospace industry is the "Lean enterprise self-assessment tool" (LESAT). It is composed by three sections: life cycle processes, enabling infrastructure and enterprise leadership processes. The first section focuses on reducing waste and cost reduction activities. The second section deals with value creation for the customer. The last section concentrates on workforce development and empowerment. Each of these three sections is divided into smaller sub-sections consisting of several questions. During the self-assessment, respondents assigned a score to each of these questions based on firm's current state. These scores are then transformed into a maturity model on a scale from 1 to 5 (level 5 is considered the best and is referred to as the "transformer" while level 1 is referred to as "traditional"). The main weakness of LESAT, nevertheless his popularity, is that the model does not provide neither an *ideal* state to reach from the current one and nor a specific direction for improvement under cost constraints (Nightingale, 2001). In short, qualitative methods for the level of lean implementation evaluation are mostly based on surveys are subjective, vulnerable to personal judgments and, therefore, may be biased and inaccurate.

3.1.2 Quantitative LAT

From the quantitative side, scholars developed different methods and techniques to determine the lean level based on mathematical logics. Bayou and De Korvin (2008) developed a systematic measurement algorithm to benchmark the *leanness* of a manufacturing system. The authors compared the *leanness* of General Motors and Ford Motor Company, choosing Honda Motor Company as the benchmarked firm. In their paper fuzzy logic was used to assess companies' performance. They chose JIT, Kaizen, and quality control as lean attributes; since the authors considered *leanness* as a matter of degree, they categorised organisations with three qualitative level: 'lean, leaner, and leanest'. Similarly, Singh et al. (2010) developed a leanness measurement methodology on a fuzzy logic base. Wan and Chen (2008) proposed an integrated quantitative measure of overall leanness using time, cost and product value as performances considered. The authors define a unit-invariant leanness measure along with self-contained benchmark to quantify level of leanness in manufacturing industries. Applying data envelopment analysis (DEA) model, leanness measure extracts value-adding savings from a manufacturing process to determine leanness frontier as a benchmark. Srinivasaraghavan and Allada (2006) have measured leanness by calculating the Mahalanobis Taguchi Gram Schmidt System distance between the current state of the system and the benchmarking performance. In this method, a comparative evaluation is determined in order to calculate the current level of lean an alternative distance between current situation and best-in-class system's practice. Vinodh and Balaji (2011) designed a decision support system based on fuzzy logic for assessing lean and utilized the Euclidean distance to determine parts of organization which need interventions and enhancements. Thanks to a decision support system, the tool reduces error probability and saved time spent in manual computations as stated by the authors. In another study, Vimal and Vinodh (2013) used artificial neural networks and fuzzy logic to cope with manual computation. They developed a simulation model for leanness assessment and validate the model with a case study of an Indian transformers manufacturing plant. Moreover, Vimal and Vinodh (2012) relaxed fuzzy assumption for leanness measurement by an interface method based on IF-THEN rules. They developed leanness attributes using linguistic variables and the associated membership functions. The fuzzy numbers are converted into crisp values for the identification of weaker criteria. Azadeh et al. (2015) proposed a comprehensive approach based on Data Envelopment Analysis (DEA), Fuzzy DEA (FDEA), Fuzzy Cognitive Map (FCM), Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Hierarchy Process (AHP) for evaluating and optimizing the leanness degree of organizations. The efficiency of organizations is assessed and optimized by DEA. A heuristic algorithm is proposed to obtain a full ranking of leanness level of an organization. Accordingly, a sensitivity analysis is carried out to determine impact of each leanness factor on firm's strategy. Wong et al. (2016) developed a measure of lean level using the multi-criteria approach: Analytic Network Process (ANP). The ANP methodology is a robust technique for integrating the various dimensions governing an organisation's lean performance. The ANP approach captures the various criteria, and their relationships as well, as interdependencies across and along the hierarchies. Behrouzi and Wong (2013) developed an integrated stochastic-fuzzy model to evaluate supply chain leanness of small and medium enterprises in the automotive industry. The authors stated that: *"many performance measures in the real world are stochastic since various random factors are affecting them; therefore Beta distribution was used to represent the stochastic measures and the resulting probability density function was applied to estimate the occurrence of different leanness levels"*. An interesting attempt to overcome some limitations of qualitative and quantitative approach is the LAT developed by Pakdil and Leonard (2015); their LAT consists in lean measures using eight quantitative performance dimensions (time effectiveness, quality, process, cost, human resources, delivery, customer and inventory) and five qualitative performance dimensions (quality, process, customer, human resources and delivery) with 51 evaluation items constructed on a fuzzy logic.

In conclusion, the quantitative tools to evaluate leanness are thus mostly confined to individual measures or indicators, and an integrated measure that combines various evaluations that quantifies the level of leanness has not been developed.

3.2 Literature Review Methodology

A systematic literature review of LPs implementation assessment tool is undertaken in this paragraph. For this purpose, Tranfield et al. (2003) systematic review methodology is employed for the following reason: in comparison to other traditional narrative reviews, the systematic review provides more clear, scientific and reproducible procedures for the literature search and analysis (Tranfield et al., 2003, Sign 2004; Suarez-Barraza et al., 2012).

Tranfield et al.'s (2003) methodology has the intent to be located at the heart of a *'pragmatic'* management research, which aims to serve both academic and practitioner communities. The authors state that, on one hand, for the academics "*the aim of systematic review is to provide collective insights through theoretical synthesis into fields and sub-fields, the reviewing process increases methodological* rigor". On the other hand, for practitioners and managers, "*systematic review helps develop a reliable knowledge base by accumulating knowledge from a range of studies"*.

Thank to this purpose of supporting academicians and practitioners at same time, Tranfield et al.'s (2003) methodology has been widely applied in many different fields of management research such as innovation and firm's organizational learning (e.g. Macpherson and Holt, 2007; Becheikh et al., 2006; Phelps et al., 2007, Adams et al., 2006), operations and supply chain management (Carter and Easton, 2011; Suarez-Barraza et al., 2012; Shepherd and Günter, 2006; Röglinger et al.,) and SME management (e.g. Garengo et al., 2005; Thorpe et al., 2005; Mazzi, 2011). According to Tranfield et al. (2003), the systematic review consists of three stages: the planning review stage, conducting review stage and reporting and dissemination stage.

Planning the review

Prior to beginning the review, a review panel is formed as indicated by Tranfield et al. (2003) with the participation of experts working in the field. The review panel consists of three academicians (one is the author of this thesis and the other two are associate professors of management engineering at University of Padua), all the persons involved have a long-time experience founded both in academia and in industry. The review panel takes place at least three times per year during the duration of PhD course (from the academic year 2014/2015 to the 2016/2017), the meetings' topic embraced the systematic literature review during the first year of PhD course and the objectives, evolutions and writing of the present PhD thesis during the other two years.

The proper scientific bibliographic databases for the research are also identified during the panel meetings; they are ISI Web of Knowledge – Web of Science, Scopus, ScienceDirect and Google Scholar. Only papers written in English and published in scientific journals are included. Newspapers, magazines, books or chapters, manuals, and reports are excluded as these types of works provide frequently only a generic picture of LPs implementation rather than the well detailed and in-depth description or discussion that the author of this thesis would like to consider. Moreover, conference proceedings and working papers are also excluded as the findings and contents of these kind of contribution are subject to change due to evolution in the research.

For the definition of the keywords, since this study is focused on Lean implementation within SMEs, Lean was the main term of the literature review. The academicians involved in the review panel decide to not circumscribe the research only to SMEs in order to avoid missing important scientific contributions in field of assessing; in fact, many contributions have not a specific/declared applicability based on plant-size, or rather they are proposed as general tool/framework/model regardless company's size. The keywords are shown in the Table 3.2:

Lean or Leaness	AND	Assess* or Implement* or Perform*	AND	Tool* or Framework* or Procedur* or Model*

Table 3.2 – Keywords definition

The research of these combination of keywords was conducted in: title, abstract and paper's keywords. The period of time analysed starts from 1996, the year of the publication of Womack and Jones (1996) work in which the five key principles of lean production are defined. In our opinion, this is the watershed in the literature from the studies based on TPS, and the related techniques developed in Toyota as JIT, to the researches on lean production/management/thinking.

In conclusion, the review panel is a useful approach to cross-check the robustness and reliability of implemented method, it allows to verify if any significant omissions or over-sights resulting from the selection of search terms, time periods, databases, etc. occurred (Hu et al, 2015). The period of time analysed ends in January 2016, in conjunction with the beginning of the second year of PhD course.

In the Figure 3.1, the literature review process is shown with inclusive and exclusive criteria defined for all the choices abovementioned. In addition, Figure 3.1 shows other choices in terms of review conducting as described in the next section.

Criteria	Reason
Inclusive Criteria	
Paper written starting form 1996	Shifting in the literature from the TPS focus to the lean thinking
Paper written in English	The language of most relevant journal in the topic of this research is English
Papers on assessing lean implementation issues	This is the objective of the current research
Exclusion Criteria	
Newspapers, magazines, books or chapters, manuals, and reports	Providing only a generic picture of LPs implementation
Conference proceedings and working papers	Findings and contents may change
Papers not focused on Lean	This is not in line with the objective of the current research

Figure 3.1 – Literature review criteria, source: the author

Conducting the review

In order to conduct the systematic literature review, Tranfield et al. (2003) methodology prescribes to define the search strings that are most appropriate for the study. Therefore, the research strings are based on Figure 3.1 and utilized exactly with the selected bibliographic databases. Initially, the number of papers identified is in total 867. After applying the exclusion criterion (books or chapters, manuals, conference proceedings, no written in English, duplication in more than one database, etc.) an amount of 181 is identified. The first abstract reading is performed by one researchers from the panel for checking the adherence with the research focus, moreover all no full accessible papers are removed. As a result, a total of 103 papers is defined for the second abstract reading and consequent full text reading. At this point, in order to choose only the relevant papers for the present research, all the review panel agree to select only the papers that provide tool/framework/model with a complete and comprehensive description of the methodologies, operative elements and results from employment in order to define the applicability of the proposed tool/framework/model. The result of this last selection identifies a list of 25 articles as shown in Figure 3.2. In order to track and manage all the above-mentioned phases, an Excel spread sheet has been created containing papers information as title, publication year, authors, journals and other features (geographic areas, industry sectors and LPs assessment approaches).

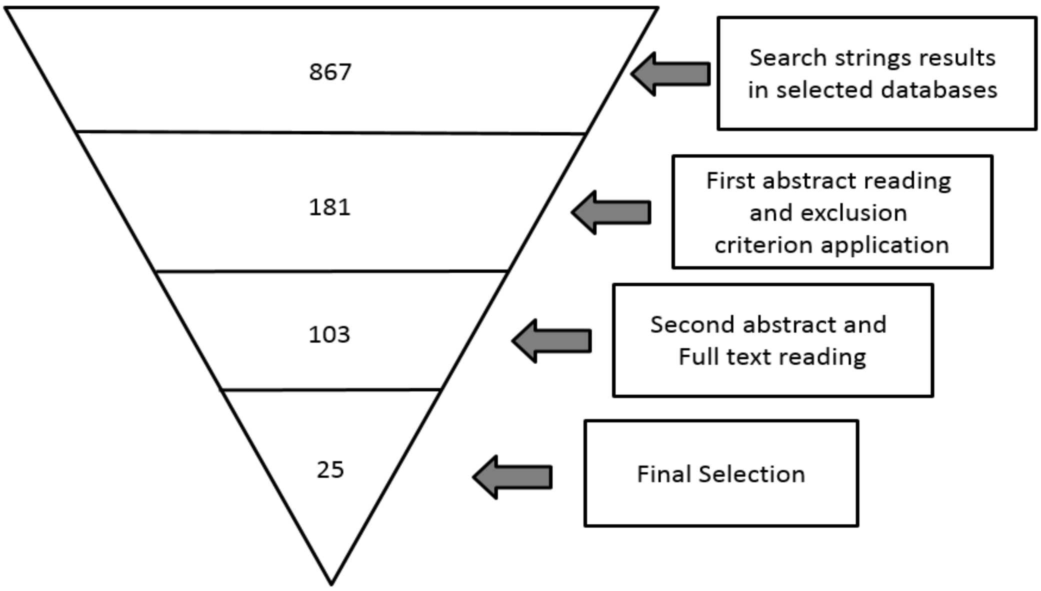


Figure 3.2 – Conducting review phase results, source: the author

Reporting and dissemination the review

In conclusion, as recommended by Tranfield et al. (2003) to report and disseminate the review, two main analysis should be performed: a "descriptive analysis" and a "thematic (interpretative) analysis". The descriptive analysis is based on the data from the Excel spreadsheet, while the thematic interpretative analysis provides an in-depth overview of main themes emerged from the literature review.

3.2.1 Descriptive analysis

This section depicts the descriptive analysis of the carried literature review. As prescribed by Tranfield et al. (2003), in this section *"researcher should be able to provide a broad ranging descriptive account of the field".* The section provides the categorization of the literature review according to year wise distribution, journal distribution, industrial sectors, geographical areas and SME applicability.

Year-wise paper distribution

Figure 3.3 shows the year wise distribution of the selected 25 articles from 1996 to January 2016. It is meaningful to highlight that recently the number of publications has risen, it shows an increasing interest in assessing LP implementation.

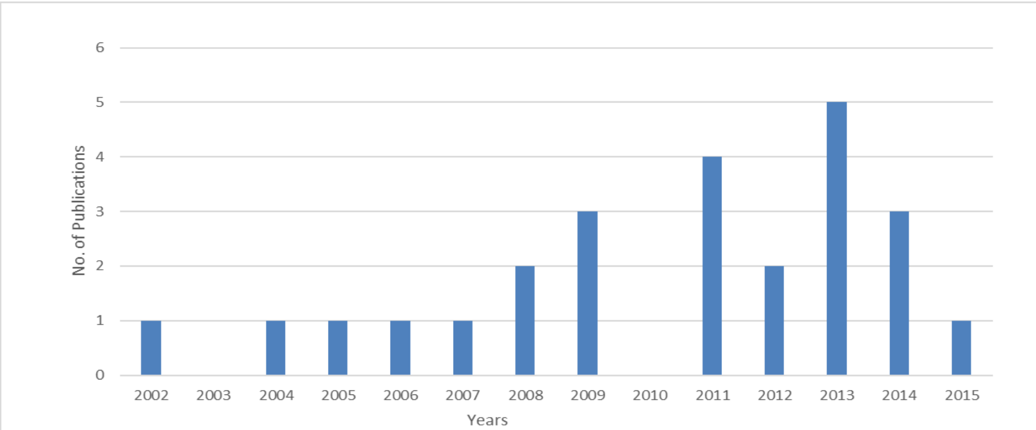


Figure 3.3 – Year wise distribution of reviewed papers

It is in line with other researchers that highlight how lean assessment topic has picked up from the first decade of the twenty-first century assuming more relevance in the academia (Bhamu and Singh Sangwan, 2014; Camacho-Miñano et al., 2013).

Journals-wise paper distribution

The selected papers are mainly published in journals with aims and scope focused in operation management, but also journals typically from others research fields are listed in this section. It shows a wide-ranging interest in the topic of lean assessment, from different perspectives, research streams and approaches. Table 3.4 shows the number of publications per journals.

Journal Name	No. of articles
The International Journal of Advanced Manufacturing Technology	5
International Journal of Production Research	3
Benchmarking: An International Journal	1
Business Process Management Journal	1
Computers in Industry	1
Expert Systems with Applications	1
Harvard business review	1
International Journal of Industrial Engineering & Production Research	1
International Journal of Production Research	1
International Journal of Productivityand Performance Management	1
Journal of Engineering and Technology Management	1
Journal of Manufacturing Technology Management	1
Journal of operations management	1
Management Decision	1
Measuring Business Excellence	1
Procedia Computer Science	1
Production Planning & Control	1
Strategic Finance	1
Technovation	1
Total	25

Table 3.4 – List of journals distributions

Distribution of papers by type of industry

The type of industries has been classified in compliance with United Nations International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4, Department of Economic and Social Affairs (available at https://unstats.un.org/unsd/cr/registry/ regcst.asp?Cl=27). As expected, Table 3.5 shows how manufacturing sector is predominant with electrical equipment and automotive production sector. The automotive sector has been characterized by fierce competition and stationary demand in USA and European countries for the last decade, while the electrical equipment manufacturing has been characterized by an increasing demand from the emerging economies (Bhamu and Sangwan, 2014). Moreover, the fact that the papers selected are from a wide range of different type of industry shows how LM has been implemented in diverse manufacturing type consist of different production systems (e.g. product, process, or fixed layout; batch or mass productions; discrete or continuous production).

Lastly, some authors do not provide specific information about the sector in which their tools has been employed; these contributions are counted as "*not specified* sector".

International Standard Industrial Classification (ISIC)	No. of articles
Manufacture of electrical equipment	5
Manufacture of motor vehicles, trailers and semi-trailers	4
Manufacture of computer, electronic and optical products	2
Architectural and engineering activities; technical testing and analysis	1
Electricity, gas, steam and air conditioning supply	1
Manufacture of fabricated metal products, except machinery and equipment	1
Manufacture of furniture	1
Manufacture of rubber and plastics products	1
Printing and reproduction of recorded media	1
Manufacturing sector not specified	8
Total	25

Table 3.5 – Distribution of papers by type of industry

Distribution of papers by geographical areas as per first author

As shown in Table 3.6, around 30 percent of papers are published by authors from USA and UK. Authors from India have also published around 20 percent of the papers. Moreover, there are authors from many growing economies as Turkey, Malaysia and South Africa. This demographic distribution of authors shows that the LPs implementation and assessment research spread out all over the globe.

Geographical areas as per first author	No. of articles
USA	7
India	6
UK	4
Turkey	2
Malaysia	2
Australia	1
China	1
Iran	1
South Africa	1
Total	25

Table 3.6 – Distribution of papers by geographical areas

SME applicability

Lastly, due to the fact that the aim of this research is to propose an assessment tool for SMEs, in this section we examine the applicability of identified LATs in the literature review. Generally, organisations can be simply categorised into two groups: large enterprises (LEs) and small- and medium-sized enterprises (SMEs).

World area	Definition of SMEs
USA	No more than 499 employees (manufacturing sector)
Canada	No more than 199 employees
EU	No more than 250 employees
Australia	No more than 200 employees
China	No more than 999 employees (manufacturing sector)

Table 3.7 – Definition of SMEs in different world areas (Hu et al., 2015)

First of all, it may be also useful to examine how SMEs are defined. There is no consensus on definition, as definitions across the world vary as shown in Table 3.7 (Hu et al., 2015). The European commission defined SME in the EU recommendation 2003/361 providing a harmoniously agreed definition across European Union: Staff headcount cannot exceed 250 employees and turnover 50 million of Euros. In other world regions, this threshold is indeed different as in USA (499 employees in manufacturing sector) or in China (999 employees in manufacturing sector).

The LATs contained in the selected paper of this literature review are classified as follow in regard to SMEs applicability:

- LAT applicable **only** for SMEs as stated by the authors;
- LAT applicable **also** for SMEs and LEs as stated by the authors;
- LAT **explicitly** not applicable for SMEs as stated by the authors;
- LAT applicability in regard to SMEs is **not** defined.

The result of this analysis is shown in the Table 3.8. Most of contributions selected do not define if the LAT proposed is applicable to SMEs. In this case, these researches propose generally empirical tests of the tool in a single firm without clearly defining the characteristics of organization chosen and the applicability in terms of plant size. Furthermore, Taj (2005) and Chen (2009) state that their LAT are applicable also for SMEs, in fact the sample of firms utilized for testing the tools are composed by companies of different sizes among the same industrial classification. Other LATs proposed by Bayou and Korvin (2008), Srinivasaraghavan and Allada (2006), Gurumurthy and Kodali (2009), Cil and Turkan (2013), Gupta et al. (2013) are explicitly not applicable for SMEs. The reason of this distinction may vary from a LAT to another, for instance Bayou and Korvin (2008) propose a tool that compares the production systems of Ford Motor Company and General Motors using Honda Motor Company's system as a benchmark over the years 2001–2003. It is obvious, due to scope of that research, that the tool cannot be applied in SMEs context. Moreover, Cil and Turkan (2013) propose a LAT based on ANP where relationships between business objectives and enterprise stakeholders are the distinctive elements in delivering value to all stakeholders. In fact, the firm chosen for testing the model is part of a multinational company with plants in three different continents and thousands of employees. Therefore, referring to value with regard to LE stakeholders such as strategic partners, unions, and society is a strong limitation to the application of the tool within SMEs. Only Behrouzi and Wong (2013) propose a LAT formulated explicitly for SMEs. The authors utilize an integrated stochastic-fuzzy modelling approach to evaluate the performance measures of SMEs in the automotive industry in Iran. For this purpose, they select 28 measures setting the leanness thresholds for each measure. This tool unfortunately is mainly focused on performances and do not provide to the assessed firm clear paths of improvement and related LPs to enhance coherently with firm strategy.

In conclusion, in Table 3.8, all selected papers of this literature review are shown. Briefly, the contribution to research of each of them is described in order to provide a general overview and highlight their key elements.

Authors	Year	Industrial Sector	Contribution to the research	SMEs Applicability
Karim and Arif-Uz-Zaman	2013	Manufacture of electrical equipment	A structures methodology of implementing lean strategies is proposed and a new method of leanness evaluation metric is defined comparing firm's performances evolution	not defined
Almomani et al.	2014	Manufacture of furniture	The proposed assessment has the aim to find the best route for lean implementation thanks to experts comparative judgments based on AHP	not defined
Gupta et al.	2013	Manufacture of rubber and plastics products	This research is an empirical contribution where the opinions of a group of experts consulted to formulate an interpretive structural model (ISM) of the critical success factors of lean manufacturing implementation	explicitly not for smes
Cil and Turkan	2013	Manufacture of fabricated metal products, except machinery and equipment	ANP-based model is proposed for detecting plausible relationships among different levels of design decisions: from enterprise level to shop floor level in implementing LPs	explicitly not for smes
Behrouzi and Wong	2013	Manufacture of motor vehicles, trailers and semi-trailers	An integrated stochastic-fuzzy modelling approach to evaluate the leanness of SME is proposed. Due to the fact that performance measures in the real world are stochastic since various random factors, authors propose to apply a fuzzy logic in performance evaluation	only for sme
Vimal and Vinodh	2013	Manufacture of electrical equipment	Due to the presence of highly repetitive work in manual computation of leanness using fuzzy logic, artificial neural network concept is applied to a multiple criteria decision making evaluation	not defined
Gurumurthy and Kodali	2009	Electricity, gas, steam and air conditioning supply	This research lists out the elements and performance measures of LM highlighting the gaps in terms of performance and practices between the two organizations through a benchmark	explicitly not for Smes
Vinodh et al.	2011	Manufacture of electrical equipment	The paper defines lean competitive bases (LCBs), lean attributes (LAs) and lean enablers (LEs). Moreover, customer's voice needs to be accurately translated into technical languages and for this purpose QFD has been widely used for performing this kind of translation. Due to the vagueness associated in the assignment of correlations and relationships, triangular fuzzy numbers have been used in the QFD framework.	not defined
Bayou and Korvin	2008	Manufacture of motor vehicles, trailers and semi-trailers	Using a fuzzy-logic methodology, this case study lists the steps of an algorithm and applies it to the automobile industry. The measure compares the production systems of Ford Motor Company and General Motors using Honda Motor Company's system as a benchmark over the years 2001–2003, thanks to their audited consolidated financial statements and other pertinent information	explicitly not for smes

Table 3.8 – Literature Review list

Authors	Year	Industrial Sector	Contribution to the research	SMEs Applicability
Srinivasaraghavan and Allada	2006	Architectural and engineering activities; technical testing and analysis	The authors propose to utilize the Mahalanobis distance, it is used to distinguish the pattern of a certain group from other groups. However, the procedure to identify the direction of abnormality is limited to cases where the characteristics of the variables are known. The proposed methodology also allows for optimizing the number of variables or the amount of information that needs to be collected for assessing the level of lean implementation in an organization with a benchmarking approach	explicitly not for SMEs
Taj	2005	Manufacture of computer, electronic and optical products	Nine key areas of manufacturing are evaluated by this assessment; each ranks the plant's performance as a percentage. Participants will be asked to answer three to six questions for each area, namely: (1) inventory; (2) team approach; (3) processes; (4) maintenance; (5) layout/handling; (6) suppliers; (7) setups; (8) quality; and (9) scheduling/control. The tool is based on a work of Quarterman Lee at Strategos Inc.	also for SMES
Pakdil and Leonard	2014	Manufacturing Not specified	The LAT measures quantitative aspects of leanness through eight performance dimensions: time effectiveness, quality, process, cost, human resources, delivery, customer and inventory along with detailed sub-performance indicators. These performance dimensions are related to seven types of waste considered in lean production. In the qualitative section, the LAT demonstrates a perceptional view within five performance dimensions: quality, process, customer, human resources and delivery, using 51 items. As a calculation method, the fuzzy logic is applied.	not defined
Chen	2009	Not specified	A web-based tool for lean decision support (DS) is presented in this paper. DS determines the type of production system and ranks the importance of selected lean principles and related practices	also for SMES
Shah and Ward	2007	Manufacturing Not specified	This research takes an initial step toward clarifying the concept of lean production and develops and validates a multi-dimensional measure of lean production. The discussion of research's results into three sections: what is lean production (i.e. identify critical factors), how are the various factors of lean production related to each other, and why are they related.	not defined
CIA	2009	Manufacturing Not specified	The Lean Performance Score (LPS) provides companies with another lean accounting tool to help measure the overall success of their lean journey. Although a LPS isn't a substitute for the various operational and financial results companies track, it can be a powerful signal as to whether companies are staying on the lean journey path	not defined
Vinodh and Balaji	2011	Manufacture of computer, electronic and optical products	The tool architecture consists of the inputs leanness enablers, leanness criteria, and leanness attributes as well as performance weights and importance ratings. These inputs are processed in the database. Queries are established which act as processing methodology and outputs are generated.	not defined
Behrouzi and Wong	2011	Not specified	Using fuzzy membership values, this study has presented the steps of a performance measurement method to measure the lean performance of a manufacturing system. The performances evaluated are Scrap, Inventory Cost, non value added time, customer's complaints, transportation cost, setup time and lead time	not defined

Table 3.8 – Literature Review list (continued)

Authors	Year	Industrial Sector	Contribution to the research	SMEs Applicability
Azadeh et al.	2015	Printing and reproduction of recorded media	Based on the results of on data envelopment analysis (DEA), fuzzy DEA (FDEA), fuzzy cognitive map (FCM), Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Hierarchy Process (AHP) , the causality relation between all leanness factors are determined. Handling multiple inputs and outputs, uncovering relationships that remain hidden for other methodologies and capable of being used with any input–output measurement; an overall lean performance index evaluation platform has been introduced	not defined
Vinodh and Chintha	2011	Not specified	Application of multi-grad fuzzy logic for enabling leanness in a manufacturing organization, the leanness index was computed and the practical inferences were derived	not defined
Chauhan andSingh	2012	Not specified	It proposes a Lean manufacturing index and presents the descriptive statistics (mean and standard deviations) of lean manufacturing parameters of the surveyed units.	not defined
Sanati and Seyedhoseini	2008	Manufacture of motor vehicles, trailers and semi-trailers	The types of wastes in the assessed organization are defined by using Axiomatic Design Methodology (ADM). After defining the types of wastes, a model for assessment of leanness is submitted. In this quantitative model, the amounts of leanness in each phase of lean journey are determined and combined to make a unique measure for total leanness. Dimensions of leanness are presented for quick understanding, by using a radar chart	not defined
Goodson	2002	Manufacturing Not specified	The Rapid Plant Assessment (RPA) rating sheet presents 11 categories for assessing the leanness of a plant, and the RPA questionnaire provides 20 associated yes-or-no questions to determine if the plant uses best practices in these categories.	not defined
Kojima and Kaplinsky	2004	Manufacture of motor vehicles, trailers and semi-trailers	The paper proposes a Comprehensive Lean Production Index (LPI) based on flexibility index, quality index and CI index	not defined
Vinodh and Vimal	2012	Manufacture of electrical equipment	The model is divided into three levels. The first level consists of five leanness enablers; the second level consists of 30 lean criteria; and the third level consists of 59 lean attributes. In order to improve the comprehensiveness of 20 criteria model, additional ten criteria has been included, namely resource utilization, flexible business practices, standardization, systematization, and simplification, workplace organization, maintenance management, visual controls, continuous improvement, waste quantification, activity categorization, and pull production	not defined
Wong et al.	2014	Manufacture of electrical equipment	The paper proposes a lean index to assess the leanness level of the organization in sustaining lean transformation. This 'lean index' is developed from theory, and is quantified using a multi- criteria approach, the analytic network process (ANP). This index adopts a holistic approach of performance evaluation	not defined

Table 3.8 – Literature Review list (continued)

3.2.2 Thematic analysis

According to the chosen methodology, in the thematic analysis *"researchers need to report their findings, defined as themes, outlining that which is known and established already from data extraction forms of the core contributions"* (Tranfield et al., 2003). In more detail, researchers should identify the emerging themes and potential future research questions, interpreting the degree of consensus in terms of key themes in the relevant literature field (Hu et al., 2015). Therefore, in this section the author proposes three main themes identified during the panel sessions in compliance with above-mentioned methodology. The main activities performed in this phase were categorizing and sub-categorizing the collected papers analogously with the Suarez-Barraza et al. (2012) in their literature review. Moreover, in order to provide a detailed audit trail back to the main contributions for justifying and grounding his conclusions as prescribed by Tranfield et al. (2003), the author proposes an interpretative analysis of the defined themes in LAT literature review. The three identified themes are:

- *Theme 1:* examination of LPs in implementing LM
- *Theme 2:* focusing on approaches and contents of LATs
- *Theme 3:* addressing the knowledge base incorporated in the tools according to the logic of LATs

Theme 1: examination of LPs in implementing LM

In the literature, there is a wide range of LPs, tools and approaches to operationalise or facilitate Lean implementation (Hu et al., 2015). As stated by Bhamu and Sangwan (2014), LM has become "an integrated system composed of highly inter-related elements and a wide variety of management practices, including 5S, JIT, quality systems, work teams, cellular manufacturing, TPM, Kanban, etc." In order to shed light on this plethora of different element, in the Tables 3.9 and 3.10 the identified elements are shown and categorized. For this purpose, author identified two main groups as suggested by Achanga et al. (2006): *Lean Primary Practices* that support the implementation of LM in the organization in the context of operations in compliance with the five principles identified by Womack and Jones (1996), and *Lean Support Practices* that are mainly focused on organizational aspects inspired to the fifth lean principle: *continuously strive to improve*.

Analysing this theme, another relevant issue arises: LPs, tools and techniques have multiple names and it generates ambiguity. Some LPs overlap with other ones, and specific tools/techniques might even have a different implementation way proposed by different researchers (Pavnaskar et al., 2003). For this reason, the review panel adopt the classification present in literature, integrating the definition of LPs from three main contributions in literature: the first contribution is the research of Shah and Ward (2003, 2007) that identify 10 distinct dimensions of a lean production system investigating 22 LPs and their operational measurement system. The second contribution is Cua et al. (2012) that classify TQM, JIT, TPM and Human and Strategic-Oriented Common Techniques from Shah and Ward (2003) with 17 associated LPs. Similarly, the last contribution by Demeter and Matyusz (2011) identifies six sets of LPs as follows: process focus, pull production, quality programs, increase in equipment efficiency, from of lean organization and continuous improvement.

Therefore, the review panel propose in the Tables 3.9 and 3.10 a novel classification of LPs identifying 35 LPs, categorized in 6 distinct lean operational constructs aligned with the definition suggested by Achanga et al. (2006): *Lean Primary Practices and Lean Support Practices* and in the perspective of manufacturing context. The lean operational constructs associated to the primary practices are:

- Process and Equipment;
- Manufacturing Planning and Control System;
- Supplier Integration;
- Total Productive Maintenance (TPM).

While the operational constructs associated to the support practices are:

- Employees empowerment;
- Continuous improvement.

Moreover, in order to provide a better understanding and an extensive contribution on this LPs classification, the review panel agreed to utilize the data of 103 papers analysed during the second abstract and full text reading; these data are contained in Excel spread sheet created to classify all relevant information from the selected papers. Accordingly, in Table 3.9 proposed LPs and their appearance, in the abovementioned references, referred to the four proposed constructs are shown.

Lean Operational Construct	Lean Practices List	References
Process and Equipment	1. SMED 2. Flow Oriented Process 3. Poka Yoke 4. Workplace organization and cleanliness 5. Safety and ergonomics 6. Point of use and Supermarket 7. Flexible equipment 8. Visual control at workplace	(Agus and Shukri , 2012), (Alemi and Akram, 2013), (Azevedo et al., 2012), (Bashin, 2012), (Bonavia and Martin, 2006), (Büyüközkan, 2015), (Cil and Turkan, 2013), (Daud et al., 2011), (Deif,, 2012), (Diaz-Elsayed et al., 2013), (Doolen and Hacker , 2005), (Dora et al., 2013), (Eswaramoorthi et al., 2011), (Goodson, 2002), (Gurumurthy and Kodali, 2009), (Hofer and Eroglu , 2012), (Hofer et al., 2011), (James-Moore andGibbons, 1997), (Kojima and Kaplinski , 2004), (Kuhlang et al., 2011), (Kull et al., 2014), (Kumar and Thomas, 2002), (Manzouri et al., 2013), (Marvel and Standridge, 2009), (Matsui, 2007), (Mostafa et al., 2013), (Muhamad, 2009), (Nasab et al., 2012), (Nawanir et al., 2013), (Nightingale and Mize, 2002), (Nightingale, 2000), (Nordin et al., 2010), (Pakdil and Leonard, 2014), (Rahman et al., 2010), (Rose and Rahman, 2013), (Rymaszewska, 2014), (Salem et al., 2006), (Sánchez and Pérez, 2001), (Saurin et al., 2011), (Seydhosseini et al, 2011), (Sezen et al., 2011), (Shah and Ward , 2007), (Singh and Sharma, 2010), (Srinivasaraghavan and Allada, 2005), (Taj and Morosan, 2011), (Taj, 2008), (Vimal and Vinodh, 2013), (Vinodh and Balaji , 2011), (Vinodh and Chintha, 2011), (Vinodh and Vimal , 2012), (Wan and Chen, 2007), (Wan and Chen, 2009), (Wanitwattanakosol and Sopadang, 2012), (Wu and Wee, 2009), (Zhou, 2012)
Manufacturing Planning and Control System	1. Levelled production 2. Pull planning system 3. Pull scheduling system 4. Synchronized production 5. Small lot sizing 6. Zero Inventories	(Chauhan and Singh, 2012), (Agus and Shukri , 2012), (Azed et al., 2015), (Azevedo et al., 2012), (Bashin, 2012), (Bayou and de Korvin, 2008), (Bonavia and Martin, 2006), (Büyüközkan, 2015), (Calarge et al. Eugenio Carretero, 2012), (Cezar Lucato et al. Damasceno Calado, 2014), (Cil and Turkan, 2013), (Cua et al., 2001), (Dal Pont et al., 2008), (Deif,, 2012), (Demeter and Matyusz, 2008), (Diaz-Elsayed et al., 2013), (Doolen and Hacker , 2005), (Dora et al., 2013), (Eswaramoorthi et al., 2011), (Fadly Habidin and Sha'ri Mohd, 2013), (Ghosh and Manimay, 2012), (Goodson, 2002), (Gurumurthy and Kodali, 2009), (Hofer and Eroglu , 2012), (Hofer et al., 2011), (Karlsson and Åhlström, 1996), (Kojima and Kaplinski , 2004), (Kull et al., 2014), (Marvel and Standridge, 2009), (Matsui, 2007), (Muhamad, 2009), (Nasab et al., 2012), (Nawanir et al., 2013), (Nightingale and Mize, 2002), (Nightingale, 2000), (Nordin et al., 2010), (Pakdil and Leonard, 2014), (Rahman et al., 2010), (Rose and Rahman, 2013), (Rymaszewska, 2014), (Salem et al., 2006), (Sánchez and Pérez, 2001), (Saurin et al., 2011), (Seydhosseini et al, 2011), (Sezen et al., 2011), (Shah and Ward, 2003), (Shah and Ward , 2007), (Singh and Sharma, 2010), (Soriano-Meier and Forrester, 2002), (Subashini and Mohan Kumar, 2013), (Taj and Morosan, 2011), (Taj, 2008), (Vimal and Vinodh, 2013), (Vinodh and Chintha , 2011), (Vinodh and Balaji , 2011), (Vinodh and Chintha, 2011), (Vinodh and Vimal , 2012), (Wan and Chen, 2009), (Wanitwattanakosol and Sopadang, 2012), (Yang et al., 2011), (Zhou, 2012)
Suppliers Integration	1. Blanket Orders 2. Total Cost of Ownership 3. Kanban with suppliers 4. Free pass 5. Information openness and mutual exchange 6. Supplier development 7. Supplier rationalization	(Alemi and Akram, 2013), (Azed et al., 2015), (Azevedo et al., 2012), (Bashin, 2012), (Calarge et al. Eugenio Carretero, 2012), (Cezar Lucato et al. Damasceno Calado, 2014), (Cil and Turkan, 2013), (Doolen and Hacker , 2005), (Dora et al., 2013), (Eswaramoorthi et al., 2011), (Fadly Habidin and Sha'ri Mohd, 2013), (Ghosh and Manimay, 2012), (Goodson, 2002), (Gurumurthy and Kodali, 2009), (Hofer and Eroglu , 2012), (Hofer et al., 2011), (Karlsson and Åhlström, 1996), (Kumar and Thomas, 2002), (Matsui, 2007), (Nawanir et al., 2013), (Nightingale and Mize, 2002), (Nightingale, 2000), (Nordin et al., 2010), (Rahman et al., 2010), (Rose and Rahman, 2013), (Rymaszewska, 2014), (Sánchez and Pérez, 2001), (Seydhosseini et al, 2011), (Shah and Ward , 2007), (Singh and Sharma, 2010), (Taj and Morosan, 2011), (Taj, 2008), (Vimal and Vinodh, 2013), (Vinodh and Balaji , 2011), (Vinodh and Chintha, 2011), (Vinodh and Vimal , 2012), (Wanitwattanakosol and Sopadang, 2012)
Total Productive Maintenance	1. Autonomous Maintenance 2. Planned Maintenance 3. Proactive maintenance 4. TPM Training 5. Maintenance Indexes utilization	(Alemi and Akram, 2013), (Bashin, 2012), (Bonavia and Martin, 2006), (Büyüközkan, 2015), (Cil and Turkan, 2013), (Cua et al., 2001), (Diaz-Elsayed et al., 2013), (Doolen and Hacker , 2005) , (Dora et al., 2013), (Eswaramoorthi et al., 2011), (Ghosh and Manimay, 2012), (Goodson, 2002), (Gurumurthy and Kodali, 2009), (Hofer and Eroglu , 2012), (Hofer et al., 2011), (James-Moore andGibbons, 1997), (Kumar and Thomas, 2002), (Muhamad, 2009), (Nasab et al., 2012), (Nawanir et al., 2013), (Nordin et al., 2010), (Pakdil and Leonard, 2014), (Rahman et al., 2010), (Rose and Rahman, 2013), (Sánchez and Pérez, 2001), (Saurin et al., 2011), (Seydhosseini et al, 2011), (Sezen et al., 2011), (Shah and Ward, 2003), (Shah and Ward , 2007), (Singh and Sharma, 2010), (Taj and Morosan, 2011), (Taj, 2008), (Vimal and Vinodh, 2013), (Vinodh and Vimal , 2012), (Wu and Wee, 2009), (Zhou, 2012)

Table 3.9 - Lean Primary Practices

Analogously, Table 3.10, shows the Lean support practices and their references' appearance referred to the two proposed constructs.

Lean Operational Construct	Lean Practices List	References
Employees empowerment	1. Training e Integration 2. Upkeep and Development 3. Multifunctional Workers	(Alemi and Akram, 2013), (Azed et al., 2015), (Bonavia and Martin, 2006), (Büyüközkan, 2015), (Calarge and Eugenio Carretero, 2012), (Cezar Lucato and Damasceno Calado, 2014), (Chauhan and Singh, 2012), (Cil and Turkan, 2013), (Cua et al., 2001), (Dal Pont et al., 2008), (Demeter and Matyusz, 2008), (Doolen and Hacker , 2005), (Dora et al., 2013), (Eswaramoorthi et al., 2011), (Fadly Habidin and Sha'ri Mohd, 2013), (Ghosh and Manimay, 2012), (Goodson, 2002), (Gurumurthy and Kodali, 2009), (Hofer and Eroglu , 2012), (Hofer et al., 2011), (James-Moore andGibbons, 1997), (Karlsson and Åhlström, 1996), (Kojima and Kaplinski , 2004), (Kuhlang et al., 2011), (Kumar and Thomas, 2002), (Manzouri et al., 2013), (Mostafa et al., 2013), (Muhamad, 2009), (Nightingale and Mize, 2002), (Nightingale, 2000), (Nordin et al., 2010), (Rose and Rahman, 2013), (Rymaszewska, 2014), (Salem et al., 2006), (Sánchez and Pérez, 2001), (Saurin et al., 2011), (Seydhosseini et al, 2011), (Sezen et al., 2011), (Shah and Ward, 2003), (Shah and Ward , 2007), (Singh and Sharma, 2010), (Soriano-Meier and Forrester, 2002), (Vimal and Vinodh, 2013), (Vinodh and Chintha , 2011), (Vinodh and Balaji , 2011), (Vinodh and Chintha, 2011), (Vinodh and Vimal , 2012), (Wan and Chen, 2009), (Yang et al., 2011)
Continuous improvement	1. Problem solving methodology 2. Standard work 3. Strategic planning 4. Tactical improvement 5. Daily Improvement 6. Organizational structure for continuous improvement	(Agus and Shukri , 2012), (Azevedo et al., 2012), (Bashin, 2012), (Bayou and de Korvin, 2008), (Bonavia and Martin, 2006), (Büyüközkan, 2015), (Calarge and Eugenio Carretero, 2012), (Cezar Lucato and Damasceno Calado, 2014), (Chauhan and Singh, 2012), (Cil and Turkan, 2013), (Daud et al., 2011), (Demeter and Matyusz, 2008), (Doolen and Hacker , 2005), (Eswaramoorthi et al., 2011), (Ghosh and Manimay, 2012), (Goodson, 2002), (Gurumurthy and Kodali, 2009), (Hofer et al., 2011), (Karlsson and Åhlström, 1996), (Kojima and Kaplinski , 2004), (Kull et al., 2014), (Kumar and Thomas, 2002), (Manzouri et al., 2013), (Marvel and Standridge, 2009), (Mostafa et al., 2013), (Muhamad, 2009), (Nasab et al., 2012), (Nightingale and Mize, 2002), (Nightingale, 2000), (Nordin et al., 2010), (Rahman et al., 2010), (Rose and Rahman, 2013), (Rymaszewska, 2014), (Salem et al., 2006), (Sanati and Seyedhoseini, 2008), (Sánchez and Pérez, 2001), (Saurin et al., 2011), (Seydhosseini et al, 2011), (Sezen et al., 2011), (Shah and Ward , 2007), (Singh and Sharma, 2010), (Soriano-Meier and Forrester, 2002), (Srinivasaraghavan and Allada, 2005), (Subashini and Mohan Kumar, 2013), (Taj and Morosan, 2011), (Taj, 2008),(Vimal and Vinodh, 2013), (Vinodh and Chintha , 2011), (Vinodh and Balaji , 2011), (Vinodh and Chintha, 2011), (Vinodh and Vimal , 2012), (Wan and Chen, 2009), (Zhou, 2012)

Table 3.10 - Lean Support Practices

For the sake of clarity, the lean operational constructs contents and the related list of LPs are described in detail in the Chapter 5, where the assessment tool and its features and components are extensively defined and depicted.

Theme 2: focusing on approaches and contents of LATs

In the literature, a relevant number of authors propose a division of assessment tool in two categories: *qualitative* and *quantitative.* This distinction has been described in detail in section 3.1 of this chapter; in summary, on one hand, Wong *et al.* (2014) define the qualitative assessments as survey based tools, influenced by personal opinion, and their complexity ranges from simple LM practices assessment until the degree of adoption of its principles. On the other, qualitative assessment are based on mathematical logics such as DEA, ANP, Fuzzy Logic, Mahalanobis Distance, etc.

In this literature review, an alternative model of classification is proposed; in our opinion this model should overcome some limitations of above mentioned classifications. In particular, the distinction between *qualitative* and *quantitative* assessment tolls is not clear defined in regard to the subjective (based on evaluator's personal judgment) and objective (irrespective of the evaluator's judgment) approaches. Therefore, in formulating the model shown in Figure 3.4, the following classification variables has been utilized:

- Method of assessment: a clear distinction in subjective and objective approaches;
- Assessment Focus: practices or performances; it is considered important to distinguish between models that measure the degree of practices implementation and models that assess the degree of performance improvements resulting from the implementation of lean transformation.

Assessment Focus	Method of Assessment: Subjective	Method of Assessment: Objective
Practices	Lean practices assessment is based on evaluator's personal judgment	Lean practices assessment is based on objective measures irrespective of the evaluator's opinion
Performances	Performance assessment is based on evaluator's personal judgement	Performance assessment is based on objective measures irrespective of the evaluator's opinion

Figure 3.4 - Assessment Methods Classification Matrix

Therefore, the analysis of literature has allowed us to develop a novel framework for categorizing the main lean implementation assessment tools developed by scholars. Two main lean assessment approaches arise from literature: the first consists in firm's performance assessment to identify the effect of lean principles implementation; the second is the direct assessment of lean practice adoption. Both approaches may use two different method of assessment: *subjective* (i.e. assessment is based upon personal judgements of evaluators) and *objective* (i.e. assessment is based on metrics independent from the evaluators). From these considerations, the existing tools can be grouped into four categories shown in the assessment methods classification matrix in Figure 3.4.

In order to review the selected papers according to the proposed classification matrix, the Table 3.11 shows the classification variables associated to each contributions.

Authors	Year	Practices	Performances	Subjective	Objective
Karim and Arif-Uz-Zaman	2013		x		x
Almomani et al.	2014		x		x
Gupta et al.	2013	x		x	
Cil and Turkan	2013	x	x	x	
Behrouzi and Wong	2013		x	x	
Vimal and Vinodh	2013		x	x	
Gurumurthy and Kodali	2009	x	x	x	
Vinodh et al.	2011	x		x	
Srinivasaraghavan and Allada	2006		x	x	x
Taj	2005	x		x	
Pakdil and Leonard	2014		x		x
Chen	2009	x		x	
Shah and Ward	2007	x		x	
Cia	2009		x	x	
Vinodh and Balaji	2011	x		x	
Behrouzi and Wong	2011		x		x
Azadeh et al.	2015		x		x
Vinodh and Chintha	2011	x		x	
Chauhan andSingh	2012	x		x	
Sanati and Seyedhoseini	2008	x		x	
Goodson	2002	x		x	
Kojima and Kaplinsky	2004		x		x
Vinodh and Vimal	2012	x	x		x
Wong et al.	2014	x	x	x	
Bayou and Korvin	2008		x		x

Table 3.11 – Review of the selected paper according to proposed Classification Matrix

Behrouzi and Wong (2013) tried to formulate a new method of classification in the direction of the one that is proposed in this section. In their research they have already identified four main approaches to measure leanness. The first is measuring the degree of implementation of lean tools, techniques and practices; the second approach is measuring performances outputs as a result of lean implementation; the third approach is a mixed mode of the first and the second and the fourth is leanness assessment through VSM. The authors missed to capture the role of the personal judgment in their analysis. Therefore, the model proposed in this section extends and enriches the knowledge in the current literature. In fact, from the Table 3.11 comes to light how practices are usually assessed with subjective approach (Gupta et al., 2013; Vinodh et al., 2011; Taj, 2005; Chen, 2009;Shah and Ward, 2007; Vinodh and Balaji, 2011; Vinodh and Chintha, 2011; Chauhan and Singh, 2012; Sanati and Seyedhoseini, 2008; Goodson, 2002); while performances are assessed with an objective approach (Karim and Arif-Uz-Zaman, 2013; Almomani et al., 2014; Pakdil and Leonard, 2014; Behrouzi and Wong, 2011; Azadeh et al., 2015; Kojima and Kaplinsky, 2004; Bayou and Korvin, 2008) and a subjective approach as well (Behrouzi and Wong, 2013;Vimal and Vinodh, 2013). The majority of identified assessment tools is separately focused on practices or performances, notably few of these models may assess both practices and performances (Cil and Turkan, 2013; Gurumurthy and Kodali, 2009; Vinodh and Vimal, 2012; Wong et al., 2014

Theme 3: addressing the knowledge base incorporated in the tools according to the logic of LATs

In order to enhance the knowledge of the fundamental features of the LATs considered in this literature review and to better understand their differences and weakness for identifying the proper gaps in this research field, a second classification matrix (Figure 3.5) adapted from Panizzolo et al. (2010) is proposed in this section. This matrix is composed by the following classification variables:

- Logic of assessment: a distinction between the assessment of adherence to a set of requirement – *conformity* and the assessment of practices or/and performances (it depends on the LAT contents as analyzed in Figure 3.4) to the application context – *coherence*;
- Knowledge incorporated in the assessment: the assessment provides a *high level of abstraction* when it provides only general principles/constructs and brief guidelines. In this case, nevertheless these characteristics steer and support the assessment process itself, the tool is not able to substitute the judgment skills of the evaluators. In contrast, at *low level of abstraction*, the tool itself contains operational and detailed indications that reduce the dependency on evaluators' judgment skills.

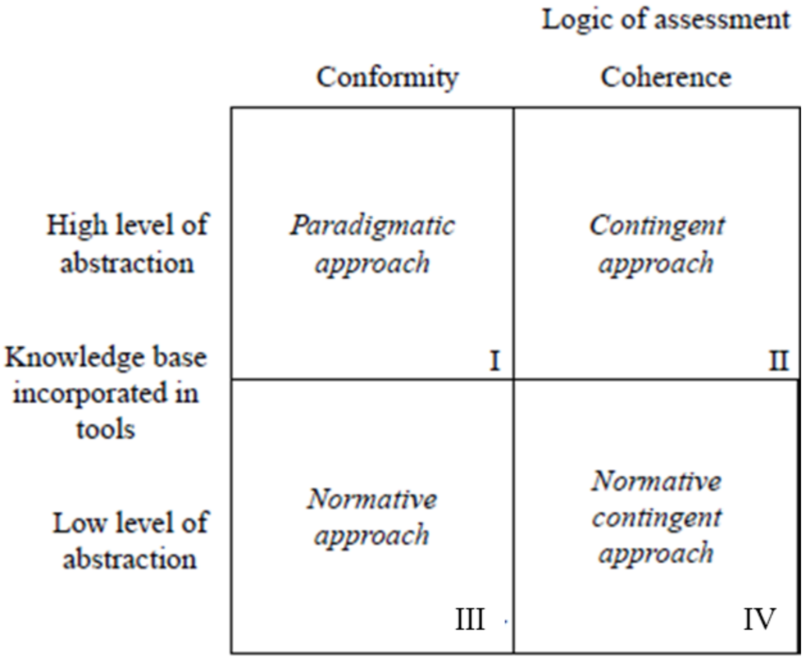


Figure 3.5 - Knowledge base incorporated/ Logic of Assessment Classification Matrix, adapted from Panizzolo et al. (2010)

The matrix proposed identifies four assessment diagnostic approaches; Panizzolo et al. (2010) define the *paradigmatic approach* (Cell I) in which "*assessment is guided by a model which requires compliance with a set of non-prescriptive requirements; this approach is called "paradigmatic" because this kind of model can be conceptualised as a "paradigm", i.e. "a management system that is not a collection of techniques, methods and approaches, but rather a coherent body of inter-dependent criteria and logic in the spheres of organization, management, decision making and motivation".* Considering one of the papers selected, Gupta et al. (2013) propose a LAT for tyres industry sector. The authors map the tyre manufacturing wastes defining structural self-interaction matrix between critical factors of lean implementation specific for this industrial context. In this way, the authors developed a leanness index with the experts of tyre manufacturing based on specific elements avoiding considering selected elements. In fact, the authors state that "*other lean wastes such as, movement and transportation are not considered for this template formulation because tyre manufacturing is highly process driven and usually requires huge setup where frequent movement and transportation are inevitable*". Therefore, this research can be placed among the paradigmatic approach since the scope and key elements are designed with a logic to provide coherent body of inter-dependent criteria related to a specific context to assess the implementation of selected LPs.

The Cell II contains the *contingent approach* to assessment, "*it is based on frameworks that act as guidelines for analysing relations between contingency factors and organizational attributes*" (Panizzolo et al., 2010); but this kind of assessment do not provide any kind of improvement action, for instance, in line with firm's strategic priorities. An example is provided by Pakdil and Leonard (2014), their LAT measures quantitative aspects of leanness through eight performance dimensions: time effectiveness, quality, process, cost, human resources, delivery, customer and inventory along with detailed sub-performance indicators. In the qualitative section, the LAT measures five operative performance dimensions: quality, process, customer, human resources and delivery, using 51 items. The result of this LAT allows an immediate, comprehensive view of the *strong* areas and those needing improvement; these areas are not analysed according to firm's characteristic in order to define priorities or improvement plans. In this sense, these kinds of tool are contingent but do not provide any improvement directions.

In the *normative approach* (Cell III), "*assessment is based upon the determination of the level of adherence to a set of prescriptive requirements which, on the whole, delineate a non-situational operational model*" (Panizzolo et al., 2010). This tool contains clear judgement criteria, usually they are formulated as self-assessment questionnaire almost composed highly detailed yes/no questions. Goodson (2002) with its *Read a plant-fast* proposes a LAT inspired by the normative approach. This LAT has two main elements; the first is a rating sheet with 11 categories for assessing the lean level of a plant referring to the best-in-class level: customer satisfaction, Safety/Cleanliness and Order, Visual Management System, Scheduling Syste, Use of Space and Production Line Flow, Inventory Level, Teamwork, Maintenance and Equipment Tool, Management of Complexity, Supply Chain Integration and Commitment to Quality. The second one is a questionnaire that provides 20 associated yes/no questions to determine if the plant uses best practices in these categories. In this way, the result of tool is in line with the normative approach, providing the level of adherence of the assessed plant to a set of best-in-class categories.

In the *normative-contingent approach* (Cell IV), prescriptive requirements are situation-specific and they are present in the LAT. Surprising, none of papers reviewed propose a tool in this approach as shown in Figure 3.6. In this figure, the selected 25 LATs are mapped in compliance with the defined four approaches.

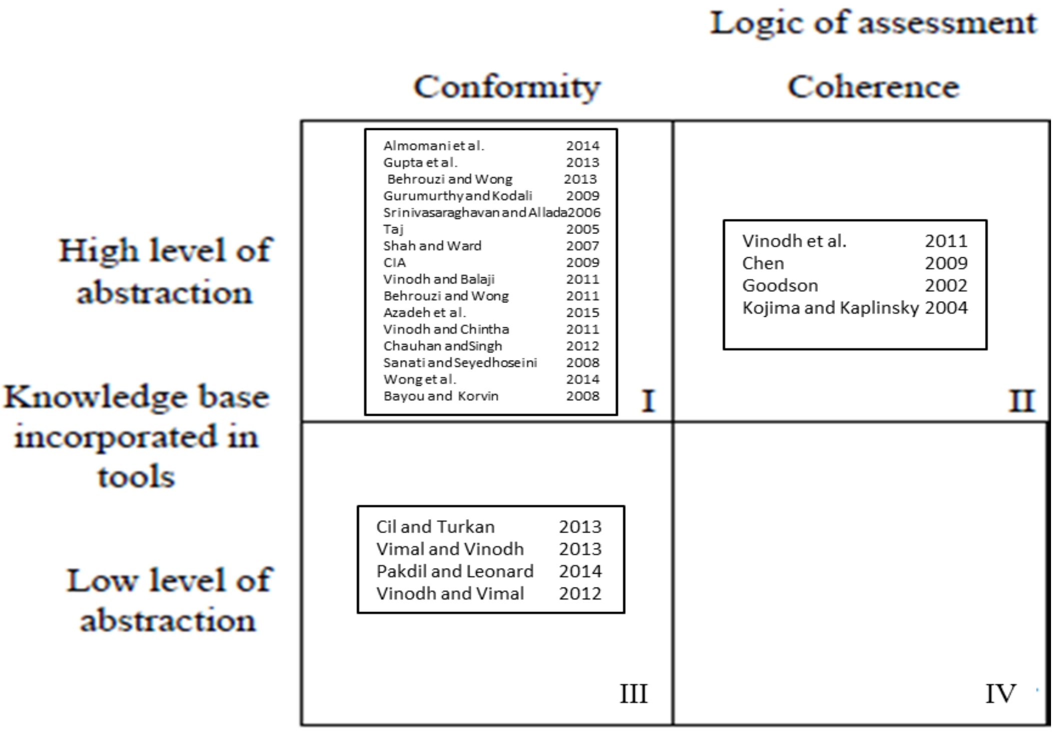


Figure 3.6 - Classification of selected LATs according to Knowledge base incorporated/ Logic of Assessment

3.3 Conclusion and Critical elements emerging from the literature review

The study of the main approaches and models used for the lean transformation assessment highlighted some criticisms. Referring to the categorization proposed the thematic analysis, the following criticisms are summarized by the review panel as conclusion of this literature review:

1) With reference to the tools within the first column of the Figure 3.4, these assessment approaches share a common weakness that are inevitably subjective due to individual judgments (Wan and Chen, 2009; Wong *et al.,* 2014; Pakdil and Leonard, 2014).

2) With reference to the tools that measure the performance improvement (second row of Figure 3.4), the linkage between the improvement of performances and the adoption of lean principles /methods is not univocal, there may be other phenomenon that impact on this improvement.

3) As regard to tools that measure the degree of implementation of practices (first row, both subjective and objective, Figure 3.4), not all practices are relevant for the assessment considering the organizational/production context. For instance, Kanban is not reasonable in process industries, while in discrete manufacturing with the absence of high volumes and high product standardization determined practices are not worthwhile. Moreover, in labour intensive companies without relevant tooling, the SMED methodology is not required. The investigation of the relationships between organizational characteristics (product vs. process focus, volume, variety, market drivers, firm peculiarity and so on) and the implementation of lean practices has largely been ignored in research. The current gap demands development of an effective methodology of assessing lean strategies implementation (Doolen and Hacker,2005; Karim and Arif-Uz-Zamam,2013; Medbo and Carlsson, 2013).

4) All the four categories identified in Figure 3.4 possess a common weakness, the lean assessment tools need to be in-line with the strategic objectives of the company and customer value (Srinivasaraghavan and Allada, 2006).

Considerations made in these two last points highlight that current lean implementation assessment tools are not based upon a contingent approach. For "contingent" we mean that information provided by the tools is elaborated according to the logic of coherence: indications vary in relation to contextual conditions. In fact, the absence of LAT developed according to a *normative-contingent approach* (Figure 3.5) highlights and confirms this crucial aspect: the lack of a tool providing a contingent approach based upon the logic of coherence, where requirements vary in relation to the contextual conditions internal and external to the organization (Panizzolo et al., 2010)

5) The last critical element is the ability of these assessment tools to provide a key role of organizational assessment as an important tool for continuous

improvement. In other words, the identified tools seem that are not able to initiate improvement paths and to support enterprises in identifying the level of implementation of adopted practices, in comparison with other companies and/or current best practices identified. For these reasons, it is important to develop an assessment tool that yields a clear understanding of the current state of lean transformation in an organization in order to facilitate a shared understanding of the weakness and deficiencies, to enable effective process management, to develop implementation plan to support change initiatives and to support process improvement using clear defined metrics.

In the Table 3.12 the abovementioned gaps are summarized to provide a clear and brief overview for the reader.

Research gaps emerging from the literature review
LATs with both performances and LPs focus and based on evaluator's individual judgments are inevitably subjective.
The linkage between the improvement of performances and the adoption of LPs is not univocal, there may be other phenomenon that impact on this improvement.
The investigation of the relationships between specific organizational characteristics and the implementation of lean practices has been ignored in research.
Lack of LATs developed according to a normative-contingent approach, where requirements vary in relation to the contextual conditions internal and external to the organization.
Existent LATs are not able to define and initiate clear improvement paths to support change initiatives.

Table 3.12 – Research gaps emerging from the literature review

3.4 Chapter Conclusion

In conclusion, the literature review has provided a critical categorization and evaluation of previous works and contributions within the research domain. The review has also highlighted the analytical observations on research gaps not currently addressed. Moreover, the highlighted research gaps provide the basic guidance in the research design. Therefore, in the next chapter, the study points the specific research methodology based on the critical elements identified through literature.

Chapter 4: Research Methodology

Investigating the existing literature in Chapter 3 allows to define in detail the focus of the research, to identify the gaps in the literature and to formulate more detailed research questions. This chapter starts with defining and discussing the research questions of the thesis and the related issue. Then, it continues by shedding some light on different paradigms and research strategies relevant to the research topic. This chapter plays a key role in the development of this study. In fact, the knowledge is valid only if it has been generated following a rigorous process, which includes a set of research strategies and tools defined in the research methodology. Therefore, the primary objective of this chapter is to demonstrate that an appropriate research methodology was developed and applied to tackle the research issues and to answer the research questions of this study. For this purpose, a summary review of the body of knowledge on areas related to research methodology is provided. The last part of this chapter describes the specific research strategies and method used in this thesis.

The chapter provides explicit definition of certain terms related to research methodology; in fact, this topic suffers from the fact that a large number of definitions have been proposed for the same term and it may lead to create confusion among researchers.

4.1 Research Questions

This is the key section within the thesis as it acts as the basis and rationale for the rest of this study. The main objective of this thesis is the formulation and design of a lean assessment tool for the evaluation of LPs implementation within SMEs. As stated by Stake (1995) *"perhaps the most difficult part of a research project is to design good research problems and questions that will direct the thinking enough and not too much.* Moreover, Stake (1995) highlighted how it is important for the researcher to keep in mind the main research problem, its development and related questions since research is an evolving, changing and incremental process. Therefore, the research questions of this thesis also evolved in two stages as new findings were unfolded. At the first stage, it has been investigated whether the current research provides a solution to the issue of assessing the level of LPs implementation within SMEs according their characteristics, for this reason the first research question has been formulated as following:

RQ1. How a SME can assess the adoption of Lean accordingly to its own characteristics?

As a result of the literature review, the evaluation of current LATs has been performed, highlighting the absence of tool for SMEs structured with a *normative-contingent* approach. In addition, the thematic literature review allows to define the characteristics of the current LATs identifying the necessary features for the proposed assessment tool. In conclusion, the identification of gaps in literature allowed the researcher to formulate consequently the others two research questions:

RQ2. Which are the methods and tools that can support SMEs in assessing the adoption of Lean?

RQ3. How can these methods and tools be applied for the improvement planning taking into account the strategic objectives of the company?

Answering to the second research question allows to clearly define the methods and techniques to be adopted and implemented in the proposed tool, defining a coherent framework, while the third research question addresses the relevance of the features that the proposed tool needs to include and possess accordingly with its purposes.

4.2 Research methodology, research strategy and research method: a terminology clarification

In order to perform a "good" methodology, Clouhg and Nutbrown (2002) state that a *critical design attitude* should permeate the entire research work and this attitude justifies and connects the different phases of the research. In fact, for these authors a successful research demonstrates a clear and logical relationship between research questions, field questions, literature review and data analysis. Naturally, these methodological issues need to be considered and incorporated among all research phases and not only in the methodology one.

At this point, it is necessary to provide a definition of research methodology, research strategy and research method. In the literature, many authors have contributed with their own definitions in compliance with their view. Based on the work of Easterby-Smith et al. (2012), Clouhg and Nutbrown (2002) and Yin (1994), a research methodology may be summarized with the following points:

- find out and justify assumptions in the research, locating the claims that research proposes within the traditions of enquiry (e.g. positivist or phenomenological paradigm at philosophical perspective);
- showing how research questions are generated, articulated and discussed;
- clarifying and justify the research strategy and methods chosen.

Likewise, many definitions of research strategy and research method are provided in the literature. While research strategy refers to a general approach of investigation (examples are case studies, surveys and experiments) while research method refers to instruments and tools utilized for the research study (examples are observations, interviews and data collection). Hence, for designing and configuring research, the knowledge of philosophy, strategy, methods and tools is crucial for the researcher to understand which methodologies are suitable and which are not (Easterby-Smith et al. 2012).

4.3 The research paradigms: philosophical perspective

Research paradigms refer to the progress of scientific practice based on peoples' philosophies and assumptions about the world and the nature of the knowledge such as concept hypothesis, theory and idea (Collins and Hussey, 2003). Therefore, paradigms are a combination of new theories and research questions that replace the old one; for this reason, is important to define a research starting from the existing paradigms.

In a philosophical perspective, research paradigms are usually discussed based on a spectrum with two clearly differentiated extremes. According to Easterby-Smith et al. (2012), these two extremes from which the methodology can be derived in philosophy are: positivism and phenomenology. The authors state that reasons to understand the philosophical issues of research are three:

- to clarify the research designs;
- to understand which research designs may work and which may not;
- to identify and may shape designs outside researchers' experience.

These two philosophical paradigms are described as follows:

– *Positivism*

The idea of positivism is that reality is objective and external to individuals. The knowledge is meaningful only if it is based on observations of this external reality. The main implications of this research paradigm are: researcher should be independent from the phenomena under study; the need establish causal relationship between variables and the need to reduce the phenomena to the simplest phenomena possible (Easterby-Smith et al., 2012). The research methods used within this paradigm are focused on developing and testing hypothesis, analysing large sample and using objective methods.

	Positivism Paradigm	Phenomenological paradigm
Ontological paradigm	The world is external and objective Observer independent	The world is socially constructed and subjective Observer is part of what observed
Epistemological paradigm	Knowledge is objective and value-free Knowledge is accessible to all	Knowledge is driven by human interest and individual experience
Researchers should	Focus on fact Look for causality and fundamental laws Reduce phenomena to simplest elements Formulate hypotheses and them test them	Focus on meaning Try to understand what is happening Look at the totality of each situation Develop ideas through induction from data
Preferred methods	Operationalising concepts so that they can be measured Taking large samples Quantitative methods	Using multiple methods to establish different views of phenomena Small samples investigated in depth or over time Qualitative methods

Table 4.1 - Key features of Positivistic and Phenomenological paradigms, Easterby-Smith et al. (2012)

– *Phenomenology*

The idea of phenomenology is that reality is socially constructed rather than objective determined (Easterby-Smith et al., 2012). Knowledge is subjective because driven by human interest and experience. The phenomenological paradigm aims to understand and explain phenomena; for this reason, research methods are focused on small sample with a deep analysis over time. The subjective nature of phenomenological paradigm implies that researchers utilize methods such as sensation, reflection or intuition within qualitative methods

Each of these two philosophical paradigms includes *ontological* and *epistemological* assumptions (Long et al., 2000). The first one *"refers to assumptions held about the nature of the social world"* and the second one *"refers to assumptions about the basis of knowledge and in what manner knowledge can be transmitted to others".* Table 4.1 shows the key characteristics of these two philosophical paradigms as defined by Easterby-Smith et al. (2012).

Although in the theory the distinction between the two paradigms is clear, these two paradigms are not exhaustive. In fact, researches are located somewhere between the two poles of the abovementioned spectrum. For this reason, positioning a research under a specific paradigm is not crucial as stated by Clouhg and Nutbrown (2002): "*the issue is not a question of which paradigm to work within but how to dissolve that distinction in the interest of developing research design which services the investigation of the question posed through that research".*

Therefore, in choosing the research methods this distinction between paradigms falls apart while a mixing of qualitative and quantitative methods can have a strong synergic effect due to the combination of different types of data and perspectives (Easterby-Smith et al., 2012; Yin, 1994). Qualitative and quantitative methods have both some strengths and limitations; the choice of one over the other depends on the adequacy of each approach to resolve specific problem. In conclusion, two main variables define the characteristics of a research paradigm and the approach adopted: the nature of the phenomena studied and researcher's personal preferences and assumptions.

4.4 The Research Strategies

Research strategy refers to the essential nature of the outcome and the process by which data is found and analysed (Collins and Hussey, 2003). According to Yin (1994), strategies refer to:

- The type of research question;
- Extent of control over behavioural events;
- Degree of focus on contemporary as opposed to historical phenomena.

As for the choice of paradigms, more than one strategy can be used for conducting a research and especially for offering reliable and valid answers to the research questions. In other words, "*various strategies are not mutually exclusive; it is possible to identify situations where a specific strategy has significant and distinct advantages over other strategies"* (Lanning, 2001). Moreover, there are several common aspects between different research strategies and more than one strategy may be applicable in a specific situation as shown in Table 4.2 (Yin, 1994)

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	Who, what, where, how many, how much	No	Yes/no
History	How, why	No	No
Case study	How, why	No	yes

Table 4.2 - Relevant situations for different research strategies (Yin, 1994)

In this paragraph, a description is provided of the four typical hermeneutic research strategies as defined by (Lanning, 2001) as *qualitative*, *case study, action research and constructive research*.

Qualitative Research

Qualitative research is often defined as an investigation in which qualitative, such as descriptive data, is used and quantitative research as research in which quantitative, such as numerical data, is gathered (Lanning, 2001). Stake (1995) stated that one of the key difference between quantitative and qualitative research is the knowledge that is searched for: the qualitative researcher tries to understand the complex relationships within phenomena while the qualitative one seeks explanation and control. Furthermore, Stake (1995, 37) further highlights three major differences between quantitative and qualitative researches:

- the distinction between explanation and understanding as the purpose of the inquiry;
- the distinction between a personal and impersonal role for the researcher;
- the distinction between knowledge discovered and knowledge constructed.

Qualitative research is originated from phenomenological paradigm while quantitative is mainly linked to positivistic perspective. Therefore, in qualitative research, phenomena is studied in its natural environment and researchers are active elements of that context; in this direction "*qualitative research emphasizes qualities of entities and meanings that are not experimentally examined or measured in terms of quantity, amount, intensity and frequency"* (Denzin and Lincoln, 2011). In conclusion, qualitative research involves data collection from a variety of different empirical fonts such as interviews, case study and observations.

Case study

In the literature many definition of case study strategy has been proposed, one universally accepted is the one proposed by Yin (1994) that defines case studies as "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when:*

- *the boundaries between phenomenon and context are not clearly evident;*
- *and in which multiple sources of evidence are used.* "

Stake (1995) classifies three different types of case studies: *intrinsic, instrumental, and collective*. In the first one, the emphasis is focused on understanding one particular case, not to learn about other cases or to solve a general problem. In *instrumental* case studies, however, a case is proposed as a mean (an instrument) for answering a research question or solving a general problem. *Collective* case studies are *instrumental* studies that comprise several cases, these are also known as *multiple* case studies.

Purpose	Research question	Research structure
Exploration		
Uncover areas for research and theory development	Is there something interesting enough to justify research?	In-depth case studies Unfocused, longitudinal field study
Theory building		
Identify/describe key variables Identify linkages between variables Identify "why" these relationships exist	What are the key variables? What are the patterns or linkages between variables? Why should these relationships exist?	Few focused case studies In-depth field studies Multi-site case studies Best-in-class case studies
Theory testing		
Test the theories developed in the previous stages Predict future outcomes	Are the theories we have generated able to survive the test of empirical data? Did we get the behaviour that was predicted by the theory or did we observe another unanticipated behaviour?	Experiment Quasi-experiment Multiple case studies Large-scale sample of population
Theory extension/refinement		
To better structure the theories in light of the observed results	How generalisable is the theory? Where does the theory apply?	Experiment Quasi-experiment Case studies Large-scale sample of population

Table 4.3 – Matching research purpose in case studies, Voss et al. (2002)

Voss et al. (2002) differentiates between *retrospective* and *longitudinal* case studies; the first one collects and analyses data based on historical events while the second evaluates cause and effect relationships over long period of time. Furthermore, case studies may either be *descriptive* (describing, analysing, explaining, and understanding) or *normative* (modelling, guiding, and suggesting) in nature (Kasanen et al., 1991). In conclusion, case studies can fulfil different purposes; Voss et al. (2002) identify four purposes and related research question/structure as shown in Table 4.3: *exploration, theory building, testing and extension/refinement*.

Action Research

Kurt Lewin (1946) introduced the term "*Action Research*" (AR) referring to a combined theory generation of theory with changing the social system through the researcher acting in the social system. As defined by Rapoport (1970): "*AR aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework"*. According to Coughlan and Coghlan (2002), AR is the most appropriate strategy when research questions are related to three main issue:

- describing an unfolding series pf action overtime in a given group;
- understanding as a member of a group how and why group members action can change or improve the working of specific system part;
- understanding the process of change or improvement in order to learn from it.

In fact, according to Eden and Huxham (1996), in AR *"the research output results from an involvement with members of an organization over a matter which is of genuine concern to them"*. Therefore, AR does not seek for formulating universal laws, but rather gives insights in situation-specific context; AR is both an approach to problem solving and a problem-solving process (Lanning;2001). In the perspective of situation-specific, AR is similar to case study approach. However, AR mainly differs from case study due to the fact that in this case researchers are directly involved in the change process while, in case study approach, the role of researchers is to understand the causes of change without being part of it. At first sight, it may be argued that AR is nearly the same of management consultancy. Consultancy generally uses prescriptive approaches for the implementation of selected practices/approaches but it does not take into account the social processes that underlie the progress of every change. In conclusion, the researchers need to consider careful that issue and to ponder on the main aim of AR that is to contribute to knowledge as well to practice.

Constructive Research

Constructive research is a research approach that aims to produce solutions to explicit and precise problems (Kasanen et al., 1991). The main objective of constructive research is thus to create a solution, theoretically grounded, for a relevant problem. The generation of new knowledge in creating solutions is the main component of constructive research. At the same time, the request of theoretical novelty linked to the existing theory and the argument on applicability of solutions proposed in other context distinguish constructive research from simple problem solving initiatives and product/process development (Lanning, 2001). Therefore, constructive research proposes a *construct* that is the "*solution for a real problem*" and this research approach has research has the following characteristics as defined by Lanning (2001) in the Table 4.4:

- It produces an innovative and theoretically grounded solution to a relevant problem;
- the result of the research is proven to be useful;
- it can be suggested that the construct is also applicable in other environments.

In conclusion, constructive research is particularly applicable in situations where a solution is needed for solving a practical problem. A knowledge creation process can be covered by constructive research, as well. (Kasanen et al. 1991). Therefore, the key idea of constructive research is the formulation of a solution to a specific problem thanks to the formulation of a construct, based on the existing knowledge used in novel ways, with possibly adding a few missing links (Crnkovic, 2010). Constructive research can be outlined as applied studies, often resulting in new knowledge as normative applications. Although many studies can be defined as applied studies, what differentiate them is their end results: for this reason the constructive research approach cannot be considered just a consulting exercise (Oyegoke, 2011). In fact, on one hand, this approach provides theoretical and practical solutions as result; on the other, scientific methods are not a necessary condition for successful consulting work.

Action Research and Constructive Research

At this point, it is relevant for the sake of clarity to provide same observation about the last two research approaches. Both approaches have the main purpose to develop new theory; otherwise action research is considered as consultancy and not research. Nevertheless same relevant differences between these two approaches emerge. For instance, in evaluating the research quality criteria every different research approach predicts different tactics adopted by researches. For the action research there are a number of controls that researcher should take into account; these include for instance internal validity (the formulation of correct operational variables for the concepts being studied) and external validity (the study of cause and effect relationship, this test is applicable for explanatory research and not for descriptive or explanatory approaches). Moreover, in action research it is critical to bring sustainable change to the organisation where the study takes place. On the other hand, in constructive research the practical contribution is also a key criterion to judge the quality of the research, in fact research must demonstrate the practical relevance and usefulness of the proposed construct. In fact, all organisational science should focus on issues that are relevant for industrial/manufacturing practitioners. In the Table 4.4 an overview of these considerations is proposed.

Action Research	Constructive Research
Internal validity and external validity as quality criteria	Practical relevance
	Practical utility – *Usefulness*
Practical relevance	Link to existing theory
Bring sustainable change	Theoretical novelty
Contribution to knowledge	Applicability in other environments

Table 4.4 - Action Research and Constructive Research overview

In the next paragraph more details about the constructive research are proposed with a complete framework of this approach and relevant implications.

In conclusion, in order to provide a wider and more detailed picture to the reader about the other approaches described in this paragraph (Qualitative and Case Study Research), the following table formulated by Lanning (2001) proposes the main characteristics of different research strategies analysed.

General characteristics	When to use?	Ensuring and judging the quality of the research
Qualitative research		
• Case and field oriented • Issues are emic issues and progressively focused • Close to the real phenomenon • Researcher's personal involvement • The emphasis on observables, including the observations by informants • Includes descriptions with author's interpretations • Reporting provides vicarious experience • Knowledge is constructed, not discovered	• To understand a phenomenon, not to explain cause and effect relationships • Research questions are related with cases or phenomena	• Triangulation • Emergent and responsive research design • Sensitivity to the risks of human subjectivity • Disconfirming own interpretation
Constructive research		
• Normative in nature • Typically includes case studies • Both quantitative and qualitative methods used • Produces an innovative and theoretically grounded solution for a relevant problem • Uses a limited number of research objects	• When there is a need for an innovative and theoretically grounded solution for a relevant problem • When there is a concern about "how things ought to be in order to attain goals" – not "how things are"	The research outcome: • Relevant, simple, and easy to use • Practical relevance • Practical utility • Proved to be useful • Theoretical novelty • Link to theory • Also applicable in other environments
Case study research		
• Descriptive or normative in nature • Both quantitative and qualitative methods used • Difficult to separate analysis and interpretation from data gathering • Analysing and interpreting subjective procedures • Knowledge rather constructed than discovered or found • Generalising on the basis of a very limited number of cases • Generalising is not making statistical inferences from the sample but to generalise through a deep understanding of the phenomena • Interviews adapt to the changing situations and requirements • Captures the core meaning and feelings of the informant	• When a contemporary phenomenon within its real-life context needs investigation • To gain a better understanding of complex phenomena such as change processes • When a "how" or "why" question is being asked about a set of events, over which the investigator has little or no control • To build a theory and to test it • To produce a description	• Use of triangulation • Proper research design • Rigorous and accurate representation of empirical data • Finding rival explanations • The reader is offered a chance independently to judge the merits, the validity, and the reliability of the analysis • Significant research outcome • Valid and reliable results

Table 4.5 - Characteristics of different research strategies, Lanning (2001)

4.5 Research methodology adopted in this study

Due to the nature of the research focus of this thesis and the related research questions formulated in this paragraph, the constructive research strategy has been chosen by the author for proposing and developing the main objective of this thesis: the assessment tool.

Constructive research method implies the design of a construct (practical and theoretical relevant) that solves a domain specific problem in order to create knowledge about how the problem can be solved (or understood, explained or modeled) in principle (Crnkovic, 2010). Constructive research results have both practical and theoretical relevance and the research itself should explain several related knowledge problems concerning *feasibility, improvement* and *novelty* of the solution proposed.

In the constructive approach, it is absolutely crucial to link the problem and its solution together with accumulated theoretical knowledge. As stated by Oyegoke, (2011): "*The core element of the constructive approach is the innovation/design construct phase which is often heuristic by nature with stricter theoretical justification. The novelty and the actual working of the solution need to be demonstrated. The constructive approach is a rigorous research approach which spans through construction, application and validation that requires innovation, creativity and transparency*".

Figure 4.1 shows the operational mechanisms of constructive research strategy. It starts with identifying relevant practical problems with research potential through a state-of-the-art theoretical literature review and validated by practical experience. In this way, the researcher can understand in deep the topic and both the theory-based association and practical experience contribute to a better design of the construct. The construct can be validated through different triangulation solutions or with other approaches as a pilot study within a sample of applications. Testing, justification and validation can be empirical or theoretical, or quantitative or qualitative or both. The study should also investigate the solution applicability and the limitation in its application. Both the theoretical and research contributions should be highlighted.

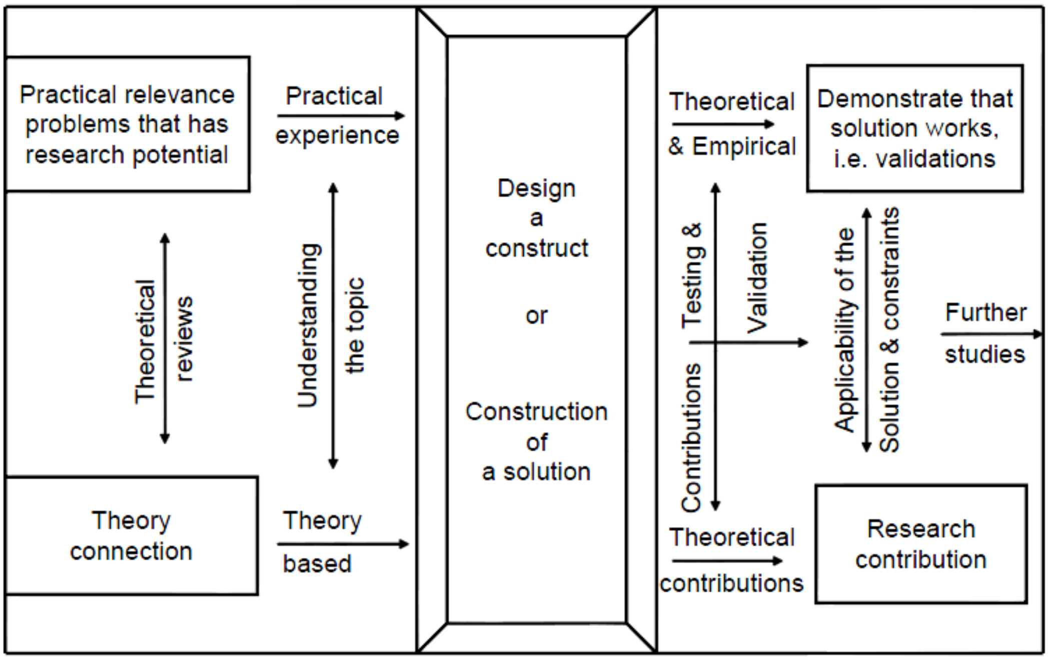


Figure 4.1- Elements of constructive research, Oyegoke (2011).

As suggested by Oyegoke, (2011), it is remarkable that" *this process is not a linear as presented or post hoc standard but a dynamic and interactive process between different phases".* Moreover, the same author defines that the rigour and application of constructive research strategy follows five phases of the constructive research process. These five phases have been also followed in the present work in order to ensure theoretical validity and results robustness from the methodology adopted. The phases are described as following:

Phase one: finding a practical relevant problem characterized by research potential

Constructive research methodology starts with strong grounding in identifying a practical problem from practice. This phase relied on pragmatism approach with the consequences on practices and theories. Practical problems should be substantiated by the literature study. However, as suggested by Oyegoke (2011) there are three major approaches useful in generating and identifying problems in constructive research:

– anecdotal evidence;

– evidence based on practical experience from practice or from the practitioners;
– and evidence from peers' theoretical work

In this work, this phase has been already developed in the first two chapters that provide a detail description of the issue related to LPs assessment.

- *Phase two: obtaining a general, comprehensive understanding of the topic*

After the problem definition, a deep understanding of the topic is performed through the theoretical understanding of what is the state-of-art in academia. In this work, the literature review developed in the Chapter 3, according to the methodology proposed by Tranfield et al. (2003), has been proposed in order to carry out this phase. The literature review proposes a descriptive and thematic analysis on the topic of LAT that represent the groundwork for the next phase.

- *Phase three: designing a new construct*

As stated by Oyegoke (2011), "*The constructive approach requires that the design of a construct should be based on an in-depth interpretation and synthesis of the contextual literature review and the practicalities of the problems. These extensive literature reviews should help the researcher to gain a thorough pre-understanding of the targeted phenomenon*". In fact, on the basis of the results of the first two phases, in the next chapter the design of an assessment tool for the evaluation of LPs implementation is proposed, this tool represents the *new construct* that is core of the constructive research as shown in Figure 4.1

- *Phase four: demonstrating that the proposed construct (solution) works*

The applied nature of the work is consequentially determined by combining the theory-based design process (phase three) and its validation process (phase four) as prescribed by Oyegoke (2011). Several are the methods to test and improve the proposed construct, the most appropriate method for an assessment tool is the pilot case study within a sample. In fact, the pilot case study allows to control the feasibility of the solution proposed, to test the procedurally changes in implementing and administrating the proposed tool in the given sample and to develop/test the efficacy of the construct (e.g. it is confusing or not clear?) . In the Chapter 6, this phase is achieved through an analysis in a sample of eight firms

- *Phase five: showing theoretical and practical contribution of the solution to the research*

This last phase involves interested scholars and practitioners to check the reliability of every former step. In the constructive approach, the initial theoretical connections should be made through a literature review, aiming to define the knowledge gap and to specify the research problem. Consequently, the significant issue should be chosen and investigated in-depth. Based on the combined theoretical and empirical bases the new construct can be designed and validated (Oyegoke, 2011). Finally, the constructive research requires that the construct adds novelty to the body of knowledge and its theoretical contributions and application scope be clearly defined. For Lanning (2001), the outcome of constructive research should be relevant, simple and easy to use, with practical relevance and utility and linked to theory providing novelty.

In the Figure 4.2, the five phases described are shown with the related key elements.

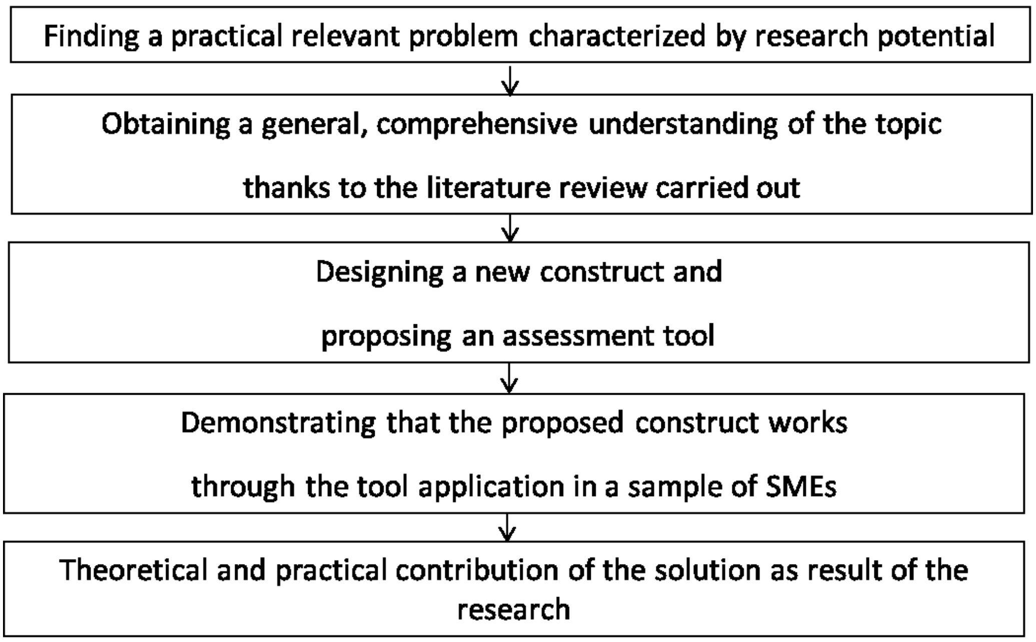


Figure 4.2 – Phases of the current constructive research strategy

4.6 Thesis Phases

In the Figure 4.3, the phases of thesis are described with the activities carried out and the outcomes produced. Moreover, in the first row of Figure 4.3 the period is shown in detail in order to provide a complete overview of the research processes of the thesis:

- The first phase encompasses the finding a practical relevant problem and obtaining a general, comprehensive understanding of the topic; it is performed thanks to a systematic literature review and comparative analysis of existing models. It provides as outcome the research gaps identification and research questions formulation;
- The second phase encompasses designing a new construct that implies formulation of prototype model, as results tool architecture is defined and theoretical characterization of tool's elements is provided;

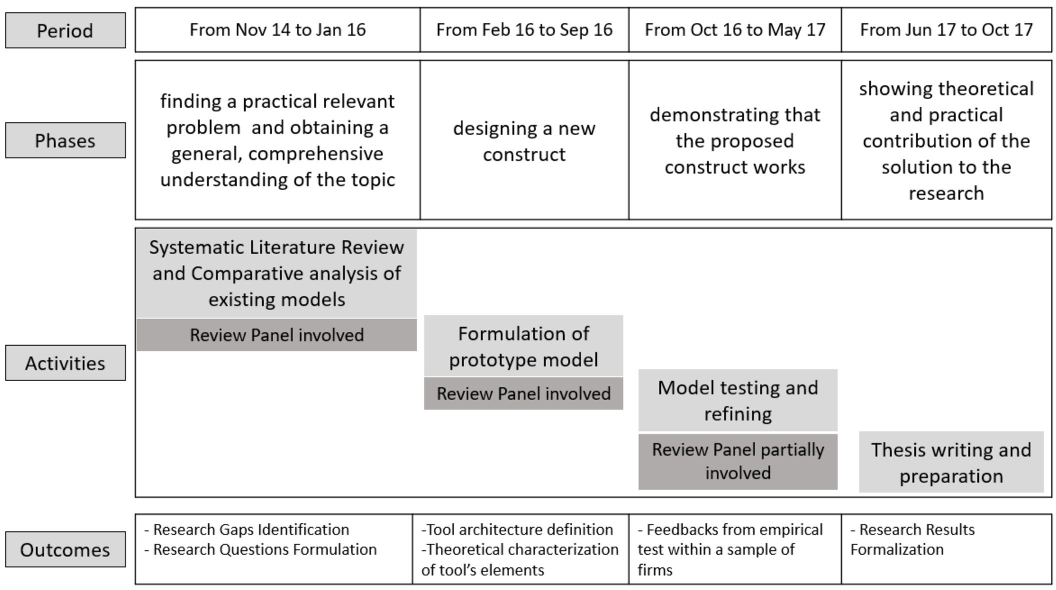


Figure 4.3 – Phases, activities and outcomes of the current thesis

- The third phase is related to the demonstration that the proposed construct works. The activities performed are the model testing and refining, as outcome of this phase the empirical test within a sample of chosen firms is performed. The author during this phase has spent a total of three months at Delft University of Technology - TU DELFT, Netherlands as visiting student from January 2017 to April 2017;

- The fourth phase is to show theoretical and practical contribution of the solution to the research. For this purpose, the research results formalization is provided thanks to the thesis preparation and writing;
- Review Panel activities: as prescribed by the adopted methodology for the systematic literature review and comparative analysis of existing models; the review panel has been involved as described in the paragraph 3.2. Moreover, in the following chapter 5 is described the role of the review panel in terms of model formulation, testing and refining.

4.7 Chapter Conclusion

This Chapter is fundamental for defining the development of this study. In fact, the knowledge is valid only if it has been generated following a rigorous process, therefore the Research Questions have been formulated and the research methodology adopted has been described in detail. On those premises, in the next Chapter the architecture of the assessment tool is proposed with a comprehensive description of all composing elements.

Chapter 5: Assessment Tool Formulation and Development

This chapter describes the development process and the evolving ideas about the proposed tool. The development process of the tool is made explicit according to the methodology adopted in Chapter 4: the assessment tool represents the *construct* proposed in compliance with constructive research methodology strategy adopted. The Figure 5.1 summarizes all the criteria for a well-functioning construct as prescribed by Lanning (2001).

Criteria for a well functioning construct

Based on the research strategies:

- Construct's connection to the existing theory and theoretical novelty
- Practical relevance of the construct
- Proved use of the construct
- Proved practical usability, e.g:
  - Simple and easy to use
  - User-friendly
  - Possibility to modify
  - Tempting
- Proved practical usefulness, e.g:
  - Assists and supports project success
  - Brings in effectiveness and efficiency
  - Keeps the focus on critical actions
  - Less problems

Figure 5.1 - Main criteria for construct formulation, Lanning (2001)

From the gaps identified in the literature review, the research goal of this work is to propose a contingent assessment tool able to identify prior practices and relevant performances in line with production system characteristics and firm's strategic priorities. In summary, the tool should have the following features:

- to select the right tools for the current system condition, this is one of the key element to success in lean implementation;
- to be able to assess the current LPs implementation level within SMEs;

- to identify the weaknesses and the opportunity for improvements according to their own strategy.

Therefore, the academicians of the review panel described in the Chapter 3 have defined the main components of the tool framework in order to fit together the main features identified. Three are the main objectives in which the members of the review panel have focused in:

- identifying the current state and the future state in terms of firm LPs implementation, this feature may not only assess the level of implementation of specific LPs but also identify a gap to fill for achieve a successful lean transformation
- analysing the current organizational/production context in order to identify for each LP its relevance according to firm's strategy
- providing an easy and clear instrument within the tool to identify and analyse possible improvement paths for the management; a visual element that allows to picture firm's weaknesses and opportunity for improvements

For these objectives, different suitable techniques/instruments already available in the literature have been recognised. In the Table 1.1, these techniques/instruments are shown:

Objective	Techniques and Instruments
Identifying LP gap	**- Maturity Grids** **- Relationship Matrix of Quality Function Deployment** **- Radar Chart**
Identifying LP relevance	**- Relationship Matrix of Quality Function Deployment**
Visualising opportunity for improvements	**- Priority Map**

Table 5.1 – Objectives and techniques/instruments of the proposed model

For the first objective, the techniques/instruments identified are three. The first is maturity grid (MG): this kind of tool have been extensively utilized in both academia and business sector as a powerful instrument to measure; it is theoretically grounded and developed with specific methodology (Maier et al., 2012). Therefore, MG primary objective is to measure the current level of implementation of defined LPs. In the paragraph 5.2.2 the MG formulation is detailed described and results widely proposed. The second element is the relationship matrix of Quality Function Deployment (QFD). In QFD methodology, the relationship matrix is where the team determines the relationship between customer needs and the company's ability to meet those needs. It is a well establish conceptual framework universally accepted that links different elements thanks to relationship matrix. The intersection between rows and columns identifies the weight of relationship, see paragraph 5.2.3 for more details. This technique has highlighted its advantages over the last twenty years (Maritan, 2015). The same technique has been successfully chosen for the second objective to analysing the current organizational/production context and LPs relevance as described in the paragraph 5.3.2 and 5.3.3. The last element is the radar chart, it is a universal visual element utilized to show current and future state in LM context. Lastly, for visualising opportunity for improvements according to the results of LPs gaps and relevance another visual element has been chosen: the priority map. This kind of maps are largely utilized for their ease of use and effectiveness in operational context.

The next paragraph provides a description of assessment logic of the proposed model developed starting from the objective identifies and the related techniques/instruments. Therefore, in the assessment tool the three objectives are the basis of the logic flows proposed in the next paragraph.

5.1 The assessment logic of the proposed tool

The tool is based on implementation practices assessment rather than firm performances and it is endowed with two levels of contingency: the first one consists in assessing the degree of LPs implementation considering the organizational/production context, the second one lies in defining improvement paths in line with strategic objective of the company. Therefore, the tool proposed works according to two parallel logic flows in assessing lean implementation: the first one highlights the gap of LPs between current and optimal state, the second one points out the relevance of practice.

The tool is designed to be proposed in SMEs during a session that involves a group of heterogeneous firm's employees that spans different organization's departments, in the next Chapter the procedure results within the sample of firms is described in detail. In the Figure 5.2 the architecture of the proposed tool is shown; the main elements that compose the tool are described as following:

- **<u>Flow A: identifying practice gaps</u>**

A1. Structured Database of Lean Practices: Starting from literature, the author built a structured database of lean practices. For each practice, a four-level maturity scale or "*maturity grid*" has been developed: the scale aims at identifying four distinct levels of complexity from elementary to an integrated and complete approach.

A2. Checklist and Optimal Profile Generation Matrix concerning the company contingent characteristics: For each practices the optimal profile for the company itis defined. The ***Optimal Profile Generation Matrix*** inspired by the Relationship Matrix of Quality Function Deployment (QFD), based on the results for the Checklist, underpins the profile definition.

A3. Maturity Grid: It is asked to the participants which scale level describes the current state of implementation of the specified practice in the most accurate way on a scale of one to four (1: not implemented ... 4: culturally embedded).

A4. Radar chart: It compares the optimal profile (step A2) with the current state (step A3), in this way for each practices the possible gap is determined.

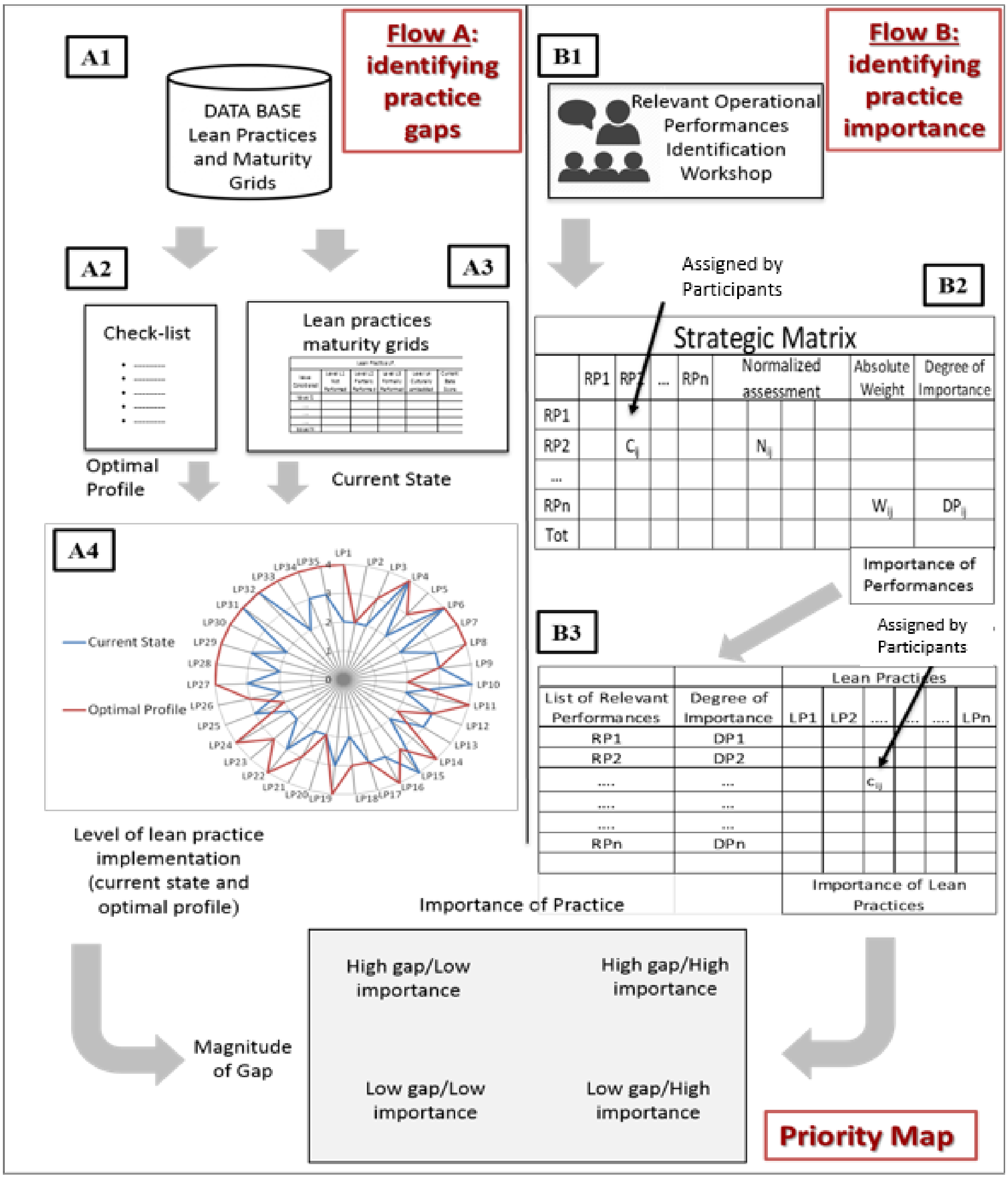


Figure 5.2 - The assessment logic of the proposed model

- **Flow B: identifying practice relevance**

B1. **Workshop:** Firm's employees involved in the assessment session identify the most relevant operational performances in relation to firm's strategy.

B2. Strategic Matrix model: in order to define a degree of importance of each relevant practices identified by firm's participants, Analytic Hierarchy Process (AHP) methodology to support decisional process is implemented.

B3. Performance-Practice matrix model: relevant performances, taking into account their degree of importance, are cross-checked with LPs thanks to the Independent Scoring Method (IMS). The level of importance is assigned to every practice; the most important practices are the most correlated with the relevant performances. In this way, the most important LPs that support the relevant performance of firm's strategy are identified.

- **Priority Map**

Having defined for each practice the degree of importance and the gap between current state and optimal profile, the last step of the proposed assessment model regards the construction of the "*Priority Map*" which helps in defining the sequences of improvement initiatives that company should be undertaken to improve its lean transformation journey. The priority map performs a *"gap size-importance"* two-dimensional mapping of practices on a Cartesian plane.

5.2 Flow A: constitutive elements description

The *Flow A* is composed by the following main elements: Database, Maturity Grids, Optimal Profile Generation Matrix with related Checklist and Radar Chart. Below a detailed description of each one is provided.

5.2.1 Database

The main element of the *Flow A* is the Database; it contains two theoretical grounded components relevant for the connection to the existent theory and theoretical novelty:

- The novel LPs classification resulting from the literature review provides to the Database the categorization of 35 LPs, organized in 6 distinct lean operational constructs distinguished in primary and support practices.
- The maturity grids of the abovementioned 35 identified LPs organized in 6 distinct lean operational constructs. In order to ensure a theoretical novelty to the tool, the maturity grids have been developed with a structured methodology shown in the next section.

5.2.2 Maturity Grids (MGs)

The primary objective of the MGs is to assess the current level of implementation of defined LPs. For the development of MGs, the methodology proposed by Maier et al. (2012) has been adopted to provide a theoretically grounded approach in formulating these elements of the tool. The reason of choosing the MGs for assessing the current state of LPs implementation is clear: as stated by Maier et al. (2012) *"in case of a voluntary evaluation of performances processes, companies often look for assessments that do not take too long and do not cost too much, which makes maturity grid assessments especially attractive"*. However, what is the reason of this success among firms? Maier et al. (2012) provide a detailed answer; it is due to the fact that MGs are built upon conceptual models and they shed light on factors important in an organization. Therefore, the assessments based on MGs jointly offer a contextual representation of different conceptualizations of organizational practices and capabilities that are viewed as relevant for organization's success.

The methodology adopted in formulating and developing MGs is shown in the Figure 5.3 and it is characterized by the following four key phases and decision points applied in thesis;

- *Phase 1-Planning*: the author of a maturity grid decides on the intended audience (user community and improvement entity), the purpose of the assessment, the scope, and success criteria.

- Audience Specification: Employees from different departments involved in the lean implementation journey within a manufacturing SME;

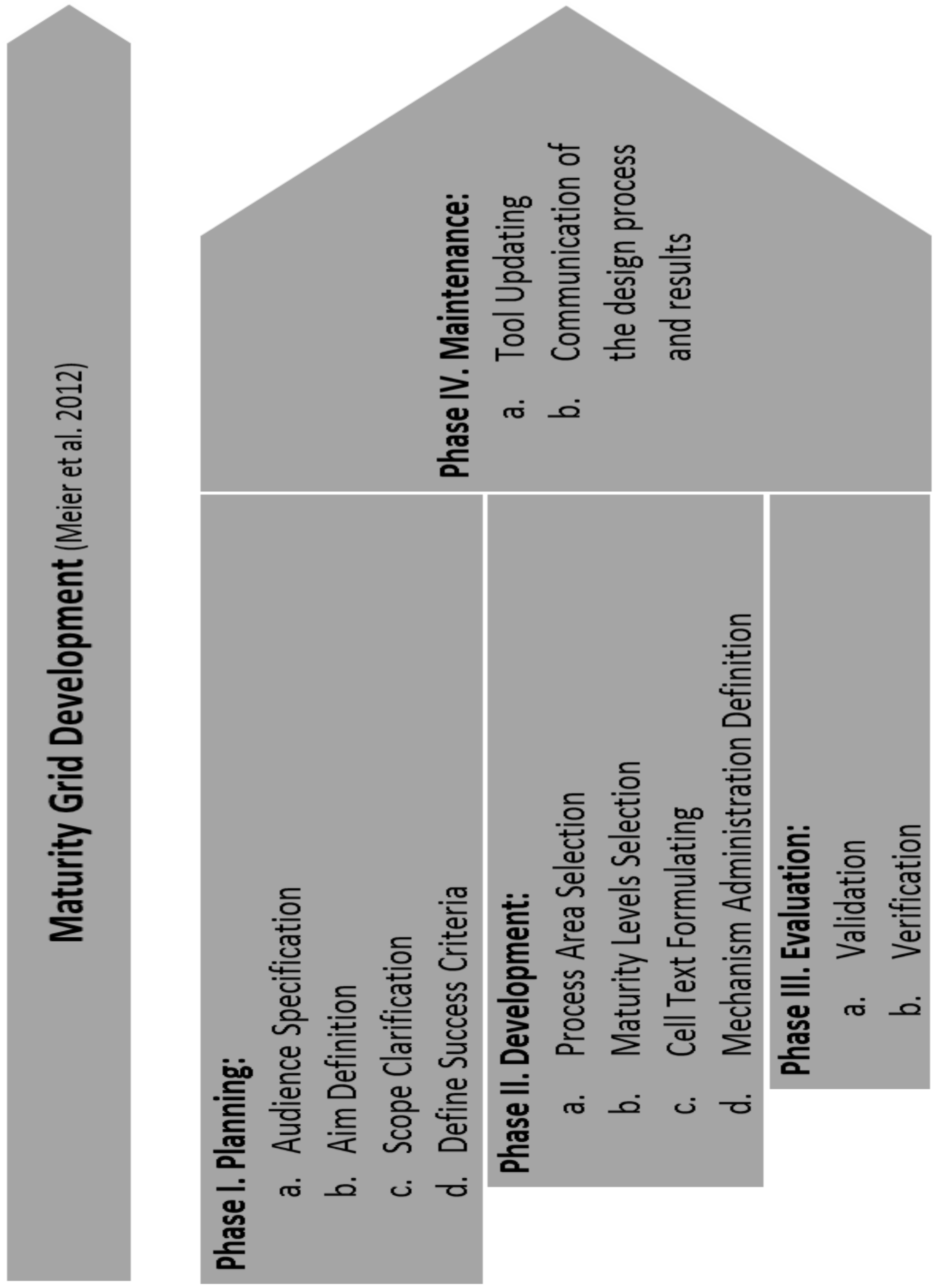


Figure 5.3 – Phases and decision points to develop new MGs, Maier et al. (2012)

- Aim Definition: To create a complete tool for assessing relevant lean practices maturity level;
- Scope Clarification: SME involved in a lean implementation journey;
- Success Criteria Definition: (1) *usability*: MG are clear and understandable for the selected audience, (2) *usefulness*: MG are an efficient tool to assess the lean practices implementation level.

- *Phase 2-Development*: the development phase, defines the architecture of MGs. The architecture has a significant impact on its own utilization; therefore, the author makes decisions about the process areas to be assessed, the maturity levels (rating scale) to be assigned, the cell descriptions to be formulated, and the MGs administration mechanism implemented.

- Process Area Selection: MGs areas are based on the extended literature review carried out in the Chapter 3. 6 Lean Operational constructs have been identified and 35 LPs as well. The list of LPs is shown in Figure 5.3 and 5.4;
- Maturity Levels Selection: A structure based on 4 levels has been chosen in order to provide distinct and well-defined levels that show a logical progression from the *"Not Performed"* to *"Culturally Embedded"* adoption degree.
- Cell Text Formulating: descriptive approach based on the contribution of academicians (the component of review panel), managers and practitioners. The information source consists in reviewing and comparing practices found in literature. As prescribed by Maier et al. (2012) *"individual text descriptions for the cells in each selected process area to be assessed are deduced from the underlying rationale and formulated accordingly"*;
- Mechanism Administration Definition: the choice of delivery method appears to be closely related to the general objectives of the assessment. In this case, the approach adopted aims at raising awareness and improving performance; that way appears to select paper-based distribution mechanisms, through interview and/or group workshops. Therefore, MGs has been distributed the person involved in the assessment.

- *Phase III—Evaluation:* The transition from Phase II to III is fluid. MGs are likely to evolve over time, and thanks to continued utilization, difficulties or limitations may be revealed. As the assessment is used and feedback gained from the experience of companies, the grid should be iteratively refined (Maier et al., 2012).

In fact, in this chapter the MGs proposed are the result of this iterative process from the pilot study carried in the next chapter. As prescribed by Maier et al. (2012) *"ideally, evaluations are conducted within companies or institutions that are independent of the development. During this phase, it is important to test input into the grid (choices made during Phases I and II) for validity and the results acquired by applying the grid in practice for correctness"*.

- Validation: content validity testing, applicability and repeatability tested by case study checking whether good translations of the constructs have been achieved;
- Verification: evaluation in relation to success criteria and requirements.

	Decision points	Decision options
Phase I – Planning	1) Specify audience	• Users (e.g. project member, project leader, change agent, or CEO) • Improvement entity (e.g. teams, organization, process, or product)
	2) Define aim	• Raise awareness or best practice benchmark
	3) Clarify scope	• Generic (e.g. energy management) or domain-specific (e.g. energy management in construction)
	4) Define success criteria	• High-level requirements (e.g. usability, usefulness) • Specific requirements
Phase II – Development	1) Select process areas (components and theoretical framework)	• E.g. Reference to established body of knowledge; Literature survey; Expert knowledge; Defining goals
	2) Select maturity levels (underlying rationale)	• E.g. Existence and adherence to a structured process; Alteration of organizational structure; Emphasis on people; Emphasis on learning
	3) Formulate cell text	• Type of formulation: prescriptive or descriptive • Information source: Synthesizing viewpoints from future users or comparing practices of a number of organizations • Formulation mechanism: Inductively generated from descriptions of practice or deducted from underlying rationale
	4) Define administration mechanism	• Focus on the process of assessment (e.g. face-to-face interviews, workshops) or focus on end results (e.g. survey)
Phase III – Evaluation	1) Validate	• Correspondence between author's intent and user's understanding • Correctness of results
	2) Verify	• Correspondence with requirements specified
Phase IV – Maintenance	1) Check benchmark (and adjust description in cells)	• If applicable
	2) Maintain results database	• If applicable
	3) Document and communicate development process and results	• Audience-specific

Table 5.1 - Decision points and options for the MGs development phases, Maier et al. (2012)

- *Phase IV – Maintenance:* this phase is a continuous ongoing phase. Constant accuracy and relevance of MGs will be guaranteed by maintaining it over time. This activity is not part of this thesis, but rather an important aspect for its future development.

- Tool Updating: to capture the domain knowledge evolution, it is a part of the tool maintenance itself;
- Communication of the design process and results: publication of the MGs and results in scientific works.

The author has followed the above-mentioned phases in order to provide theoretically grounded rationale to the proposed MGs. The MGs are organized in compliance with the categorization of LPs that identifies 6 distinct lean operational constructs and 35 LPs as shown in the Table 5.2 and 5.3 distinguished in primary and support practices

PRIMARY PRACTICES	Process and Equipment	
	1	SMED
	2	Process oriented flow
	3	Poka Yoke
	4	Workplace organization and cleanliness
	5	Safety and ergonomics
	6	Point of use and Supermarket
	7	Flexible equipment
	8	Visual control at workplace
	Manufacturing Planning and Control System	
	1	Levelled production
	2	Pull planning system
	3	Pull scheduling system
	4	Synchronized production
	5	Small lot sizing
	6	Zero Inventories
	Suppliers Integration	
	1	Blanket Orders
	2	TCO - Total Cost of Ownership
	3	Kanban with suppliers
	4	Free pass
	5	Information sharing and mutual exchange
	6	Supplier development
	7	Supplier rationalization
	Total Productive Maintenance	
	1	Autonomous Maintenance
	2	Planned Maintenance
	3	Proactive Maintenance
	4	TPM Training
	5	Maintenance Indexes utilization

Table 5.2 - Primary Lean Practices

SUPPORT PRACTICES	Employees Empowerment	
	1	Training and Integration
	2	Upkeep and Development
	3	Multifunctional Workers
	Continuous Improvement	
	1	Problem solving methodology
	2	Standard work
	3	Strategic planning
	4	Tactical improvement
	5	Daily Improvement
	6	Organizational structure for continuous improvement

Table 5.3 - Support Lean Practices

As following, the main contents and characteristics of the LPs contained in the MGs are described in detail following the list in the two tables above (Table 5.2 and 5.3). In this way, the reader no expert in LPs within the LM can have an overview of this topic useful to better understand the MGs.

5.2.2.1 Process and Equipment

In this section, MGs are proposed in regards of LPs dedicated to setup time reduction, layout organization according to the value stream and material flow, error proof system, visual control, safety ergonomics and workplace organization and cleanness.

Starting from the latter two aspects, workplace organization and cleanness provide a high degree of stability in the operational activities of line workers. Therefore, the related LP to these issues, the *5S* method is one of the cornerstones of the LM. Stability that is required to start and sustain the process of continuous improvement. It has been applied for the first time in Japanese companies in the '70s, allowing them to increase productivity and quality but and it has soon extended to the whole world. This practice focuses on customization, organization, cleanliness, and standardization of the work environment, considered the basic ingredients in order to create the foundation and the right environment for creation of best practices. It is a systematic and rational approach and it has as its primary goal to make the workplace neat, clean and safe, allowing the operator to work more efficiently, since all the waste are eliminated. The motto of *5S* is: *"a place for everything and everything in its place"*. The *5S* system deals with the basic principles besides ordering and cleaning, including discipline, ownership, responsibility and pride that are essential for an organization in its challenge for competitiveness.

The name "*5S*" comes from the initials of the Japanese words that constitute the 5 phases of the methodology (shown in the Figure 5.4): Seiri (Separate), Seiton (Order), Seiso (Clean), Seiketsu (Standardize), Shitsuke (Support). The basic principles are so simple, obvious and inexpensive that several companies may underestimate the importance.

1. Seiri - Separate

This first step consists of separating the useful things from the superfluous, eliminating all the materials, tools and components that are not used in the workstation that create only confusion, dirtiness and dangers. This principle responds to the basic one of JIT, which states: *"Just what it serves, in the amount it serves and when it serves"*. At this stage, the criterion that each object is classified as necessary or not (e.g. frequency of use) must be established; unnecessary objects are well identified (e.g. with a red card) and moved to a temporary storage area, here they typically stay for about a week. Later, if these tools are proven as unnecessary for that workstation, it is checked those that are usable for other work areas and the useless ones are definitively eliminated.

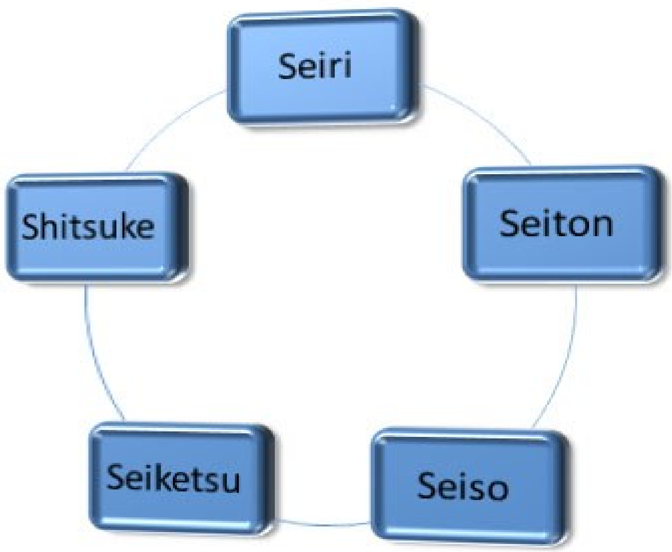


Figure 5.4 - the 5 phases of 5S methodology

2. Seiton - Order

The goal of this stage is to place order in the workstation and place the objects in a way that everyone can understand which is their place and how much they should be present. The result should be a reduction in material searching time as the strategy of "*one place for everything and everything in its place"* is applied. At this stage the organization of the workplace must avoid waste due to displacements, operations, anticipations and unnecessary movements, thus maximizing the use of resources. To achieve this, close collaboration with time and motion expert is needed to determine and standardize the most appropriate work method. The implementation of this phase requires that the place where each object is to be stored is located through the so-called *"position indicators"*: labels with the name of the object to be reported, warning signs, adhesive strips that delimit the portion of space occupied by the object or the area of carrying out operations or safe walking. All this goes under the name of *"Visual Management"*.

3. Seiso - Clean

This step aims to improve housekeeping by cleaning up the work environment and eliminating any form and source of dirt. Cleaning should be considered part of daily work and an extremely important activity, especially if it is adopted as a form of inspection. In fact, while cleaning activities are performed, problems hided by disorder and lack of cleanliness become evident (leaks, broken parts, sources of contamination, insecure areas, etc.). In addition, regular cleaning allows to maintain tools, equipment and machines in good operating conditions, leading to a reduction in downtime and number of accidents.

4. Seiketsu - Standardize

The goal of this phase is to maintain the order and cleanliness created in the previous three phases. For this purpose, the best practices to always have a clean, upright, and safe working environment become a standard. In creating standards, the employees collaboration is of utmost importance, they are the most valuable source of information related to their work.

5. Shitsuke - Support

At this stage, firm try to maintain the standards and results achieved over time, also seeking to improve them if possible. To do this, it is appropriate to impose discipline and rigor for the future; this latter phase should be applied day by day and requires constant commitment of all workers. For this stage, it may be useful to have photos that show workplace conditions before and after applying the *5S* to make everyone aware of how the workplace has changed in the best way, and how it should be maintained. This is the "S" most difficult to do and implement because it is the proper maintenance of a stable standard.

The *5S* methodology is described by Hirano (1995) in his book *"Five Pillars for the Visual Workplace: The Sourcebook for 5S Implementation"*, which explains how the *5S* can bring six important benefits:

1. Increased product diversification, because if all the tools are in order and the machines clean, the time to production change will be reduced.

2. Better quality because, if the tools are in order and the work area is clean, there is less chance of mistakes in mounting a piece on the machine, and dirt in the environment will interfere with production.

3. Lower costs from higher product quality and, therefore, a number of scraps that reach zero.

4. More reliable and punctual deliveries, as manufacturing delays caused by machine stoppages due to quality problems, cleaning, etc. are canceled.

5. Improving workplace safety by eliminating the "Seiton" and "Seiso" stages of all possible sources of danger in the area.

6. Improved machinery efficiency resulting from minor stoppages due to waste, defects, breakages, etc.

Another important LP in this context is the SMED method developed in order to reduce set up time. The acronym SMES stands for Single (Digit) Minute Exchange of Dies and refers to the goal of bringing any kind of set up to be made in less ten minutes (Shingo, 1985). SMED methodology was defined between 1950s and 1960s when Shigeo Shingo, a Toyota manager, faced the need to produce small lots while maintaining maximum efficiency. Shingo transformed the set up into something extremely elemental, so that it could be executed correctly, easily and quickly by anyone possessing a minimum of technical expertise, or by unskilled personnel. It is interesting to point out that SMED is not only confined to simplifying set up operations, but also to modify the equipment with *"poka-yoke"* techniques. These techniques are based on design characteristics that set limits on how to perform a certain operation by forcing the operator to perform it properly.

The starting point of the SMED technique is the division of the entire set-up time, defined as the time between the production of the last piece corresponding to the current production and the production of the first piece corresponding to the next production, in two categories well distinguished:

- Internal activities: the time interval in which the machine must be firmly stopped, so that it can carry out the reactivation activities for both functional and safety reasons. This is the real set up time.

- External activities: the time interval in which change-over activities can be carried out without the need to stop the machine (for example, transport on the workstation of the parts to be mounted on the production machine of the new format).

The main effort of this methodology is to transform external internal operations, thus decreasing machine stopping time while increasing its efficiency. SMED approach is developed in four phases:

1. Analysis of the starting situation

In this preliminary phase, a critical analysis of the set-up cycle is carried out, defining the objectives to be achieved, the reasons for this analysis and the members of the team, which must involve various figures such as workers, technicians and leaders. It then goes on to subdivide the tasks within the team, entrusting each component with a very precise role. The recorder will then identify the total duration of the set up as performed at the time of the analysis, and it lists all the people involved and all the tools and tools utilized. Then the timer, who is the one who timers the basic operations of set up, divides them into elementary activities. Finally, the fast collectors take note of what each single activities with extreme accuracy without forgetting any details.

2. Separate external activities from internal ones

At this stage, the distinction is made between external activities to be carried out with OED (Outside Exchange of Die), and internal ones, which can be performed with the IED (Inside Exchange of Die). To ensure that all OEDs are carried out with a working machine, Shingo (1985) recommends to use a checklist listing all tools, parts, and operating variables (pressure, temperature, etc.) necessary to set up, in order to be able to check that everything you need is available. During this phase, the transport of parts and tools from their workstations to the machine should be optimized in order to have flows faster and more efficient.

3. Convert internal activities to the outside

To reduce more the set up time, it is necessary to review the operations performed to try to convert the largest number of activities from inside to outside. Sometimes this step can be done without changing the modalities applied, but simply by postponing or anticipating the operating conditions, standardizing essential functions, using reference systems for correct positioning of parts.

4. Slide the set up operations

The goal of this step is to simplify all operations, so that they can be done in a shorter time as possible and with a virtually null error margin. For this purpose, various effective techniques can be applied such as:

- Standardization of the setting, e.g. the uniformity of the parts required for the changeover operations (add a thickness to the angles for attaching a mold in order to use the same hook in different set ups).

- Eliminate or simplify locks and hooks. In this case, it is important to try to replace fixing systems such as screws or bolts with gimmicks such as the pincers that require only one.

- Do activities in parallel and no longer sequentially. This means finding a way for different operators to participate in different areas of the machine, thus eliminating unnecessary movements such as moving around the machine and halving the time needed.

- *"Least common multiple"* Technique. It expects to have a number of mechanisms equal to the *least common multiple* of those resulting from the various settings. In this way, the number of settings is limited and there is not waste time trying to find the correct position.

Once all the improvements made during the above steps have been implemented, to maximize efficiency and safety and to speed up the work plan it is advisable to draw up a procedure that indicates the correct sequence of operations to be performed. For this purpose, *Standard Operating Procedures* (SOPs) are implemented. In conclusion, the benefits of this technique are varied: reduction of line stop times; reduction of inventories; possibility of producing small lots with no adverse effects on efficiency; greater flexibility and responsiveness to customer needs; improved accuracy and reduction in the number of production start-up waste; reduction in the level of capacity required for the set-up; rationalization of tools and equipment; and improvement of safety in set up operations.

In the *process and equipment* group, another relevant aspect is the creation of error proof system. The related LP is called *Poka-Yoke*. The term, translated literally, means "error-proofing". This term was coined by Japanese engineer Shigeo Shingo, in order to *"avoid (yokeru) distraction errors (poka)"*. This tool is used to prevent errors, or to highlight the error, so the operator can already correct it, or immediately stop the process in order to avoid the generation of further errors. This method allows to prevent errors by imposing limits on how an operation can be performed; for instance inserting one component into another must be possible in only one way, so the operator cannot position it wrongly. The errors that are most commonly committed by the operator during the productions are: omitted processing, erroneous identification, errors due to lack of experience, errors due to unregulated rules and procedures, distraction errors, errors due to different behaviors allowed by the lack of standardization, etc.

The poka-yoke methodology is based on the principle that errors can be avoided by constructing devices that alert them immediately, whenever they occur. Shingo (1985) distinguishes three types of *Poka-Yoke*:

- The contact method: the physical features of an object (shape, color, size, etc) allow to locate the correct position;

- The fixed-value method controls and warns if a number of operations have been performed;

- The motion-step method checks if all stages of a process were executed correctly.

Therefore, the benefits of applying the methodology are: preventing specific causes of errors; helping to check at low-cost if a piece is defective because the verification is performed directly by the operator and it is a very simple process.

Therefore, the following eight MGs are formulated:

- SMED;
- Process Oriented Flow;
- Poka Yoke;
- Workplace organization and cleanliness;
- Safety and ergonomics;
- Point of use and Supermarket;
- Flexible equipment;
- Visual control at workplace.

Below the MGs in their last version are proposed in the same structure in which they are utilized during the assessment session.

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

SMED Quick Changeover and Set-up Reduction

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

In our company, Set-up is relevant and we are committed to reduce it by applying SMED methodology

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Setup times not measured. • No attempt to reduce setup of equipment or processes. • No appreciation of impact of setup time.	• Some informal setup reduction has been attempted. • Limited application in isolated locations. • Some training and some awareness of the setup reduction process exists.	• Formal setup reduction program in place. • A team has been put together and attempts made to identify and separate internal and external activities.	• Approaches to reducing setup times well defined and widely understood. • Team convert internal setup activities to external ones. • Tools colour coded. • Everyone follows a standard procedure.	

Figure 5.5 SMED Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Flow Oriented Process

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

We are committed to organize machines and equipment according to the value stream in order to facilitate the material flow

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Machines located in separate departments and/or buildings. • No fixed flow for products, materials or information. • Large batches and WIP exist. • Parts routings fixed.	• Value stream mapping done and plan is made to realign processes into product families. • Some evidence of product flow, manufacturing sequences have been documented and some flowcharting has taken place.	• Production organized by product families. • Product flow clear. • Constraint processes identified. • Lot sizes fixed and Product flow close to 1:1.	• All areas have been converted to flow. • Entire production flows have been "Value Stream" mapped. • Batch sizes and WIP are at minimal levels. • Standard work is implemented in all areas and solution as Cell layout with one-piece flow are implemented.	

Figure 5.6 Process Oriented Flow Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Poka Yoke

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

Our machines and equipment are characterized by devices whose purpose is to prevent defect creation.

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• The company does not define where and how poka-yoke should be used. • No visual aids identifying the presence of poka-yoke in the operation. • No one is in charge of defining a pok-yoke implementation.	• The company defines where a poka-yoke should be used based on no formal and objective criteria. • Poka-yoke is designed by a single individual, from the department concerned with its focus. • There are visual aids identifying the existence of a poka-yoke in the operation, but they are not standardized.	• The company has general and informal guidelines that support the choice of operations in which a poka-yoke should be used. • Poka-yoke is designed by a team which held formal design meetings, the team is formed by people from the department concerned with its focus. • There is a document that details how the poka-yoke works, but sometimes it is not available at the workstation where it is used.	• Company has formal and objective criteria to choose the operations in which poka-yoke should be used. • There is a full documentation that details how the poka-yoke works, available at the workstation where it is used. • There are visual aids (e.g. posters),standardized (e.g., colors, characters and drawings are standardized),identifying the existence of a poka-yoke in the operation.	
Notes:				

Figure 5.7 Poka Yoke Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Workplace Organization and Cleanliness

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

We regularly use the 5S methodology to ensure order and cleanliness in the plant

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No formal workplace organization and no suggestion for improving activity. • Material, parts and tools not organized and have multiple location. • End of day shift clean up may occur.	• Unneeded items and information have been removed from the workplace or placed at a distance related to frequency of use. • Company aware of the 5S principles but no training underway or completed. Non-routine cleaning takes place. Teams do not investigate root causes of disorder.	• The workplace is neatly organized. • All items have a specific address and return address. • Most areas have begun 5S and cleaning schedules followed. • Materials, parts and tools assigned to permanent position. • Audit teams periodically assess 5S standard through the company. • Teams investigate root causes of disorder.	• Clean, neatly organized with mess-prevention measures in force. • 5S is clearly part of company culture. Everyone knows the well-defined procedures. • Solutions prioritized and implemented quickly. • Everyone independently analyse root causes of contamination and uncleanness.	

Figure 5.8 Workplace organization and cleanliness Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Safety and Ergonomics

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

Safety measures implemented and human factors and ergonomics method applied

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Health and Safety is not a concern. Improvements reactions due to government/authority intervention. • Numerous accidents each year, several serious. • No Human Factors and Ergonomics Method implemented. A critical analysis of the movements in production does not take place.	• Few safety measures developed. • Pilot projects completed and planning begins to implement best safety practices. • For some activity work study flow are implemented and some analysis are carried out consequently.	• Employees systematically trained to discover and eliminate unsafe operations. • Health and Safety standard and procedures documented clearly proposed. • Human Factors and Ergonomics Method implemented through a wide range of analysis of operations, standardizations and training.	• Regular, standardized safety audits by teams and management reinforce safety standards. • Factory almost accident free. Safety and ergonomics primary consideration in pre-production pioneering. • Detailed work study flow process chart completely defined for all production system, Methods-Time Measurement (MTM) fully implemented and standard time defined.	

Figure 5.9 Safety and ergonomics Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Point of Use and Supermarket

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

Most used component are close to the point of use in the assembly line or in the most comfortable place in the warehouse (supermarket)

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Quantities unclear organized in central warehouse. • Large lot sizes. • No dedicated material handlers and no standardization.	• Mostly centralized, well organized and controlled. • Some fixed point-of-use inventory, locations not clearly identified and controlled. • WIP may accumulate between processes.	• Point-of-use locations largely implemented throughout facility. • Using supermarket replenishment for high volume consumption items. • Flow racks make stock picking easy and efficient.	• Point-of-use inventory close to production line, material delivered direct to production area by suppliers. • Highly utilized and flexible material handlers.	

Figure 5.10 Point of use and Supermarket Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Flexible equipment

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

We use plants, machines and equipment to ensure a certain flexibility in volume and production mix

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Manufacturing processes are very limited in terms of volumes and production mix flexibility.	• Production system and machinery can perform flexible production mix. • Production volumes variation are more stiff.	• Some machinery and equipment have a satisfactory flexibility in terms of volumes and production mix at same time.	• Manufacturing processes have been oversized to ensure an excellent flexibility in terms of production volume and meanwhile they are very flexible in mix changing.	

Figure 5.11 Flexible Equipment Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Visual Control at Workplace

SMED Quick Changeover
Flow Oriented Process
Poka Yoke
Workplace Organization and Cleanliness
Safety and Ergonomics
Point of Use and Supermarket
Flexible equipment
Visual Control at Workplace

Elements able to support visually the production process are in place in our plant

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• The workplaces do not have any kind of element able to support visually the production process	• Information signals and designated location partially implemented. • Errors and abnormalities often occur and ambiguity is widespread within the workplaces.	• Visual elements such as lines on the floor, colour coding and boards for a range of processes are largely implemented allowing quick recognition of relevant information.	• Visual controls extensively implemented contribute to the management of every process, providing a clear understanding of what is required at that point in time and eliminating avoidable waste and error in the work environment (e.g. Andon). • More elaborate tools such as Kamishibai may be implemented.	

Figure 5.12 Visual control at workplace Maturity Grid

5.2.2.2 Manufacturing Planning and Control System

In the TPS described in the Chapter 2, the JIT indicates the concept of producing the required piece at the required amount and at the right time. The concept of JIT is applied thanks to a scheduling approach that prescribes downstream operators to take the products from the previous phase and trigger the production; therefore, the material is pulled down from downstream with a pull logic. In traditional systems, the cadence and quantity required by the fabrication/assembly of different production programs for all departments, whether production departments or assembly lines, is known at all stages of the work. The production departments produce in compliance with the programs and following the method according to which the upstream process provides the downstream parts, which makes it difficult to quickly adapt to production variations caused by problems arising at different stages or for demand fluctuations. In order to be able to adapt to these variations, the company must continually change every production plan of the different departments every month. Therefore, frequent changes become very difficult. In order to try to deviate from the demand, the company tends to store stocks across all phases of production, so that it can cope with the losses due to production processes or fluctuations in demand. Inventories between the phases are a cost due to the immobilization of the material and the use of spaces.

LM instead proposes a pull system. It is the working phase downstream to pick up the pieces upstream, relying on the idea that only the downstream work phase knows exactly cadence, quantity and type of the necessary pieces. Therefore, these pieces are taken from the upstream phases that produce only the pieces consumed throughout the production process. In this way, it is not necessary to provide continuously production programs for each production phase. On the contrary, only the final assembly line is informed of variations in the program.

Heijunka is a Japanese term that means levelling production, is a technique to prevent waste caused by demand variability, e.g. *muri* (overload) and *mura* (irregularities). By using the Kanban system, if the downstream phases take up the upstream materials in a fluctuating way upstream, the upstream processes must provide the material, machinery and workmanship needed to meet peak demand. In addition, if there are several successive production steps, these variations can be multiplied up to the early stages of the production process. To reduce the great turbulences caused by this phenomenon, it is useful to try to reduce the fluctuation of production on the final assembly line by conveying sequentially each product into the minimum possible batch with the goal of bringing this to the unit in terms of production and transport. Production levelling therefore allows to minimize the variations in the quantities taken of each component at each assembly stage, allowing at this stage to manufacture each piece according to a constant cadence or predetermined time quantities. To ensure a stable production pace, it is useful to sequentially place orders received by following a repetitive pattern and dampening variations over several days. In this way, it is possible to meet the long-term demand of customers without departing from the unstable order of the orders. The *Heijunka Box* (Figure 5.13) is the tool to get a constant production flow. It is generally represented by a wall hanging that is divided into several compartments. Each column represents a specific time span and in the lines are placed production Kanban or tags, subdivided by product line or type of product, visualizing what is needed to be done.

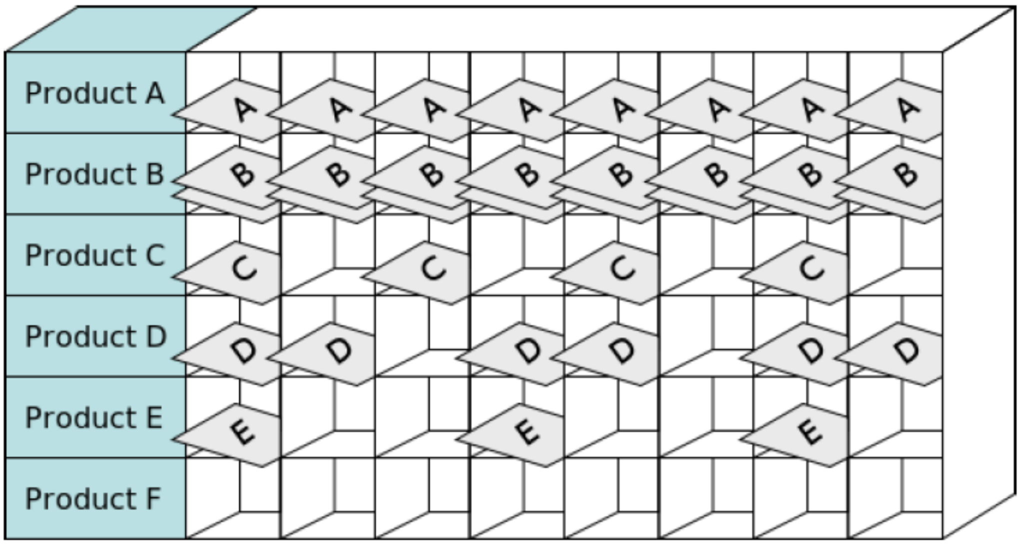


Figure 5.13 – Example of Heijunka Box

The *Heijunka* can be taken to extremes to one-piece flow production. In this type of production, the micro mix of production is the same as the macro one; the products are processed in single-part lots (Slack et al., 2013). This is achieved thanks to the extreme flexibility of the machines that do not need setup to work on different products. Let us take an example: A process must produce three products A, B and C in the ratio 8: 5: 4. It could produce 800 units of A followed by 500 of

B and 400 of C or 80 of A, 50 of B and 40 of C. Ideally to sequentially produce the products as smoothly as possible the repeated sequence would be continuous BACABACABACABACAB.... In this way, it is possible to obtain a relatively linear and sliding flow, still counting on a considerable process flexibility when the downstream demand so requires.

The main element in LM that allows to establish a pull system is the *Kanban*. It is a system of information born with the aim of controlling the quantity to be produced at each stage of the production processes and, at the same time, providing a visual tool for the stocks (Ohno, 1988). *Kanban* in Japanese means *"card*" or *"signal"* and usually consists of a card sheet protected by a plastic envelope. The information contained in the card indicates the material code, the pick, transfer, and production information: it communicates to the worker how much to produce and which product or parts to pick up or assemble. According to the lean production philosophy, assembly and transportation should be managed with this system in order to prevent overproduction. The *Kanban* actually starts from the final editing and the information goes back to the value stream by invoking downstream parts.

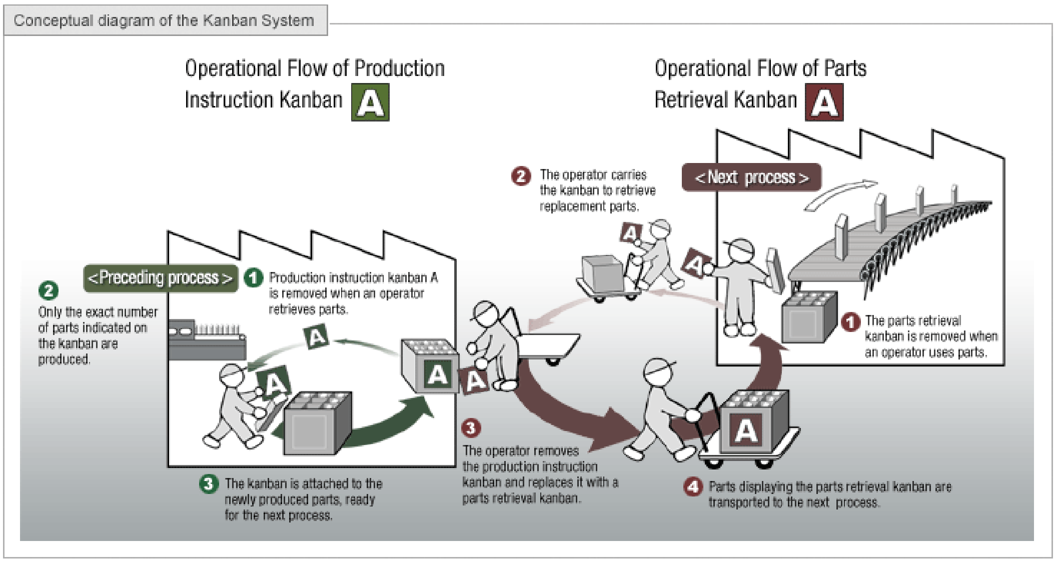


Figure 5.14 – Conceptual diagram of Kanban System (available at http://www.toyota-global.com)

Only the necessary parts are produced and their amount is completed consumed. It is a "product-related" order that prevents defective products by identifying the process that produces them without following the specifications and revealing the existing problems while maintaining stock control. It is also a usable tool for adapting to demand fluctuations

The implementation of Kanban control represents a revolutionary step: the idea of thinking about the conventional flow of production, transfer and delivery is overturned. It looks at the process from a new perspective, no longer from the beginning of production and just following the sequence of activities but starting from the customer demand that triggers production phases. Production is no longer driven by capacity but rather by demand. Production levelling is achieved through small batches and reduced setup times. The restoration process is based on the reinstatement of the stock to ensure the sustainability of the system and the batches taken must be kept small (Figure 5.14). There are several types of *Kanban*, as defined by Monden (1986):

- Kanban- Parts retrieval indicates the type and quantity of pieces that the downstream phase needs to pick up from the upstream stage.
- Kanban-Order of production indicates that the product upstream must produce and in what quantity.
- Kanban-Supplier is used for withdrawals from a supplier, it provides details indicating to the supplier what components to deliver.
- Kanban-Signal, for example it is applied to a container belonging to the batch. Once you have reached Kanban's position, it is necessary to set up a production order.

Lastly, the parameter that allows to link market demand to production is the *Takt time*. It is a fundamental indicator for the correct implementation of the pull logic and indicates the time within a finished product unit must be produced to meet market demand. The parameter is calculated on the basis of the time available for production in a given period and the demand in the period. It should be emphasized that the *Takt time* does not coincide with the cycle time. The latter represents an intrinsic value of the production, line or cell consisting of several sections or phases. It is calculated from the very beginning for the realization of the product and ends when it is ready for delivery. *Takt time*, however, indicates the average time between the beginning of the production of a unit and the start of the next production. This must reflect the customer's demand.

Therefore, the following six MGs are formulated:

- Levelled production;
- Pull planning system;
- Pull scheduling system;
- Synchronized production;
- Small lot sizing;
- Zero Inventories.

Below the MGs in their last version are proposed in the same structure in which they are utilized during the assessment session.

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Levelled Production

Levelled production
Pull planning system
Pull scheduling system
Synchronized production
Small lot sizing
Zero Inventories

We define production plans in order to maintain production sufficiently levelled (HEIJUNKA)

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Daily production not tied to takt time. Supervisor sets schedule daily with frequent adjustments. • Production does not meet the demand, typically batch production is performed.	• Takt time is defined. Some attempts to determine the product volume/type levelling. • No type standardization and no efforts in order to reduce changeover time.	• Line employees follow the motto: "Work slowly and consistently". • Buffer inventories ready to ship at the beginning of each production cycle for smoothing production and levelling demand at consistent rates. • Consistent changeover reduction and type standardization.	• Full levelling of type and volume production over a fixed period of time in order to meet the demand. • Production utilizes Heijunka Box and Board. • Production performs several distinct models of a product on the same assembly line without changeovers, Mixed Model Production is full implemented: "Make every product every day"	

Figure 5.15 Levelled production Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Pull planning system

Levelled production
Pull planning system
Pull scheduling system
Synchronized production
Small lot sizing
Zero Inventories

We plan production activities to ensure a certain degree of flexibility in production, in this way plant and machineries are not fully saturated

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Batches size are predetermined (production order quantity - POQ) and company is not flexible to unplanned market requests	• Company operates according to POQ batches but, in certain conditions, it meets market demand. • Company is not enough flexible to unplanned market demands.	• POQ production batches are defined but the company often follows independently the market demands. • Sometime, the production capacity is not completely filled in order to be flexible to unplanned market demands.	• Production is planned taking into account the actual demand, production batches can be very different and the production capacity is not completely filled in order to be flexible for unplanned market demands.	

Figure 5.16 Pull planning system Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Pull scheduling system

Levelled production
Pull planning system
Pull scheduling system
Synchronized production
Small lot sizing
Zero Inventories

Productive flows are pulled from downstream demand through the kanban system

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No pull systems are being used for production processes or supply.	• Little knowledge of pull systems. Some form of kanban used in some areas may occur.	• Kanban is used to schedule finished goods. • Employees understand value of a visual signalling system and it is understood and visible to all.	• Production is performed with kanban systems. • Employees fully understand and utilize it and make adjustments. • Documentation shows improvements. • Prioritized list of replenishment/pull system improvement projects exists.	

Figure 5.17 Pull scheduling system Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Synchronized production

Levelled production
Pull planning system
Pull scheduling system
Synchronized production
Small lot sizing
Zero Inventories

We plan production activities to ensure synchronization of material flows

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Operations not linked to previous or next operations. • Inventory waits in queue for next processes.	• Operations produce at varying rates, but linked to subsequent operations.	• Processes produce at a planned cycle time based takt time. • Transfer in small batches with minimal WIP. • Production stops at predetermined WIP level.	• All steps in process produce at takt time. • Items move through process one at a time. • Virtually no WIP.	

Figure 5.18 Synchronized production Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Small lot sizing

Levelled production
Pull planning system
Pull scheduling system
Synchronized production
Small lot sizing
Zero Inventories

We are committed to the continuous reduction of production lots through overlapping techniques

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Company determines batches by instinct, tradition or guess. Thus, most batches are far too big. Occasionally, they are too small. • Company has never done any kind of analysis, e.g. Economic Lot Size.	• Company determines batches thanks to lot sizing techniques as: Fixed Order Quantity, Economic Order Quantity, Lot-for-Lot, Period Order Quantity etc.	• Transfer Batches system is implemented beside the process ones. • In combination with setup time reduction, small transfer batches can be processed when it arrives at the next operation.	• Batches size is reduced to the minimum level and that allows a full implementation of overlapping techniques in combination with Transfer Batches.	

Figure 5.19 Small lot sizing Maturity Grid

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Zero Inventories

Levelled production
Pull planning system
Pull scheduling system
Synchronized production
Small lot sizing
Zero Inventories

We are committed to the continuous reduction of stock material

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Large quantities of WIP. Not well organized or at fixed location. Inventory stored everywhere.	• Limited WIP, amount controlled. Organized but not pull-based.	• Well-organized, limited quantities of WIP. Replenished with pull.	• Standard in-process stock level controlled. Kaizen efforts systemized to reduce inventory.	

Figure 5.20 Zero Inventories Maturity Grid

5.5.5.3 Supplier Integration

In regards to the external processes of the company, particular attention should be paid to the suppliers. They should guarantee deliveries within the agreed deadlines and quantities, meeting the approved quality standard. A company that intends to implement the Just in Time approach with suppliers should focus on few suppliers, engaging in trusted relationships, and open and long-term contracts to get high performance from their partners. The principal objectives of an efficient integration of suppliers are:

- To improve synchronization and promptness of material flows across the entire supply chain, resulting in reduced inventory, improved inventory rotation levels, and customer service levels;
- To improve the level of integration and overall performance of suppliers, resulting in lowering non-compliance and / or missing production;
- To make the material supply and management system more efficient, thus eliminating waste and non-value-added activities in internal processes and suppliers.

Therefore, in the relationship with the suppliers, contractual strength plays an important role. In this context, contracts like *Free Pass* (obtained thanks to improvement of quality control in acceptance) and *Blanket Order* are crucial for a successful implementation of LM. In particular, Kanban system with supplier has been the instrument that has allowed close cooperation between the company and its supply chain, with the aim of stabilizing inventory, space occupied and connecting the internal production line to that of the supplier. In the Table 5.4 are shown the difference between classical Material Requirements Planning (MRP) and Kanban placing order method to highlight the benefits of this last.

Therefore, the following seven MGs are formulated:

- Blanket Orders;
- Total Cost of Ownership;
- Kanban with suppliers;
- Free Pass;
- Information sharing and mutual exchange;

- Supplier development;
- Supplier rationalization.

MRP	KANBAN
Spot agreement for lead time and delivery terms	Mid-term lead time and delivery terms Agreement
Supplies based on expected consumption	Replenishment of materials independently from forecast consumption
It is necessary to consider lead time for programming the production	Lead time is not considered; Kanban provides for the replenishment of the materials automatically
No visual control	Visual management tools such as Kanban box and colored billboards
Spot contracts, not tied to agreements	Continuous sharing of information between firm and suppliers

Table 5.4 - MRP and Kanban placing order method comparison

Below the MGs in their last version are proposed in the same structure in which they are utilized during the assessment session.

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Blanket Orders

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

With our main suppliers, we have defined blanket orders

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Company is not aware and does not utilize the blanket orders with suppliers.	• Company does not utilize blanket orders, company only shares a rough demand forecast for few next months with some suppliers.	• Company defines only with some suppliers the yearly demand forecast and it agrees price, payment and delivery procedures.	• Company establishes blanket orders with all strategic suppliers defining yearly quantities, purchase price, delivery and payment methods.	

Figure 5.21 Blanket Orders Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

TCO - Total Cost of Ownership

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

We evaluate our suppliers according to the Total Cost of Ownership approach

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Company merely assesses quality and reliability characteristics of the product: quality compliance with specifications and performance over time. • The purchase price is the fundamental element for choosing the suppliers.	• In addition to the purchase price, many others elements are taken into considerations in order to evaluate the suppliers: delivery delays, inventory levels, obsolescence risks, lost sales, production downtimes, inspections and tests, scrap, reworks, disputes, complaints, etc.	• Besides the supplier's total service cost and non-quality costs, improvement actions are evaluated. • The supplier should be able to respond to gradual changes in performance requirements over time. For example, the capability to reduce lot size, the capability to improve flexibility and mix volume, the reduction of defectiveness index, etc.	• Compared to the previous level, in a partnership logic it is required an overall assessment of supplier characteristics through a examination of its technological, financial and organizational profile. • Company evaluates the coherence of supplier management strategies and philosophies.	

Figure 5.22 TCO Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Kanban with suppliers

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

With strategic suppliers, we use Kanban system for the shipping

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Purchasing has no strategic direction and reacts to requests of other functions. • Time spent on quick fixes. Little cross-functional communication.	• The company provides to several suppliers production information/forecast in order to determine quantities of parts and materials to be ordered. • No other systems for the exchange of information are implemented in cooperation with suppliers.	• Company provides monthly and daily information to its strategic suppliers. • Later replenishment system ("Ato-Hoju") or withdrawal system ("Jungio-Biki") implemented in several strategic suppliers. • Maximum inventory levels are more predictable.	• Full Kanban supplier system implemented for all strategic suppliers. • Dedicated inventory locations: supplier is required to ship materials in standard lot and container sizes and excess inventory in the supply chain is eliminated. • A demand driven supply chain is established.	

Figure 5.23 Kanban with suppliers Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Free pass

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

Our leading suppliers guarantee quality at source

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Too many supplier quality issues. • No feedback to supplier and no long term relationship with them. • No cost reduction process.	• Limited feedback to suppliers in problem occurrence. • Suppliers' issues not found until they reach manufacturing. 100% Incoming inspection required.	• Incoming inspection based on high part per millions or batch defect. • Supplier inspects own material and they guarantee minimal defect allowances. • Chargebacks for defective material and formal cost reduction activities in place.	• No incoming inspection, free pass for the great majority of suppliers.	

Figure 5.24 Free Pass Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Information sharing and mutual exchange

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

We continuously exchange with our major suppliers information on production plans

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Demand is communicated to suppliers primarily by purchase order. • Production plans are not shared with suppliers.	• Some pull systems for suppliers has been implemented. • Inadequate sharing of production plans with suppliers.	• Pull systems exist for key suppliers. • Sharing of short and medium-term production plans with key suppliers	• Demand is communicated to external partners through pull systems based on production plans. • Key suppliers have access to company's information system and evaluate in real time the evolution of production and demand. • Material flow from supplier to customer has been maximized.	

Figure 5.25 -Information sharing and mutual exchange Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Supplier development

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

We are committed to developing our suppliers

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Doing nothing to improve supplier competitiveness.	• Willing to help suppliers solve problems. • Response ranges from quick fixes to in-depth solutions.	• Taking a systematic approach to help suppliers improvement. • Training and certifying first-tier suppliers, sometimes even the second tier ones.	• Systematic approach to develop the key suppliers in second tier as well. • Supplier are regularly involved in problem resolution. • Lean events held jointly with supplier.	

Figure 5.26 – Supplier Development Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Supplier rationalization

Blanket Orders
TCO - Total Cost of Ownership
Kanban with suppliers
Free pass
Information sharing and mutual exchange
Supplier development
Supplier rationalization

In order to reduce the number of suppliers and their distance from our plant, we rationalise them.

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Too many suppliers who ship poor quality, chosen based upon lowest bid and immediate need. • Many suppliers for single parts. Change suppliers often. Contracts awarded strictly on piece price	• Each part has several suppliers. • Suppliers used to keep competition and recovery unplanned disruptions. • Some supplier rationalization programs implemented in order to reduce the number of first tier suppliers.	• Company evaluates all first tier suppliers. • Required certification reduces number of suppliers. • Most parts have one or two suppliers. • Self-certification promoted.	• Dual sourcing with long-term contract per many parts. • Suppliers considered an extension of manufacturing internal process. • Support provided to bring partners to world-class status.	

Figure 5.27 – Supplier Rationalization Maturity Grids

5.2.2.4 Total Productive Maintenance

The Total Productive Maintenance (TPM) refers to the concept of *"productive maintenance realized with the participation of all"*. This is a Japanese-originated technique, theorized by the Japanese Institute of Plant Maintenance (JIPM) in the 1960s and has been successfully applied in many manufacturing sectors around the world. The main innovative point with respect to the traditional maintenance view is that the TPM builds its success on the activity of small working groups, involving cross-organizational levels, from top management to production line staff. Therefore, it represents a new approach for team building dedicated to the maintenance of plants/equipment, managing their lifecycle and improving process reliability. It involves operators, supervisors, technicians, engineering and all those who, with their own expertise, are linked to the facilities and their efficiency. Maintenance service, therefore, is no longer the only entity to be involved in maintenance activities, but it is a coordination procedure for all corporate services and for all people.

For its features, TPM cannot be considered as a simple maintenance system, but rather as an approach to business improvement. TPM pursues to the utmost limit the maximum efficiency of the production system (manufacture, technical offices, administrative and any service present in the company), aiming to create a system that prevents any kind of loss, tending to "zero accidents", "zero defects" and "zero failures". Therefore, it is an approach that aims to increase efficiency, reliability, production capacity and plant stability through increased staff skills while reducing maintenance costs and stress for workers.

This can only be achieved through the elimination of the so-called "*The Six Big Losses"* or the six major causes that reduce the efficiency of machinery production. The Six Big Losses identified by Seiichi Nakajima include: equipment failures, set-up and adjustments, idling and minor stops, reduced speed, process defects and reduced yield.

The TPM can be divided into eight improvement paths, called "TPM pillars", which accompany the organization towards achieving stable and efficient results. They are:

1. *Focused Improvements*;
2. *Autonomous Maintenance*;
3. *Planned Maintenance*;
4. *Education & Training*;
5. *Initial Phase Control*;
6. *TPM Office*;
7. *Safety & Environment*;
8. *Quality Maintenance*.

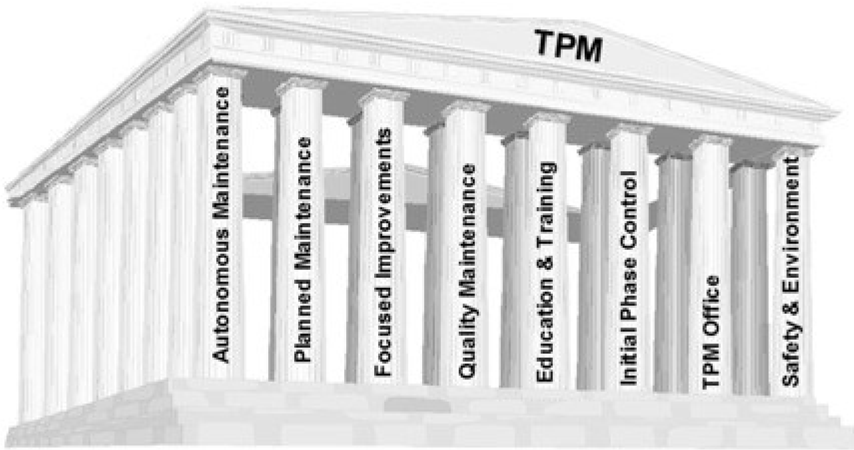


Figure 5.28 - TPM pillars (available at www.jmaceurope.com)

In defining the Process Area Selection according to the chosen methodology, the following MGs area of interest has been developed: *Autonomous Maintenance, Planned Maintenance, Proactive Maintenance, TPM training and Maintenance Index Utilization.*

The Autonomous Maintenance (Jishu Hozen) is undoubtedly the most important innovation from this approach and involves the accountability of the machinery operator, where some maintenance activities are usually carried out by maintenance personnel. The underlying idea is based on the fact that, in close contact with the equipment, the operator sees better than anyone else about its status and he can intervene more efficiently and quickly with maintenance personnel in case of failure. He needs to be adequately trained to be able to "care" the machine carrying out, together with normal activities, small maintenance work. The maintenance starts with the normal cleaning, lubrication and inspection procedures to get repairs, replacements, and setup to the early detection of faults. Operators are not only prepared to be active partners with the maintenance staff but must also be motivated to collaborate with engineers in improvement activities by providing them with alternative proposals and solutions. With the Scheduled maintenance. With the planned maintenance, maintenance takes advantage of the active production and maintenance staff who, however, mainly engages in specialized activities. It is natural to assume that autonomous maintenance cannot replace all typical maintenance activities, so maintenance support is still paramount. The latter has three main objectives: conducting effective preventive plans for plant engineering, refinement of technology and maintenance practices (new technologies, increased skills, etc.) and improvement of plants. The maintenance technician also looks for a new role considering the skills and knowledge he needs to possess besides the ability to evaluate the effects that the maintenance activity has on the production process. Of course, the TPM still should use more maintenance policies, including preventive, predictive or conditional policies.

Another important aspect is the training activity. According to this philosophy, the *"competitive advantage"* is generated by the value of people working in the company. TPM, like other improvement activities coming from the Far East, is based on the continuous growth of the skills/capabilities of the members that operate there. Operators should be trained in autonomous maintenance principles and must be motivated and able to deal with their installations; maintenance staff must keep up-to-date on technological developments and must acquire the skills needed to perform their functions at their best. Likewise, designers and production engineers as well as technology owners should be able to develop managerial skills.

The last relevant aspect is the utilization of maintenance index. To evaluate the effectiveness of TPM activities, the OEE index is calculated; it stands for Overall Equipment Effectiveness, or "Global Plant Efficiency". Defined by Engineer Seiichi Nakajima, father of TPM philosophy at the end of the 1980s, OEE is a very synthetic and quantitative index. It consists of a single number, but which can contain a large number of information concerning the production plant; OEE is a key measure, used especially in mass production, highly appreciated by managers for its synthesis and aggregation. It is also very much used since today, for production companies, since the way to remain competitive on the market is to sell products at the lowest cost: this can be achieved by using more efficiently the resources available to production facilities. OEE can help to figure out where to improve and the improvements' impact. The ability to understand where it is possible to improved is ensured by the particular composition of the OEE, in fact it is the function of three basic factors of a plant: availability, performance and quality efficiency. This particular configuration allows to know which (or what) of the three items is most likely to affect the OEE and, therefore, allows to make evaluations about the corrective interventions that can be addressed. The three constituent entries are defined as follows:

• Availability: Expresses the time when the plant is actually available for working compared to the planned production time;

• Performance efficiency: indicates actual production time compared to the time when the plant is actually available at work;

• Quality: Indicates, as a percentage, how many conforming products have been produced with respect to the total production.

Other two relevant indexes are:

- Mean Time Between Failure (MTBF). MTBF is the average time between two failure events. This index is therefore the ratio between the actual working time, given by the difference between the planned working time and the stop hours due to failure events, and the number of stops occurring at the plant.
- Mean Time to Repair (MTTR). The MTTR indicates the average stop time necessary for repairing the facility subject to failure. It is defined by the ratio between the number of hours that the plant could not operate due to the failure phenomena and the number of times these failures occurred.

Therefore, the following five MGs are:

- Autonomous Maintenance;
- Planned Maintenance;
- Proactive Maintenance;
- TPM Training;
- Maintenance Indexes utilization.

Below the MGs in their last version are proposed in the same structure in which they are utilized during the assessment session.

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Autonomous Maintenance (AM)

Autonomous Maintenance
Planned Maintenance
Proactive Maintenance
TPM Training
Maintenance Indexes

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No autonomous maintenance activities. • All maintenance strictly reactive. • No tracking of abnormalities and employees competencies	• Company implements steps 1-3 of AM (Clean and Inspect, Eliminate problem sources and Draw up cleaning). • Quality parameters preliminary understood by employees.	• Company completes steps 4-6 of AM (Conduct General and Autonomous Inspections, Standardization through visual workplace management). • Tag Mang. System identifies abnormalities and key maintenance activities are visually monitored.	• Autonomous maintenance concepts incorporated. • AM competences tracked in the skill matrix and Visual control monitors daily, weekly and monthly maintenance activities for the team.	

Figure 5.29 – AM Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Planned Maintenance (PM)

Autonomous Maintenance
Planned Maintenance
Proactive Maintenance
TPM Training
Maintenance Indexes

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Maintenance only performed when the machine breaks down. • No formal planned maintenance system in place. • Chronic breakdowns known are not monitored and solved.	• Company leads preventive maintenance system, but lacks measures and tracking of results. • Many missed tasks due to scheduling problems and lack of involvement.	• Company has scheduled planned maintenance activities installed. PM program measures performance and tracks results. • Downtime is scheduled. • Company wide usage of predictive maintenance tools.	• Central Master Schedule for all maintenance activities held, monitored and updated by the maintenance team. • Company has modified machines to allow for computer diagnosis and prediction of problems. • A daily/weekly preventive maintenance schedule is visible. • Maintenance personnel and operators work together to identify root causes and develop solutions	

Figure 5.30 – PM Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Proactive Maintenance

Autonomous Maintenance
Planned Maintenance
Proactive Maintenance
TPM Training
Maintenance Indexes

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No priorities assigned. • No work requests or jobs planned. Schedules not issued. • Poor machine utilization and unpredicted downtime.	• Operators and technical personnel identify the equipment downtime. • Inadequate tracking and measures of results. • Lack of involvement.	• Some methodology or statistical tool is utilized to monitor the equipment. • Some software is used by the operators and technicians for the analysis and control of the operational failures. • The management formally reviews the operational failures and result are shown on billboard/signboard.	• There is a program structured by the company for the reduction of failures, defects, downtimes, shutdowns and operational failures. • Company organizes periodic formal presentation of the results of the improvement lines projects.	

Figure 5.31 – Proactive Maintenance Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

TPM Training

Autonomous Maintenance
Planned Maintenance
Proactive Maintenance
TPM Training
Maintenance Indexes

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No formal training activity for line operators/technicians. • No mapping of skill level and related records.	• Technical training (in basic process concepts) is given to the operators of the line in order to reduce the downtime line.	• There is a formal training plan to raise the skill level of operators / technicians. • Records are kept about the trainings of line operators and technicians.	• There is a program to train operators in Problem Solving Processes or Focused Improvements. • The Skill Matrix is defined and updated for each operator and technical personnel position. • TPM awareness training is provided for all employees.	

Figure 5.32 – TPM Training Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Maintenance Indexes

Autonomous Maintenance
Planned Maintenance
Proactive Maintenance
TPM Training
Maintenance Indexes

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Many breakdowns and machine downtime not tracked. • Nor performance indices are measured neither data are collected.	• Company sporadically defines the calculation of some performance index for extemporaneous activities/project. • The data collection is not performed in a structured way.	• Company has preventive maintenance system installed and pilots predictive maintenance. • All downtime tracked and addressed. Downtime tracked and analysis such as Pareto, done. Major reasons addressed	• Clearly defined use of a wide range performance indices (OEE, MTTR, MTBF, MTTF, etc,). • Results are periodically calculated, analysed, and acted upon by the team members.	

Figure 5.33 – Maintenance Indexes Maturity Grids

5.2.2.5 Employees Empowerment

LM adoption has a profound impact on human resources management insofar as LPs implementation requires increased involvement and commitment on the part of employees. Human resources have a strategic role in carrying out the continuous quality improvement plans which are the basis for success of lean transformation programs. In particular, the involvement of employees in continuous quality improvement programs, the development of their autonomy and responsibility and the training of multi-functional workers are crucial for improvements in firms' LM implementation. In order to promote employee contributions, empowerment and responsibility, several LPs and tool may be adopted for the personnel evaluation and reward, such as the Skill Matrix or Plan for Every Person. Skills Matrix is a visual tool; it shows the tasks and skills required for specific activity/role and the current competency and skill level of each employee for each defined task. It may be utilized for training programs highlighting the skills to improve or upkeep. For this purpose, another tool is the Plan for Every Person is a training and development schedule for employees, showing the skills needed and the skills attained.

Therefore, the following three MGs are formulated:

- Training and Integration;
- Upkeep and Development;
- Multifunctional Workers.

Below the MGs in their last version are proposed in the same structure in which they are utilized during the assessment session.

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Training and Integration

Training and Integration
Upkeep and Development
Multifunctional Workers

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No formal training is provided for new employees. They are not aware of lean principles and techniques	• A training is provided for the incoming employees but there are minor inconsistencies in training content. An approximate glimmer of lean principles is given.	• Incoming employees are required to meet training standards. • Training is conducted during regular working hours or outside the regular working hours. • Training records are accurate and complete and its effectiveness is measured.	• Incoming employees have an appropriate and complete mandatory training for different processes and tasks within a probationary period. • A dedicated training area is prepared in the plant with a wide variety of machineries and tools utilized during the production with a focus on lean principles.	

Figure 5.34 – Training and Integration Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Upkeep and Development

Training and Integration
Upkeep and Development
Multifunctional Workers

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No training or instructions. Company does not assess and track employees' proficiency in specific skills and knowledge. • Compensation based on hours & seniority, recognition arbitrary or based on seniority.	• Some training is performed for the employees but not on a systematic approach. • Performance-based pay initiated for managers, suggestion schemes initiated for hourly employees	• Frequent training activities for maintaining and developing individual skills. • Limited performance-based pay also for workers, recognition system based on monetary and non-monetary parameters.	• "Plan For Every Person" training and development schedule implemented for all employees thanks to a Skills Training Matrix.	

Figure 5.35 – Upkeep and Development Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Multifunctional Workers

Training and Integration
Upkeep and Development
Multifunctional Workers

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• Each employee only knows one job.	• Some employee knows different production processes and has some specific training. • For some employees job rotation is carried out. • Employees' proficiency in specific skills and knowledge is assessed in informal way, without tracking any training information. • The skills are recognized thanks to personal subjective judgment	• Company assesses and track employees' proficiency in specific skills and knowledge with a proper tool such as the skill matrix. • This tool is not regularly up-to-date and is not always used in order to define job rotation plan.	• Full implemented Skill Matrix, updated and reviewed giving the opportunity to verify that information are correctly recorded for all employees. • Full awareness of what employee's 'role' entails including the relevant skills competencies required. • Full awareness of the desired areas of growth.	

Figure 5.36 – Multifunctional Workers Maturity Grids

5.2.2.6 Continuous Improvement

Before to describe in detail the Continuous Improvement approach and its main elements, it is relevant to introduce the concept of Kaizen. The term is composed of two words: "*kai*" meaning "change" and "*zen*" which translates to "good". Literal translation is therefore "good change" or "change in the best". Many people translate this term with "continuous improvement" which is very different from the meaning of "good change". "Good change" means a total redefinition of the status quo, while the term "continuous improvement" presupposes an aging of existing logic. Actually, kaizen requires the contribution of both meanings, the "change in the best" of building solid foundation, while "continuous improvement" such as gradual progression to "perfection".

The term also indicates a total involvement within the company and implies relatively modest costs; Kaizen finds a solution to today's problem that assists many firms. In addition, this perspective is in contrast with the typical Western management attitude that sees technological innovation (kaikaku) as the only source of change. Kaizen places attention on innovation as a drive to look differently the reality by opening the mindful of change and acting for small improvement steps. Therefore, Kaizen's focus is the elimination of muda in contrast to the approach that identifies in the big investments the way to increase added value. In addition to the benefits in terms of business results, the kaizen, if applied well, makes the work more human, eliminates work too hard, both mentally and physically, and teaches people how to locate and eliminate waste during the work.

A fundamental method of Continuous Improvement is the PDCA, designed by W. Edwards Deming in Japan in the 1950s. In those years in Japan, quality production was ensured simply by the final testing phase. Subsequent process inspections provided the only possibility of discarding defective parts and, in that logic, the increase in quality would mean increased inspections and consequently costs. Waste and costs were not in line with the concept of quality sought after by Japan, which relied on American experts, including W. Edwards Deming, to introduce tools to ensure a progressive improvement in quality. The Japanese firms subsequently elaborated the Deming's wheel and called it PDCA Cycle, forming a method to apply at all stages and to all situations.

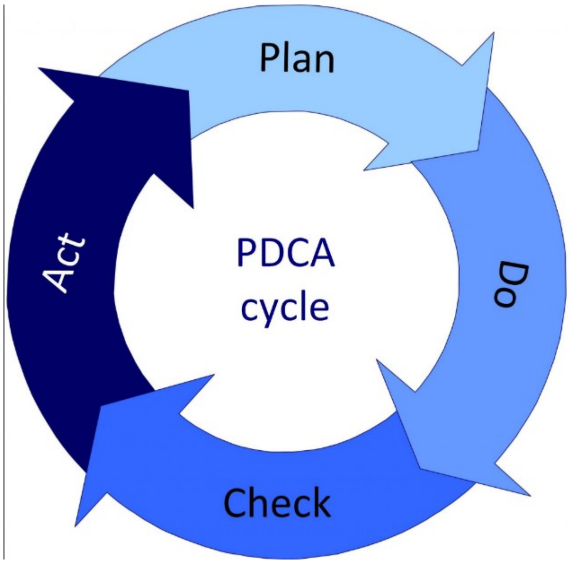


Figure 5.37 – The PDCA cycle

Nowadays the concept of constantly *turning* Deming's wheel to generate continuous improvement is extended to all management phases, and the four stages of the wheel correspond to precise activities. The PDCA is a tool to solve problems and represents the scientific approach to problem solving. It is a method of universal validity as it allows to tackle any activity strictly and systematically. The PDCA term derives from the initials of the four phases in which it is possible to subdivide the problem-solving process, which have this meaning: P = PLAN = plan before starting. D = DO = do what you have decided. C = CHECK = measure the results. A = ACT = standardize and make a procedure or repeat a new cycle. From a graphical point of view, the P.D.C.A. is represented by a moving circle called the Deming wheel. The movement is a representation of dynamism and continuity of the application process (Figure 5.37).

1. Find out the problem (PLAN)

Identify and describe the problem to be addressed by analysing the main aspects. To describe the problem, it is necessary to collect data by observing and analysing. Only data and facts should be used, not opinions, and must be verified for validity and reliability. Since data collection of all elements that identify a phenomenon may be too expensive and long, data must be collected only on particular samples that must be representative and significant. It means that all data must have a quantitative consistency and can be stratified in several ways to make them significant. The data representation must ensure a correct representation of the phenomenon. The following are the actions to perform in this phase:

-Define the ultimate objective in a clear, quantitative and complete way, quantifying the benefits of achieving it, such as economic, tangible or intangible effects. Time, indicators, and control tools must also be defined.

- Examine the problem by analysing data describing it and identifying negative effects or studying, defining their importance and intervention priorities. Every improvement action must be based on objective considerations, that is, on the result of data processing that most reliably represent the phenomenon being studied.

- Explore all the possible causes, i.e. develop a complete picture of all the causes of the problem and identify the most probable causes (hypotheses); then test them with data collections, elaborations, experiments, etc. It is necessary to find an agreement on the causes that are at the origin of the problem and to define the "*law of priority*", iterating the process until proven real causes.

-Record corrective actions, starting with research and analysis of possible corrective actions and identifying the most effective remedial actions, then designing the tasks to be performed, defining modes and times, and finally defining the criteria for evaluating the results.

2. Experiment (DO).

Prepare the interventions by defining everything needed to implement them. Train those in charge of implementing corrective actions. Apply corrective actions and implement planned solutions. Check the correct application of the actions.

3. Compare the results (CHECK).

Verify that corrective action has been taken within the scheduled time. Check the results of the actions taken and compare the data obtained with the starting situation. Compare the results obtained with the goals set. If the target is reached, proceed to the Act stage, otherwise repeat a new PDCA cycle on the same problem by critically analysing the various steps in the previous cycle to identify the causes of failure to reach the target.

4. Standardize the solution (ACT).

Make the solution found (PROCEDURE) a standard practice so that corrective actions are consolidated and irreversible. It is also necessary to carry out specific and in-depth training of the operators and to schedule verification of the validity of the corrective actions by establishing the modalities and timing from the beginning. Eventually prepare a new plan phase by activating a new PDCA on the same theme for further improvement

In this way, the continuous improvement approach is activated. As seen for the ACT phase of PDCA, creating standard becomes a key aspect of the continuous improvement. With Standardization term it is indicated the creation of procedures and instructions approved and shared by all involved persons who identify in a precise and systematic manner how a task or operation should be carried out. If no shared standards are registered, each person would work according to one's own methodology and it creates problems, confusion and disadvantages. Let us take the example the succession of two different shifts in a manufacturing firm: if the sequence of operations is uniquely defined, it is enough to define which stage of the production is reached; otherwise, if it is not defined, it is necessary to list all the operations performed with a remarkable risk of error. In order to standardize, it is important to get teamwork idea into people's culture. In this way, the differences between their working methods are smoothing out.

At strategic level the LP applied is the Hoshin Kanri. In Japanese Hoshin Kanri, it indicates a strategic decision tool. In Figure 5.38 an example of the matrix is shown, this tool allows to plan the strategic direction that the company should take in the future. This planning differs from traditional approaches since Hoshin

Kanri is used as a useful tool for aligning all employees involved in continuous improvement in the various departments or different functions of the company. Instead of receiving orders from top management that are then carried by lower-grade employees without a shared agreement; it is necessary that every level of the company highlights current problems by identifying the causes at plan begin planning. Possible solutions will be put in a plan with a different level of detail depending on the company department, even if all will be aligned with the overall objectives of the company. Each department will be responsible of its own plan, in this way personnel will propose creative solutions to the problems.

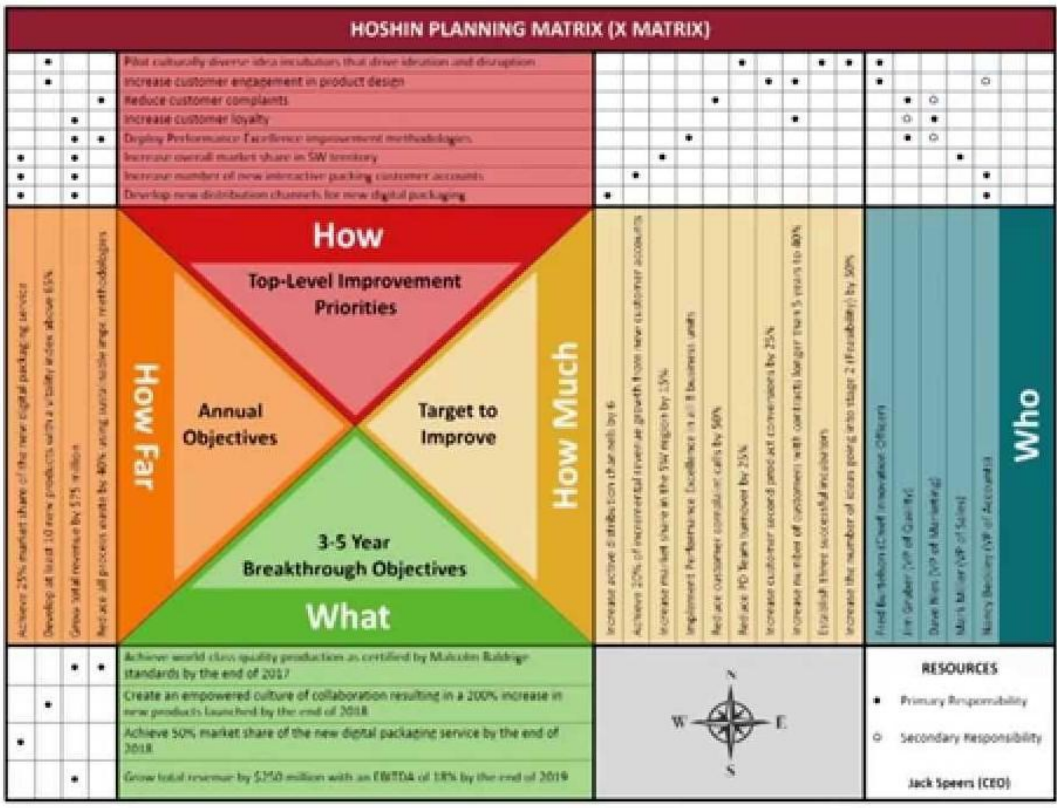


Figure 5.38 - example of Hoshin Kanri x-matrix

The Hoshin Kanri also provides goals to various managers of different levels and controls the progress towards achieving them. Evaluation refers not only to the result but also takes into account the method used to achieve this result. This tool succeeds in promoting the people's culture of co-operation towards a common goal.

Therefore, the following six MGs are formulated:

- Problem solving methodology;
- Standard work;
- Strategic planning;
- Tactical improvement;
- Daily Improvement;
- Organizational structure for continuous improvement.

Below the MGs in their last version are proposed in the same structure in which they are utilized during the assessment session.

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Problem solving methodology

Problem solving methodology
Standard work
Strategic planning
Tactical improvement
Daily Improvement
Organizational structure for continuous improvement

We regularly use the PDCA - Plan, Do, Check and Act - and DMAIC - Define, Measure, Analyse, Improve and Control - methodologies

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No systematic training in PDCA methods. • Reliance on inspection or customer to find defects. • Processes not designed defect-free	• Defects and errors identified, compiled and analysed; therefore some improvement actions implemented. • Training in PDCA tools under way.	• Development programs support education and training in advance skills and PDCA methods. • Individuals and teams know how to select and fully use tools.	• Related tools used systematically: PDCA and DMAIC. • All activities based on principle of zero defects. Continuous training and retraining of employees in best practices systematized.	

Figure 5.39 – Problem Solving Methodology Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Standard work

Problem solving methodology
Standard work
Strategic planning
Tactical improvement
Daily Improvement
Organizational structure for continuous improvement

For all of our workstations we have developed standards

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No standards visible at workplace. • Uncoordinated local efforts to address quality problems. • High scrap and reject rate.	• Some standards, but often hard to follow. Most of them out of date or inaccurate. • Plant quality data poorly tracked and measured.	• Standards for major problems in place. • Info available to employees. • The sequences of the activities for productive processes are defined and updated	• There is a formal process for the updating of manufacturing requirements and specifications: Standard Work Chart. • Standards for key quality problems easy to find and follow. • Full time employees train, implement, monitor, control.	

Figure 5.40 – Standard Work Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Strategic planning

Problem solving methodology
Standard work
Strategic planning
Tactical improvement
Daily Improvement
Organizational structure for continuous improvement

We regularly use Hoshin Kanri's approach in order to define our strategy; system Kaizen - Kaikaku

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No clear mission, vision, or long-term strategy.	• Improvement initiatives not linked to strategy or based on company wide diagnosis. • Plans focused on results, not on process.	• Clear improvement policies emerge from diagnosis and analysis of last year's results. • Systematic training in Hoshin Kanri begins.	• Hoshin Kanri is the methodology that leads the company strategy. Improvement and breakthrough plans linked to a focused profit plan. • X-Matrix provides links and clear correlations at different levels: Strategy, Tactics, Process and Results. • Plans are driven with "Catchball" approach for a full involvement.	
Notes:				

Figure 5.41 – Strategic Planning Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Tactical improvement

Problem solving methodology
Standard work
Strategic planning
Tactical improvement
Daily Improvement
Organizational structure for continuous improvement

We regularly organize activities such as Kaizen week

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No recurring Kaizen events are performed by the company.	• Sometimes specific working groups study specific problems arising in production. These are isolated and sporadic events, not well organized and conducted.	• Workshops are organized only for the most significant problems through a structured methodological approach for analysis. • There are no organizational support roles defined. • There is no formal plan for continuous improvement.	• Kaizen week events are led by a specific facilitator and/or a team composed by members of the area in which the kaizen event is being conducted plus a few additional people from support areas and even management. • Kaizen weeks are part of an overall program of continuous improvement. • Clear measures of performance are defined in order to compare the progress obtained.	

Figure 5.42 – Tactical Improvement Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Daily Improvement

Problem solving methodology
Standard work
Strategic planning
Tactical improvement
Daily Improvement
Organizational structure for continuous improvement

We regularly organize activities such as Obeya meeting

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No daily Kaizen events are performed by the company.	• When certain problems occur, daily meetings are planned with production, warehouse and production planning manager. • These initiatives are not well structured, without a clear problem solving methodological approach.	• Production managers daily meet in order to discuss any problems encountered and to study possible improvement initiatives. • The methodological approach is not well structured, the roles are not well defined and the responsibilities not clearly assigned. • Absence of dedicated meeting areas and visual tools to describe the project timing, progress, problems and countermeasures.	• Daily improvement activities are performed in a formal and structured way. • During the Asaichi, the "morning market" meeting , employees briefly discuss about the new problems detected. • A full range of visual tools are provided: boards, problem strips, images and other collaborative materials. These tools allow employees to find solutions proactively.	

Figure 5.43 – Daily Improvement Maturity Grids

Process and Equipment
Manufacturing Planning and Control System
Suppliers Integration
Total Productive Maintenance
Employees Empowerment
Continuous Improvement

Organizational structure for continuous improvement

Problem solving methodology
Standard work
Strategic planning
Tactical improvement
Daily Improvement
Organizational structure for continuous improvement

Our structure includes precise organizational roles that support continuous improvement

Level 1 Not Performed	Level 2 Partially Performed	Level 3 Formally Performed	Level 4 Culturally embedded	Current Score (1 – 4)
• No structured organization focused on continuous improvement established within the company.	• Employees perform several activities such as "Quality Control Circle" without a formal structure established. • The results of these activities are not tracked or deeply analysed.	• Company identifies a person/team to manage and implement specific and distinct improvement project. • Feedback from these projects based on Hansei (reflection meetings) held at key milestones and at the end of a project ib order to identify problems, develop countermeasures, and communicate the improvements to the rest of the organization.	• All improvement projects are managed by a defined lean agent/team. • Therefore, a full functional and structured role/function (e.g. lean promotion office) is established in order to lead lean and improvement projects.	

Figure 5.44 – Organizational Structure for Continuous Improvement Maturity Grids

5.2.3 Checklist and Optimal Profile Generation Matrix

The main objective of the Checklist and Optimal Profile Generation Matrix proposed for the purpose of assessment tool is to define the optimal level of implementation of the defined LPs according to firm characteristic.

The Optimal Profile Generation Matrix is inspired to the Relationship Matrix of QFD. In QFD methodology, the relationship matrix is where the team determines the relationship between customer needs and the company's ability to meet those needs. The team asks the question, *"what is the strength of the relationship between the technical descriptors and the customers' needs?"*. Relationships can either be null, weak, moderate, or strong and carry a numeric value of 0,1, 3 or 9. These values have been defined by Akao (1990), the same author has defined the algorithm of relationship matrix: the Independent Scoring Method (ISM). Likewise, the Optimal Profile Generation Matrix determines the relationship of different firm's characteristics with the identified LPs thanks to the same approach.

The firm's characteristics are assessed with a Check List that contains 44 items. These items are divided in four categories:

1. Production Processes: this category defines firm's production typology, (discrete or process), layout, level of WIP, batch size and maintenance issue.
2. Production Planning: this category defines if firms utilizes MRP or CRP system, if it plans the production according to market forecast or demand and if the seasonality effects the production itself.
3. Interface with the market: this category defines if the firm assembles or/and fabricates the products offered to market. Moreover, it is defined if the firm offers products on demand or not.
4. Suppliers: they are evaluated in terms of flexibility, punctuality, responsiveness, level of integration etc.

The employees involved in the assessment are asked to rate the 44 items of the Check List with a score from 1 to 10. The scores given are inserted in the in the row "**Score**" of the Optimal Profile Generation Matrix (*Figure* 5.45). The Optimal Profile Generation

Matrix has this structure: the columns are the 44 items of the Check List while the rows are the identified LPs among the Primary Practices (Process and Equipment, Manufacturing Planning and Control System, Supplier Integration, Total Productive Maintenance). The Support Practices are not evaluated in this matrix because the LPs of Employees Empowerment and Continuous Improvement constructs should pursue the perfection independently from firm's characteristics.

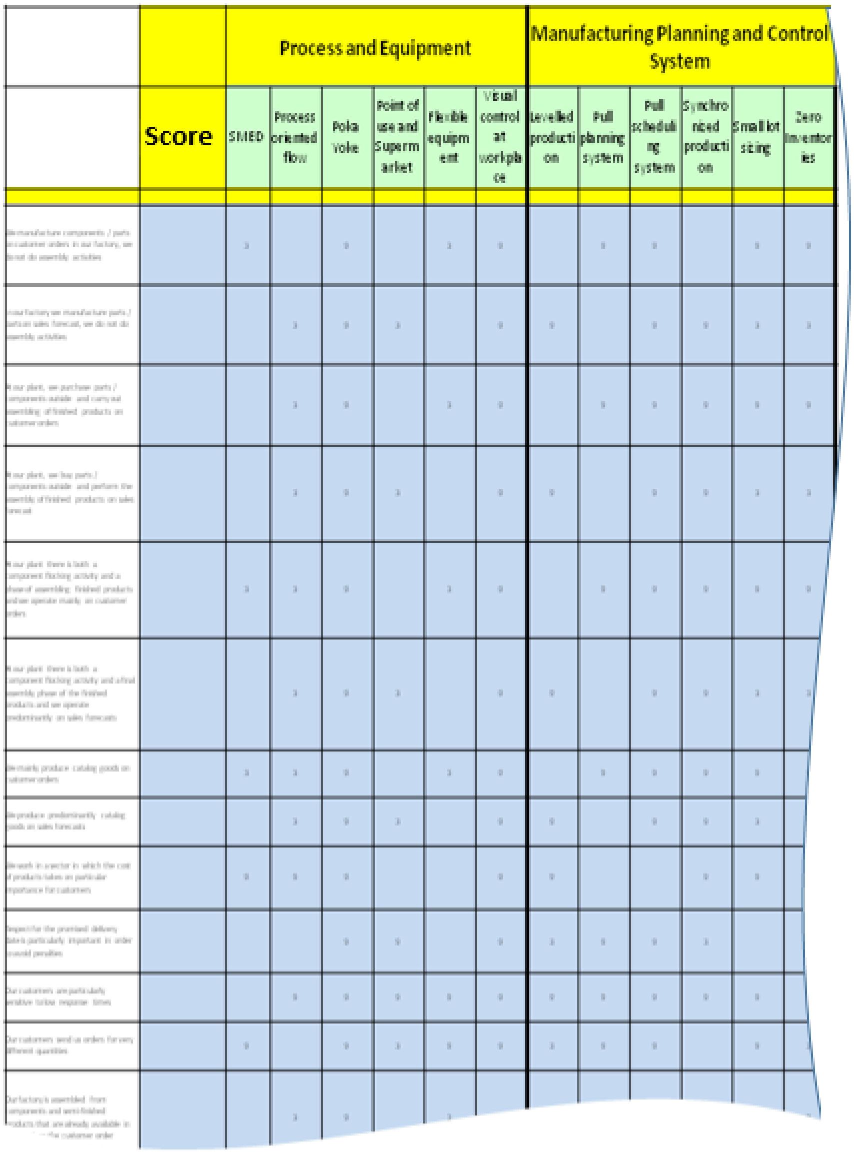


Figure 5.45 - Optimal Profile Generation Matrix

For each cell that connects Check List Items with LPs, a level of correlation has been defined with a numeric value: 0,1, 3 or 9 which represent null, weak, moderate, or strong correlation as prescribed by Akao (1990).

The Optimal Profile Generation Matrix has a considerable dimension: 44 (number of items in Check List) X 35 (number of LPs) cells. Its dimension is large and the determination of the numeric coefficients of these cells needed the contribution of the author, the academicians involved in the review panel as described in the Chapter 3, the referent academicians of the exchange period at TU DELFT, as described in the Chapter 4, and in addition the contribution of practitioners and experts. By way of example, due to the vast dimension of the matrix, the row related to job shop production system for defined batch size is shown in the Figure 5.46 with the associated coefficients related to differebt LPs.

		Process and Equipment						Manufacturing Planning and Control System						Suppliers Integration							Total Productive Maintenance				
	Manager Evaluation	SMED	Process oriented flow	Poka Yoke	Point of use and Supermarket	Flexible equipment	Visual control at workplace	Levelled production	Pull planning system	Pull scheduling system	Synchronized production	Small lot sizing	Zero Inventories	Blanket Orders	TCO - Total Cost of Ownership	Kanban with suppliers	Free pass	Information sharing and mutual exchange	Supplier development	Supplier rationalization	Autonomous Maintenance	Planned Maintenance	Proactive Maintenance	TPM Training	Mainte ance Indexe utilizati n
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Job shop production system for defined batch size		9	9	0	1	0	0	9	3	9	3	9	9	0	0	0	0	0	0	0	1	3	3	1	
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	..

Figure 5.46 – Example of row with coefficients in the Optimal Profile Generation Matrix

The ISM algorithm defines the L_i optimal implementation level for each LP with the following formula:

$$L_i = \frac{\sum_{h=1}^{35} R_h * d_{ih}}{\sum_{h=1}^{35} d_{ih}}$$

i = 1,…,35 h = 1,…,44

L_i optimal level for LP

R_h item-h evaluation

d_{ih} correlation coefficient with a scale: 0, 1, 3, 9

Where *i*- are the LPs and *h*- the items of Check List.

The results of the Optimal Profile Generation Matrix is the optimal implementation level of each LP assessed with the MGs.

5.2.4 Radar Chart

The radar chart allows to clearly show both the current state of LPs implementation from the MGs and the optimal profile of LPs implementation calculated thanks to the Optimal Profile Generation Matrix. This represents a first level of contingency of the assessment tool, the optimal level of LPs implementations is calculated according to firm's characteristics and the radar chart identifies the LPs with implementation gaps between the current state and the optimal ones or overshooting as well. In the Figure 5.47 an example of Radar Chart for the 35 LPs.

As mentioned in the former paragraph, the LPs of Employees Empowerment and Continuous Improvement constructs should set to the maximum level of implementation for the optimal profile since they should pursue the perfection independently from firm's characteristics. In fact, they are the LPs from LP27 to LP35 of the radar chart and they are set at the maximum level.

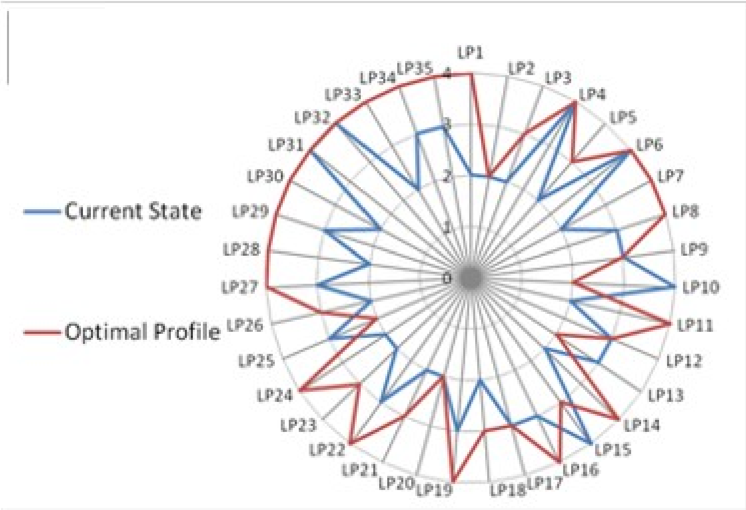


Figure 5.47 - The Radar Chart

5.3 Flow B: constitutive elements description

The *Flow B* is composed by the following main elements: Workshop for identifying relevant performances, Strategic Matrix model and Performance-Practice matrix model. Below a detailed description of each one is provided

5.3.1 Workshop for relevant operational practices identification

Firm's employees involved in the assessment identify firm's most relevant operational performances in relation to firm's strategy. The workshop is based on the well-established Strategy Canvas Action Framework (Kim and Mouborgne, 2005) and it lasts about one hour. The Strategy Canvas is a high-level depiction of current strategic position assuring robust and reliable results. It is based on the key *"Blue Ocean"* principles; it helps strategists examine value creation, value capture and opportunity. For the sake of clarity, the *"Blue Ocean"* approach and its principles are briefly described but they are **not** part of topic of this thesis. *"Blue Ocean"* is a strategy developed by Kim and Mouborgne (2005) in their book *Blue Ocean Strategy: How to Create Uncontested Market Space and Make Competition Irrelevant*; it has several key principles and associated assumptions that help organizations create compelling, sustaining and differentiating strategies. The *"Blue Ocean"* principles are principles: 1. Reconstructs market boundaries and the competitive industry aspects; 2. Focuses on the big picture; 3. Reaches beyond existing demand, creates new demand paradigm; 4. getting the strategic sequence right.

The relevant operational performances can be usually categorized in terms of cost, time, quality and flexibility; the identified ones by participants are the basis of the next element of the Flow B, the Strategic Matrix.

5.3.2 Strategic Matrix

The Strategic Matrix is inspired to the AHP Strategic Target Matrix of QFD. It define a degree of importance of relevant practices identified during the workshop and utilizes the Analytic Hierarchy Process (AHP) methodology to support decisional process (Saaty, 1980). AHP is a technique for supporting decisions, developed by Saaty during the Seventies, in order to work with complex problems of a technological, economical and sociopolitical nature. The objective of AHP analysis is to determine the best option (or a rank), among those available to the decision maker by studying the subjective importance that they each have compared to the others (Maritan, 2015).

Strategic Matrix										
	RP1	RP2	…	RPn	Normalized assessment				Absolute Weight	Degree of Importance
RP1										
RP2		C_{ij}				N_{ij}				
…										
RPn									W_{ij}	DP_{ij}
								Tot		

Figure 4.48 - The Strategic Matrix

The AHP is based on pairwise comparison judgments and provide a flexible and powerful, at same time, tool for handling both qualitative and quantitative multi-criteria problems. AHP provides an estimate of additive utility weight that best matches the initial information provided by the decision maker and it provides a meaningful way to evaluate and combine tangible and intangible criteria in any decision (Nasab and Zare, 2012).

The Strategic Matrix has the following structure. The relevant operational practices (RP) are on the rows and columns on the left part of the matrix. In every cell of the matrix (area on the left side) a numeric value C_{ij} is inserted by participants of the assessment, chosen in a predetermined range that corresponds to the assessment of how important the specific objective row is compared to the corresponding objective column. The flow direction also is relevant: row versus column, not the opposite.

The range of values used is the following:

1 = the row is equally important as the column
3 = the row is slightly more important than the column
5 = more important
7 = much more important
9 = very much more important
0.33 = slightly less important
0.20 = less important
0.14 = much less important
0.11 = very much less important.

The second step is to normalize the assessments along the columns of the matrix, the value N_{ij}. The following stage is the sum the normalized values, this time along the rows; the so-called "Absolute weight" W_{ij} is obtained of the RP, which is shown in the penultimate column of Figure 4.48, on the right. Finally, for every performance, the "relative" value of the absolute weight is the "Degree of Importance" DP_{ij}, calculated dividing the absolute weight by the sum of the absolute weights, represented as percentage.

5.3.3 Performance-Practice matrix model

Thanks to the Performance-Practice matrix model (Figure 4.49), the relevant performances, taking into account their degree of importance, are cross-checked with

LPs thanks ISM algorithm (Akao, 1990) in the same way of the Optimal Profile Generation Matrix at paragraph 5.2.3. The level of importance c_{ij} is assigned to every practice by the participants; the most important practices are the most correlated with the relevant performances. In this way, we have identified the most important lean practices that support the relevant performance of firm's strategy adding a second level of contingency to the assessment tool.

The structure of Performance-Practice matrix model is: the columns are the relevant operational performances identified by participants at the beginning of the Flow B with the relative degree of importance in the second column. The others columns are the 35 LPs identified in the flow A. Again, the ISM algorithm (Akao, 1990) is applied, in order to define this time the degree of importance I_i of each LP.

		Lean Practices					
List of Relevant Performances	Degree of Importance	LP1	LP2	….	….	….	LPn
RP1	DP1						
RP2	DP2						
….	…			c_{ij}			
….	…						
….	…						
RPn	DPn						
		Importance of Lean Practices					

Figure 4.49 - Performance-Practice matrix model

The formula applied is similar to the one utilized for the Optimal Profile Generation Matrix at paragraph 5.2.3, since the same ISM algorithm has been applied.

$$I_i = \frac{\sum_{h=1}^{35} D_h * c_{ih}}{\sum_{h=1}^{35} c_{ih}}$$

$i = 1,\dots,35 \qquad h = 1,\dots,n$

I_i importance of LP
D_h evaluation of n- practice
c_{ih} correlation coefficient with a scale: 0, 1, 3, 9

Where *i*- are the LPs and *h*- the identified relevant operational performances.

The results of the Performance-Practice matrix is the level of importance of each LP taking into account the relevance of the firm's operational performances.

5.4 Priority Map

Having defined for each practice the degree of importance and the gap between current state and optimal profile, the last step of the proposed assessment tool regards the construction of the "*Priority Map*" which helps in defining the sequences of improvement initiatives that company should be undertaken to improve its lean transformation journey.

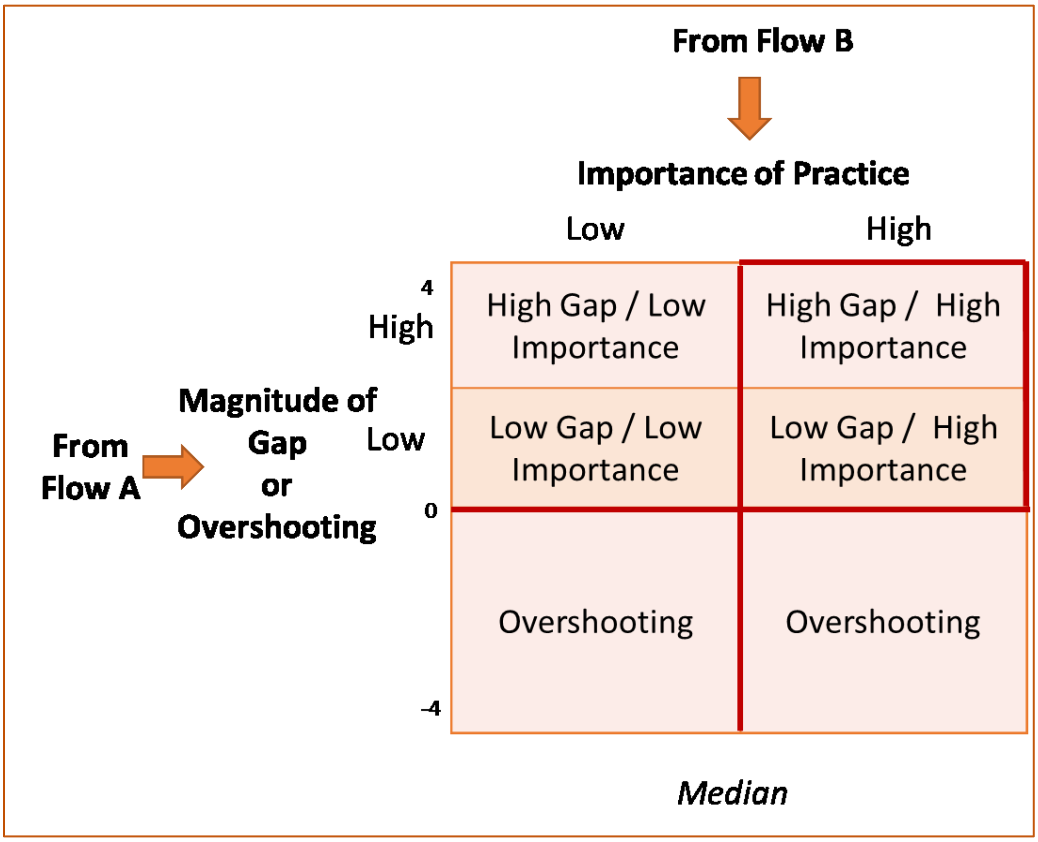


Figure 4.50 - Priority Map

The priority map performs a *"gap size-importance"* two-dimensional mapping of practices on a Cartesian plane as shown in the Figure 4.50. Finally, some useful observations on the Priority Map structure:

- The practices that have a level of implementation higher than the recommended one are in overshooting;
- The median of the practices importance values is the threshold to determine low and high level;
- The priority map helps in defining the sequences of improvement initiatives that company should be undertaken to improve its lean transformation journey. In fact, the MGs provide, with their four level of implementation, the improvement initiatives in order to reach progressively the desired level for a specific LP.
- The firm, according to the resource available in terms of financial, time, skill and competences, may decide to focus on LPs with low gap of implementation and high level of importance in order to obtain the so-called "Quick Win" in short time or it may decide to be committed in filling the high gap of most important practices.

The priority map allows identifying improvement paths thanks to this structure. In fact, the two quarters in the upper part contain the LPs with a gap of implementation where the firm should focus in. The LPs analysed are also distributed according to their degree of importance. At this point, the firm can chose in which LPs focus its improvement efforts according to different approaches. The Figure 4.51 shows a possible path inspired to the *quick win* approach, the firm firstly focuses in the LPs with a lower gap and high importance in order to carry out positive results as soon as possible, then it focuses on the LPs with higher gap to fill that may require a greater effort. Lastly, if the company has enough resources to invest, it may focus in the LPs with high gap and lower degree of importance. Moreover, the Figure 4.52 shows another approach; the firm decides to invest its resources firstly in the LPs with a high gap to fill in order to obtain robust and valid results, then it focuses on the LPs with a low gap that require less effort. Finally, if the company has enough resources to invest, it may focus in the LPs with high gap and lower degree of importance.

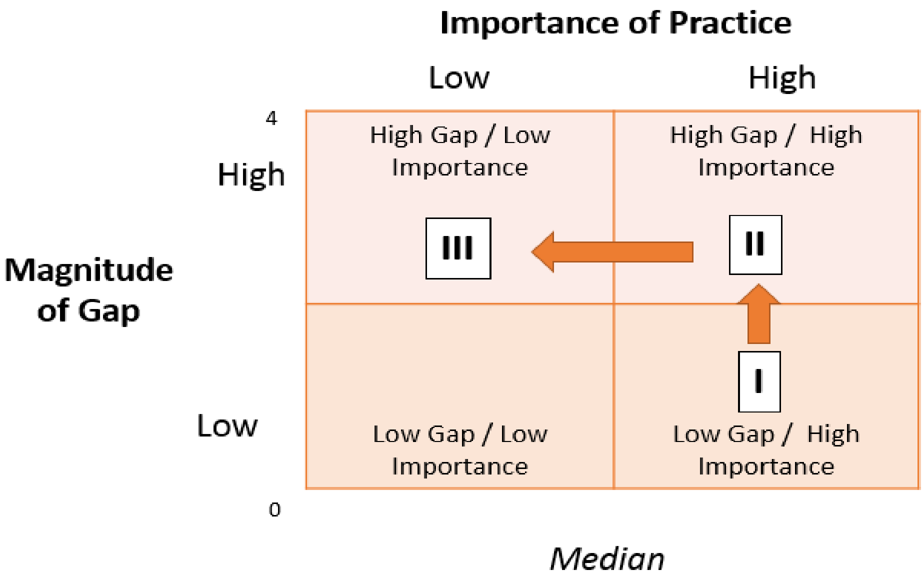


Figure 4.51 – A possible improvement path #1

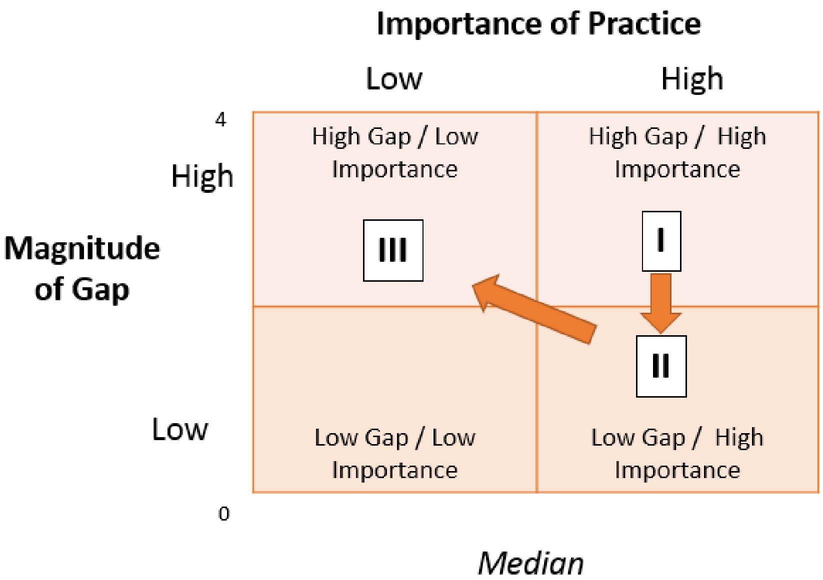


Figure 4.52 – A possible improvement path #2

5.5 Chapter conclusion

In this chapter, the structure and the main elements of the proposed assessment tool are described in detail. The tool is composed by three main parts:

- the Flow A dedicated to identifying the LPs implementation gaps (or overshooting) that provides the first level of contingency;
- the Flow B dedicated to identifying the LPs importance according to firm's strategy that provides the second level of contingency;
- the Priority Map that is a visual tool for identifying the LPs characterized by implementation level gap (comparing the current state with the optimal profile) and high level of importance.

In the next Chapter, the assessment tool test is proposed in a sample of SMEs located in the northeast region of Italy, one of the most industrialized region of the country and of the all Europe. The results emerged from the application within the sample are described. Moreover, the theoretical contributions of the construct in terms of novelty to the body of knowledge and application scope are described.

Chapter 6: Assessment Tool Test and Contributions Evaluation

In this chapter, first the testing phase of the tool in a sample of eight SMEs is proposed according to the methodology adopted. The depiction of the chosen sample is provided; in addition, the results of one application of the proposed tool in the Chapter 5 is described in details. The chapter continues with the illustration of the tool application results in the sample in order to capture the tool relevance and utility as prescribed by the chosen methodology. Lastly, the theoretical contributions of the proposed tool to the body of knowledge are discussed.

6.1 Sample Description

The first criteria adopted in choosing the firms of the sample is their size. In fact, the proposed assessment tool is tailored for SMEs as described in the previous chapters. The definition of SMEs can vary since there is not a universal accepted characterisation of this kind of organizations. In this thesis, the author chose the SMEs definition proposed by the European Commission (EC) with the EU recommendation 2003/361 (available at: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_it). This definition prescribes that the main factors determining whether an enterprise is an SME are two:

1. staff headcount;
2. either turnover or balance sheet total.

Company category	**Staff headcount**	**Turnover**	or	**Balance sheet total**
Medium-sized	< 250	≤ € 50 m		≤ € 43 m
Small	< 50	≤ € 10 m		≤ € 10 m
Micro	< 10	≤ € 2 m		≤ € 2 m

Table 6.1 – SMEs ceilings definition, EU recommendation 2003/361

Moreover, the EC identifies three main categories with the EU recommendation 2003/361 as shown in Table 6.1: Micro, Small and Medium-Sized.

An important specification defined by EC is that ceilings in Table 6.1 apply to the figures for individual firms only. In fact, *"a firm that is part of a larger group may need to include staff headcount/turnover/balance sheet data from that group too*".

The second criterion in choosing the firms is that they have already started a lean transformation program. As declared in the first chapter, SMEs should call for reviewing their Lean transformation program in order to create opportunities for continuous improvement concerning LPs implemented, monitoring the path took and the direction to follow. In fact, this aspect is the main of this thesis: provide an assessment tool for the evaluation of LPs implementation within SMEs, that have already started a lean transformation program, in order to identify the most urgent area to enhance according to firm's characteristics and strategy and to provide clear initiatives of improvement.

The third criterion is the industrial sector of the firms chosen. The tool proposed is focused on the LPs developed in the context of production. Therefore, the author's choice has fallen upon manufacturing SMEs discounting firms from other sector as service, education, health etc. because not relevant to this research.

Therefore, the firms of the sample have been chosen following the above-mentioned criterion. As result eight manufacturing SMEs have been selected from the northeast region of Italy, one of the most industrialized region of the country and of the all Europe. This geographical decision has twofold reason; the first is: in order to carry out the tool application in a SME of the sample it is necessary a close cooperation with the firm itself. The reason lies in some key characteristics of manufacturing SMEs described in the Chapter 3 such as the lack of information sharing, the role of the *"owner manager"* and tendency to adopt mainly short-term management logic; in this sense, the geographical proximity is crucial for a successful test of the tool. The second is the purposes specification of the scholarship that financed this research. As stated in the introduction, this research is financed by the Italian Law N. 170, July 11th 2013, for the improvement of advanced manufacturing systems relevant for the "Made in Italy" industry. The Italian Law N. 135, September 25th 2009 states that only products totally made in Italy (planning, manufacturing and packaging) are allowed to use the labels "Made in Italy, 100% Made in Italy, 100% Italia, Tutto Italiano" in every language. Therefore, the registered offices and the production and packaging processes of the sample's firms are located in the Italian territory in compliance with the abovementioned regulations.

Company Name	Manufacturing Typology	Production Sector	Staff Headcount	Turnover	Starting year of lean journey
AAA	Discrete	Advanced system for window fixtures	212	€ 25,7 m	2002
BBB	Discrete	Machinery for bakeries and pastry	57	€ 18,9 m	2012
CCC	Process	Alcoholic beverage	131	€ 41,1 m	2008
DDD	Discrete	Marine engine inverter	192	€ 32,3 m	2011
EEE	Discrete	Agricultural machinery and tractors	46	€ 15 m	2007
FFF	Discrete	Stoves, boilers, fireplaces and concrete inserts	86	€ 25,4 m	2010
GGG	Discrete	Pipes and Connectors for oleo-dynamics	57	€ 9,9 m	2007
HHH	Discrete	liquid and gas filtering equipment for non-domestic use	223	€ 46,5 m	2011

Table 6.2 Firms Sample main characteristics

In the Table 6.2 the main characteristics of the firms' sample are shown. For every firm is indicated the manufacturing typology (discrete or process manufacturing), production sector, number of employees, turnover or balance sheet total and year of beginning of lean journey towards lean transformation. The data are extrapolated from AIDA - Bureau van Dijk database for the fiscal year 2016. The database has the following bibliographic characteristics: AIDA contains comprehensive financial, stock and commercial information on over 500,000 companies operating in Italy. Financial information is provided by Honyvem; it buys and re-elaborates all official balance sheets filed with the Italian *Chambers of Commerce*. All data, with a 10-year history, is indexed and can be used as search keys, processed, evaluated, and exported in multiple formats.

The name of the firms participating to the sample is not shown in compliance with confidentiality agreements. However, a brief description of each firm is provided as follows in terms of company's profile, history and lean transformation programs adopted in order to provide a complete overview of the sample chosen.

Company AAA

The company was founded in 1986 as individual firm by Mr. T.F. as commercial activity with a storage of carpentry equipment, located in a small warehouse. In 1988, the company AAA moved into an industrial warehouse with the aim of design and marketing its own wood / aluminium pairing system; this kind of window-dresser was, up to that time, absent on the Italian market. In 2000, company built approx. other 4000 sq. m. of industrial plant. The 50% of this space is used for the production of assembled frames and welded frames, the rest of the space consists in the painting for the finishing phase of aluminium products (both bars and frames). In 2001, the firms acquired an additional 1200 sq. m. for the showroom department and it promoted the production of finished welded frames on order. In 2006, the expansion works were completed for the creation of new spaces for automatic warehouse. The innovation of AAA is the development of combined wood/aluminium systems that adapt to existing wood systems in the market. The firm's strength remains the efficiency and speed in designing/making custom profiles/systems at customer's request from the experience gained on these combined wood/aluminium systems. An additional system has been adopted to create versatile solutions when composing the external surface with profiles combined on different planarity, keeping the same wooden structure. The need to use these systems without overly altering the original structure of historic buildings, that require structures appropriately matched to the stylistic context, has led to the realization of wood/bronze systems equivalent to those already made with aluminium. On Since 2002, the company has started to work on adopting lean principles in the production. These first lean transformation initiatives can be summarized as follows:

• Realization of the Current state map thanks to VSM;
• Estimates of production time and cost of current industrial transformation;
• Discussion and definition of areas of analysis and intervention;
• One-piece-flow (or similar) hypotheses in the welding and balancing department;
• Future state map thanks to VSM;
• Evaluation of production time and cost of future industrial transformation.

After these first initiatives, many others have been implemented: One-piece-flow in the welding department, production Kanban system, buffer and WIP reduction, Supermarket creation in others department such as cutting and packing departments etc.

Company BBB

The history of BBB began in the early seventies as a company for creating and implementing bakery solutions. The first machines produced were the spiral kneader and the volumetric breaker, soon considered authentic technological innovations in this industry sector. These machines have been an added value in BBB business activity, referring to customers and competitors. In the 1980s, the company evolved to promote further development in international markets by selling industrial lines for baking. Innovative propulsion and the extensive presence of BBB in the markets, the high technical and human value of its team contributed to the remarkable development of the company since the early nineties. During this period, BBB formed with a French world leader in ovens market a cross-selling arrangement. The recent history of BBB has a turning point in 2010, with the introduction of a new product as a result of a strong push to innovation, which led the company to turn to the start-up segment. This product is an innovative brewing and bakery workshop, which in its simplicity guarantees an excellent quality of the finished bakery product: fresh and without preservatives, natural leavening, without artificial components, with energy saving and respect for the environment. With this innovative workshop, it is possible to get a fresh product in only 30 minutes, in only 32 square meters of laboratory and with only five machineries. It re-invents the baker's job: no more at night but by day. Innovation is therefore the key word in BBB’s panorama and future scenario. The firm, in parallel to the revision of its market, is developing a redesign of many organizational components with a radically innovative method compared to the traditional one: the customer is the centre and starting point for analysis, development and design. In 2012 a Kaizen internal team has established, it worked on the plant for the process of complete transformation. The Kaizen initiative started due to the economic downturn and decrease of sales volumes at BBB. Therefore, it was necessary to revise the organization of the company with two main objectives: margins and revenues recovering and becoming to be more competitive in global markets. The decision was to rely on the *Kaizen Institute* consulting firm to develop a lean transformation program. Thus, BBB’s activities began with the aim of learning, through a shared experience, to look at the flow of value within the factory, to identify muda and to reorganize the processes according to the Kaizen logic. The first step was the formation of the Kaizen team for the factory improvement projects: the choice was to involve both operations with production and purchasing offices and engineering from the technical office. The Kaizen workshops carried out until now refer to establish a production flow oriented to customer value, redesign of the plant layout, implementation of Supermarket in the production and integration of the supply chain with the suppliers.

Company CCC

The CCC is a leading company in production of alcoholic beverages and in particular of Lager beer. The actual plant was inaugurated in 1973, occupying an area of 5500 sq. m. In 2002, the plant was expanded thanks to the acquisition of an adjacent building, thus reaching the current size of 7800 sq. m. , of which about 5000 sq. m. are industrial building. In this area, all the activities necessary for the production, packaging, storage and distribution of beer are carried out. The layout of the plant includes the offices, the raw material handling area, the fermentation area, the manufacturing and packaging departments and the storage areas, including two warehouses. In the manufacturing department all the production processes necessary for obtaining beer are performed, such as malting, grinding, stirring, cooking, cooling, fermenting, ripening and filtration. The plant works seven days per week with three shifts a day, due to the nature of the brewing process that can never be interrupted. The packaging department is composed by three lines, one is used to fill the tin barrel, the other two are used for packing beer in bottles. Since 2003, the company has outsourced much of the internal logistics of the plant in order to reduce its maintenance and management costs and focus on its core competences. In particular, an external company has the following functions:

- Warehouse management of circulating material, warehouse management packaging material and feeding of packaging lines;
- Receipt of finished goods warehouse;
- Finished stock warehouse management.

Thus, an outsourcing company is responsible for managing the flow of input and output materials from the plant as well as supplying the lines of the packaging department with the material required by CCC. From the construction to date, the plant has undergone several modifications and improvements that have allowed to shift from the original production capacity of 30000 hl/year to the present value of 160000 hl / year (more than five times higher). This success has been accomplished also thanks to the implementation of a lean journey started in 2008. The lean pilot project started in the manufacturing department. A few months later, the packaging department was also involved with line 2. Since 2010, the lean project has been extended to the other two lines of packaging, while the utility department has been involved since 2011. The Logistics Department is still in a lower stage of implementation due to the fact that it started in January 2016, and this year the project will also extend to administrative offices. At the present time, ten years after the start of the project, the plant is in the "midterm stability and reliability of results" phase, and is about halfway to achieve excellence as estimated by the management.

Company DDD

The origins of DDD date back to 1929 when Mr. D.M. started his production of gears and precision parts for motorcycles in a small workshop. Thanks to product quality and technical capability, the company acquires market share in the manufacture of precision mechanical components and gears. In 1965, the 55 employees became aware of the need for an extension of the site, so Mr. D.M. acquires another machine tool maker company, creating the actual DDD. The company becomes a manufacturer of chassis and transmissions for commercial, industrial and rail vehicles. In 1975, the production of the marine sector started with the first marine transmission. In 1994, the company took the strategic decisions of modifying the company's production mix, marine transmission production gains ever-greater importance and prevalence in firm’s sales. Between the late 1990s and the 2000s, DDD decided to focus only on the Marine Business Unit. In adopting the lean principles, DDD developed in 2011 an original interpretation of LM that is based on six principles. They define the “*DDD production system”*:

- Orientation towards employees and team: it defines the employee as a key factor in achieving success;
- Process orientation in customer-supplier relations: throughout the value stream, the processes the next one is always the client of the process just concluded;
- Standardization and flexibility: every improvement becomes a standard for all workers;
- JIT: DDD implements this principle through the market takt time;
- Zero defects: do not produce, forward or accept defective parts; the cause of possible errors must be quickly recognized and removed systematically through concrete solutions (e.g. by using Poka-yoke in product design);
- Innovation and continuous improvement process: all processes must be constantly analysed and improved with respect to the lean waste.

Company EEE

The development of the current EEE started in 1983 when the company, active in the industry of hammock mills, was picked up by a new generation of entrepreneurs. From that moment, the company has experienced a steady growth trend that led to 1990 to expose in Kiev its first mill plant for the production of food flours that revolutionized the traditional cannons of cereal grinding. The '90s were also a key milestone for the industry of agricultural machinery: in 1991 the mobile drying machine for cereals was realized, awarded as "Technique Innovation of the Year" during the international EIMA

"International Machinery Industry Exhibition for Agriculture and Gardening”. In addition, to meet the most varied customer needs, the already wide range of spreaders (for salt, sand and fertilizer) has been implemented with new models. In 2000, the pace of activities implied the expansion of production facilities and it reached the current 10,000 sq.m. of production area. In 2001, the EEE inaugurated sale offices in North America and sub-Saharan Africa. In 2007, EEE decided to start a lean transformation program to ensure better product quality and customer satisfaction. Looking at the Toyota experience, EEE developed original production system. It is a modus operandi inspired by the Toyota Production System (TPS). The objectives of EEE production system are:

- elimination of waste;
- standardization of work;
- levelling of production.

For these purposes, EEE has adopted the TPS principles: Jikoda, JIT and employees training. With the use of these techniques, EEE, a company operating according to the traditional batch and line system, has decided to become flexible and dynamic, able to produce for the customer only what is sold and when it is required without waste, defects or delays. For EEE, Lean transformation should not only affect production areas, but also the non-production areas (e.g. offices) where there is no actual transformation raw material physics in finished product, but planning and management processes equally important and equally critical for that change towards being lean.

Company FFF

FFF was founded in 1976 and the company was born as a manufacturer of refractory fireplaces and marble coatings, unique products result of the experience and know-how of the local stonecutters, skilled artisans with a strong tradition in the processing of marble. These features have enabled the company, both to create a well-known brand for its artistic products, both to grow as an important company in its own field. From his foundation, it has always been characterized by a very high level of quality, with a production based on craftsmanship which brought high production costs and a level of export less than 15%. The artisan fireplaces have been over the years a niche market increasingly weak. The production of marble fireplaces has been replaced to the one-burner fireplaces and heating inserts by the market. In addition, the consequences of the crisis in markets forced the company to face economic difficulties resulting in a strong contraction in sales. Therefore, to survive there was a need for radical change through the offer of economic products that can save on energy costs compared to traditional heating systems. In 2007, a process of transformation from a craft industry to the manufacturing industry started. The question leading this change was: *"What do a car, a cell phone and a stove have in common?"* Apparently nothing, but the revolution made inside FFF is based on product features logic of other industries, such as mobile phones or automobiles. What led to this parallelism was a complete product re-design, the creation of a new range of models based on standardization of the base body and the customization of the coating, as, for example, with cellular covers. Customers can, customize their heating system, such as the colour of a car, with the choice of a wide variety of coatings. This is the real innovation brought in the first years after 2010s by FFF: from the realization of unique artworks, there is therefore the transition to the production of more standard products. Stoves, boilers and inserts are currently produced as standard customizable external platforms by choosing the coating between a wide range offered of different options. This can reduce costs and FFF is able to offer a product highly customizable at an affordable price. To undertake this new path, which has led to a radical transformation of human and technological resources, the company relied on the collaboration with a local consultant company specialized in implementing LM within SMEs. Production has changed from department structure to a flow logic. By doing this, the production lines adapt to the market in order to meet customer needs, minimizing storage and eliminating inventory costs. The final customer receives two separate packages for the stove, one with the heating body and one with the tailor-made coating chosen; the coating can be also changed to match with any new furniture of the customer.

Company GGG

GGG is a leading company in the field of connectors for the oleo-dynamics production; in fact, their main business concerns the production of connectors, moulded and flexible pipes. In 1959, Mr. C.G. founded a mechanical workshop characterized for the production of special agricultural machinery. At that time, hydraulic installations turned out to be difficult to recover; in fact, it was necessary to contact several suppliers and, in several cases, pipes on the market often did not respond well to the specific requirements. Hence, the intuition of C.G. was to come up with a complete kit for hydraulic systems. In the 1990s, the production of fittings, hoses and adapters was added to the initial one of shaped tubes, proposing for the first time a complete kit. The company was the first in Europe to realize galvanized shaped tube after fold. In 2007, LM become part of company culture thanks to an agreement with an important consulting company in order to ensure continuous training to the management and personnel. The company GGG is continuously growing, in terms turnover with nearly the same share capital invested. The first LM initiative applied was the rethinking of the production layout, which followed the implementation of one-piece-flow logic. After the production plant improvements, the second stage of GGG transformation involved the application of lean principles to the supply chain. The change concerned the supplier-customer relations, revised from a partnership perspective. Collaborations with suppliers and major customers took place. This integration has moved further, in fact, traditional Kanban has been perfected with the *"Web Kanban"*, giving the most important customers the opportunity to order directly via web by accessing the GGG website thanks a dedicated Kanban board (integrated with firm SAP). In the last years, the company has successfully implemented the Heijunka box to plan the production and try to level it as much as possible, the milk run with suppliers and Poka-Yoke elements in the production. The *Kaizen* Promotion Office is the central brain of continuous improvement in the company. In fact, there are many meetings that involve people from all departments. At the same time, the projects to be set up and who will be the responsible for them are decided; the general production trends are monitored and all aspects that can give the company opportunities for improvement are daily discussed.

Company HHH

HHH was founded in 1940. At that time, natural gas was used massively as a source of energy for car engines, industry and home heating. In fact, the first patent of HHH was precisely for natural gas market: a regulating valve for LPG cars, which had the gas tank on the roof, and therefore needed a system to regulate the transmission of gas from this tank to the engine. The first production was focused on household appliances, then on gas distribution systems and on facilities for North Italian industries. In the early seventies, the first modular controllers, a real innovative technical, started to be designed and built. They allow devices to be upgraded over time without a complete replacement but with only one modification and installation. In 1973, the company began to develop even more natural gas-related activities due to the oil crisis of those years. The production range, meanwhile, became more and more complete: from throttle to complete systems in addition to regulators. However, in the 1990s, the company was in crisis, with serious problems of profitability and growth; but it is precisely in those years that there was a radical revolution of the firm. In 2011, the first initiatives of lean transformation started: for instance, all the walls that separated the different production areas were demolished, the layout was reformulated and various production cells were created. At the same time, an intensive Kaizen Week campaign began, supported by the Sensei Chihiro Nakao, a student of Taiichi Ohno, and John Black, the lean transformation expert in Boeing. Experts with twenty years of experience, who have joined the company's staff, suitably trained with a variety of practical and theoretical classes. In 2016, Kaizen Week number reached a total of 200. The Kaizen Promotion Office was established, consisting of people dedicated to continuous improvement and constantly trained. This change of philosophy, both productive and managerial, has raised HHH again and, nowadays, HHH is expanding very quickly from the period of crisis.

6.2 Tool Application Case

The methodology adopted for this thesis prescribed a formulation of a construct to answer to a practical relevant problem. The process of formulation and development of this construct is described in the Chapter 5, where the assessment tool architecture is proposed. Due to the applied nature of the work, the validation of the tool requires to demonstrate its applicability for the solution of the practical problem identified. For this reason, in this paragraph the application of the tool in one of the company of the sample is described. Certainly, the objective of this thesis is not to assess the level of LPs implementation of sample’s firms, but rather to demonstrate at this stage that the proposed solution, on one hand, works and, on the other, provides theoretical contribution. For these reasons in the next paragraph are shown the results of the tool application in terms of characteristics and features that the construct should possess according to the methodology adopted. Meanwhile, by way of example in this section all the steps of the application of the tool in the firm AAA are described in detail.

The tool application session involved seven employees of the firm AAA: the plant director, two process engineers, the manager of production planning office, the manager of technical office, packaging department floor manager and a maintenance technician. The session was carried out in a conference room dedicated and in the production sector to discuss more in detail same aspects of LPs. Following the steps described of tool architecture in Chapter 5, the assessment activities were performed and related results are illustrated.

LEAN OPRATIONAL CONSTRUCT	LP#	LEAN PRACTICE	CURRENT STATE
Process and Equipment	LP1	SMED	2
	LP2	Process oriented flow	2,5
	LP3	Poka Yoke	2
	LP4	Workplace organization and cleanliness	2
	LP5	Safety and ergonomics	3,5
	LP6	Point of use and Supermarket	2,5
	LP7	Flexible equipment	3
	LP8	Visual control at workplace	2,5
Manufacturing Planning and Control System	LP9	Levelled production	2
	LP10	Pull planning system	4
	LP11	Pull scheduling system	2,5
	LP12	Synchronized production	2
	LP13	Small lot sizing	3,5
	LP14	Zero Inventories	2
Suppliers Integration	LP15	Blanket Orders	2
	LP16	TCO - Total Cost of Ownership	1,5
	LP17	Kanban with suppliers	1,5
	LP18	Free pass	1
	LP19	Information sharing and mutual exchange	2
	LP20	Supplier development	2
	LP21	Supplier Rationalization	2
Total Productive Maintenance	LP22	Autonomous Maintenance	2
	LP23	Planned Maintenance	2,5
	LP24	Proactive Maintenance	2
	LP25	TPM Training	1
	LP26	Maintenance Indexes utilization	1
Employees empowerment	LP27	Training and Integration	3
	LP28	Upkeep and Development	4
	LP29	Multifunctional Workers	4
Continuous improvement	LP30	Problem solving methodology	1,5
	LP31	Standard work	2
	LP32	Strategic planning	1
	LP33	Tactical improvement	3
	LP34	Daily Improvement	1
	LP35	Organizational structure for continuous improvement	1,5

Table 6.3 – LPs implementation level as current state

Step 1: Current State: the evaluation of LPs through the Maturity Grids

The first step of the assessment is the evaluation of current level of LPs implementation. It is asked to the participants which scale level describes the current state of implementation of the specified LP in the most accurate way. The score ranges from 1 to 4 (1: not implemented ... 4: culturally embedded) and fractions equal to half point are allowed. The participants, after reading each MG level and discussing the different characteristics of each of them, should agree to give a score to the specific LP contended in the MG. The Table 6.3 shows the results of this first phase: for the 35 LPs a score is assigned in order to evaluate the current state.

Step 2: Optimal Profile: the evaluation of LPs through the Check List and Optimal Profile Generation Matrix

The participants are asked to rate the 44 items of the Check List with a score from 1 to 10. According to the description in the paragraph 5.2.3, the scores given are inserted in the in the row "*Score*" of the Optimal Profile Generation Matrix and, thanks to the ISM algorithm, the L_i optimal implementation level for each LP is calculate. The optimal implementation levels for the firm AAA are shown in the table 6.4.

Step 3: Comparison between the current state and the optimal profile through the radar chart

The radar chart allows to clearly show both the current state of LPs implementation from the MGs and the optimal profile of LPs implementation calculated thanks to the Optimal Profile Generation Matrix. In the Figure 6.1, the radar chart generated for the firm AAA is illustrated. The optimal levels of implementation for same primary practices is the maximum, such as Poka-Yoke, Workplace Organization and Cleanliness, Safety and Ergonomics, TCO and Free Pass while the current level of implementation is low. It identifies clearly and in an easy way that for these LPs there is a gap of implementation. Already in this phase, critical reflections arise spontaneous among the participants and observations on the gap are shared. On the other side, it is also interesting to identify LPs in overshooting, for instance the Planned Maintenance. In fact, for the firm it is not a criticality in production.

LEAN OPRATIONAL CONSTRUCT	LP#	LEAN PRACTICE	OPTIMAL PROFILE
Process and Equipment	LP1	SMED	3
	LP2	Process oriented flow	3
	LP3	Poka Yoke	4
	LP4	Workplace organization and cleanliness	4
	LP5	Safety and ergonomics	4
	LP6	Point of use and Supermarket	2
	LP7	Flexible equipment	3
	LP8	Visual control at workplace	4
Manufacturing Planning and Control System	LP9	Levelled production	2
	LP10	Pull planning system	3
	LP11	Pull scheduling system	3
	LP12	Synchronized production	2
	LP13	Small lot sizing	3
	LP14	Zero Inventories	3
Suppliers Integration	LP15	Blanket Orders	2
	LP16	TCO - Total Cost of Ownership	4
	LP17	Kanban with suppliers	3
	LP18	Free pass	4
	LP19	Information sharing and mutual exchange	3
	LP20	Supplier development	2
	LP21	Supplier Rationalization	2
Total Productive Maintenance	LP22	Autonomous Maintenance	2
	LP23	Planned Maintenance	2
	LP24	Proactive Maintenance	2
	LP25	TPM Training	2
	LP26	Maintenance Indexes utilization	2
Employees empowerment	LP27	Training and Integration	4
	LP28	Upkeep and Development	4
	LP29	Multifunctional Workers	4
Continuous improvement	LP30	Problem solving methodology	4
	LP31	Standard work	4
	LP32	Strategic planning	4
	LP33	Tactical improvement	4
	LP34	Daily Improvement	4
	LP35	Organizational structure for continuous improvement	4

Table 6.4 – LPs implementation level as optimal profile

It is important to remind that, as mentioned in the paragraph 5.2.4, the LPs of Employees Empowerment and Continuous Improvement constructs should set to the maximum level of implementation for the optimal profile since they should pursue the perfection independently from firm's characteristics. In fact, they are the LPs from LP27 to LP35 of the radar chart and they are set at the maximum level.

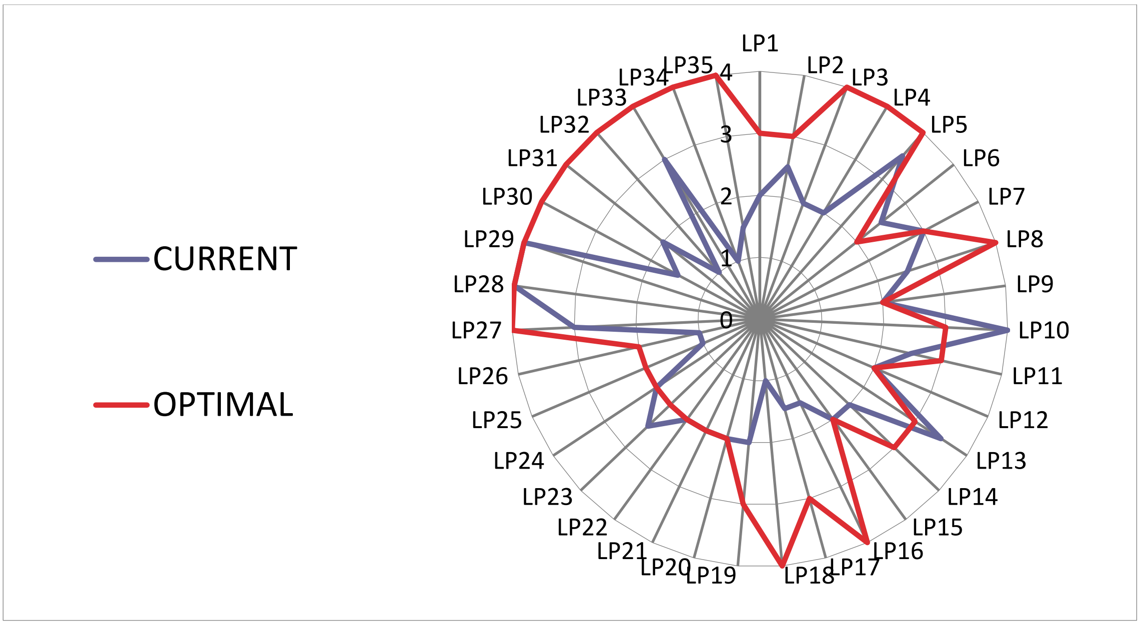


Figure 6.1 – The radar Chart for firm AAA

Step 4: Workshop for relevant operational performances identification

As described in the paragraph 5.3.1, participants are asked to identify the most relevant performances according to the firm strategy. Due to the fact that the people participating are coming from different sectors of the company and they have a role with different level of responsibility, the workshop ensures that in this phase all the key aspects of the firm's performance and strategy are mainly considered and evaluated from different point of view. The participants in this session identify seven relevant performances:

- Turnover;
- Punctual deliveries to the customer;
- Non-conformity of the products;
- Absenteeism of workforce;
- Delivery time to the customer;

- Worker Efficiency;
- Product performance as technical specification (Company AAA produces advanced system for windows fixtures).

Step 5: Assessing the performance degree of importance Strategic Matrix

At this point the participants, thanks to the Strategic Matrix assess the importance of the identified performances. The matrix is based on the AHP pairwise comparison judgments, the participants give a numeric number that describes how important the specific objective row is, compared to the corresponding objective column as shown in the Figure 6.2. In the same Figure, in the last two columns the columns represent the Absolute Weight and the Percentage Weight of the identified performances. In the Table 6.5 these results are shown; the main relevant performances for the firm AAA are: to ensure prompt delivery time to the customer and punctual deliveries of finished product. This is coherent with the product offered by the company. In fact, in construction sites or building restoration it is crucial to deliver windows fixtures running on schedule. Any delay may compromise the rest of the work.

Operational Performances	Absolute Weight	Weight %
Turnover	0,38	5,38%
Punctual deliveries	1,41	20,20%
Non-conformity	1,19	17,07%
Absenteeism	0,15	2,13%
Delivery time	3,03	43,24%
Worker Efficiency	0,49	6,99%
Product performance	0,35	4,99%
Total	7,00	100,00%

Table 6.5 - Performances weight from Strategic Matrix

STRATEGIC MATRIX																	
	Operational Performances							Normalized Column									
Operational Performances	Turnover	Punctual deliveries	Non-conformity	Absenteeism	Delivery time	Worker Efficiency	Product performance								Absolute Weight	***Weight %***	Operational Performances
Turnover	1,00	0,14	0,14	3,00	0,11	0,20	5,00	*0,03*	*0,02*	*0,01*	*0,08*	*0,06*	*0,01*	*0,16*	0,38	**5,38%**	Turnover
Punctual deliveries	7,00	1,00	3,00	7,00	0,20	3,00	9,00	*0,24*	*0,14*	*0,31*	*0,19*	*0,11*	*0,14*	*0,28*	1,41	**20,20%**	Punctual deliveries
Non-conformity	7,00	0,33	1,00	9,00	0,20	5,00	7,00	*0,24*	*0,05*	*0,10*	*0,24*	*0,11*	*0,23*	*0,22*	1,19	**17,07%**	Non-conformity
Absenteeism	0,33	0,14	0,11	1,00	0,11	0,20	0,33	*0,01*	*0,02*	*0,01*	*0,03*	*0,06*	*0,01*	*0,01*	0,15	**2,13%**	Absenteeism
Delivery time	9,00	5,00	5,00	9,00	1,00	9,00	9,00	*0,30*	*0,71*	*0,52*	*0,24*	*0,54*	*0,42*	*0,28*	3,03	**43,24%**	Delivery time
Worker Efficiency	5,00	0,33	0,20	5,00	0,11	1,00	0,33	*0,17*	*0,05*	*0,02*	*0,14*	*0,06*	*0,05*	*0,01*	0,49	**6,99%**	Worker Efficiency
Product performance	0,20	0,11	0,14	3,00	0,11	3,00	1,00	*0,01*	*0,02*	*0,01*	*0,08*	*0,06*	*0,14*	*0,03*	0,35	**4,99%**	Product performance
Total	29,5	7,1	9,6	37,0	1,8	21,4	31,7	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	7,00	100,00%	**Total**

Figure 6.2 - The Strategic Matrix

Step 6: Assessing the importance of LPs through the Performance-Practice Matrix

In this last step, the relevant performances, taking into account their degree of importance, are cross-checked with LPs thanks ISM algorithm by Akao (1990). The level of importance is assigned to every practice by the participants as prescribed in the paragraph 5.3.3; the most important practices are the most correlated with the relevant performances. In the figure 6.3, the Performance-Practice Matrix is shown with the absolute weight of performances calculated thanks to the Strategic Matrix and the level of importance given by the participants with a numeric value: 0,1, 3 or 9 which represent null, weak, moderate, or strong correlation as prescribed by Akao (1990). The results of the Performance-Practice Matrix are the LPs level of importance as shown in Table 6.6.

Process and Equipment	SMED	13,86	Total Productive Maintenance	Autonomous Maintenance	9,40
	Process oriented flow	33,33		Planned Maintenance	34,03
	Poka Yoke	12,22		Proactive Maintenance	18,37
	Workplace organization and cleanliness	12,78		TPM Training	1,47
	Safety and ergonomics	6,94		Maintenance Indexes utilization	18,37
	Point of use and Supermarket	18,37	Employees Empowerment	Training and Integration	8,43
	Flexible equipment	31,48		Upkeep and Development	8,13
	Visual control at workplace	3,58		Multifunctional Workers	21,76
Manufacturing Planning and Control System	Levelled production	1,47	Continuous Improvement	Problem solving methodology	62,11
	Pull planning system	27,24		Standard work	31,62
	Pull scheduling system	28,71		Strategic planning	4,44
	Synchronized production	28,71		Tactical improvement	25,54
	Small lot sizing	27,24		Daily Improvement	21,76
	Zero Inventories	14,79		Organizational structure for continuous improvement	46,03
Suppliers Integration	Blanket Orders	4,24		**Median**	18,37
	TCO - Total Cost of Ownership	10,75			
	Kanban with suppliers	32,95			
	Free pass	24,57			
	Information sharing and mutual exchange	16,91			
	Supplier development	6,73			
	Supplier rationalization	4,44			

Table 6.6 – Level of LPs importance

Performance - Practice Matrix Model

Possible Value:
0=no correlation;
1=weak correlation;
3=average correlation;
9=strong correlation;

Lean Practices

Operational Performances	Operational Performances Weight	*Process and Equipment*: SMED	Process oriented flow	Poka Yoke	Workplace organization and cleanliness	Safety and ergonomics	Point of use and Supermarket	Flexible equipment	Visual control at workplace	*Manufacturing Planning and Control System*: Levelled production	Pull planning system	Pull scheduling system	Synchronized production	Small lot sizing	Zero Inventories
Turnover	0,38	1,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Punctual deliveries	1,41	0,00	3,00	0,00	1,00	0,00	3,00	3,00	0,00	0,00	0,00	0,00	0,00	0,00	3,00
Non-conformity	1,19	0,00	0,00	9,00	3,00	1,00	3,00	0,00	3,00	0,00	0,00	0,00	0,00	0,00	0,00
Absenteeism	0,15	0,00	0,00	0,00	0,00	9,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Delivery time	3,03	3,00	9,00	0,00	1,00	0,00	3,00	9,00	0,00	0,00	9,00	9,00	9,00	9,00	3,00
Worker Efficiency	0,49	9,00	3,00	3,00	9,00	9,00	3,00	0,00	0,00	3,00	0,00	3,00	3,00	0,00	3,00
Product performance	0,35	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total		13,9	33,3	12,2	12,8	6,9	18,4	31,5	3,6	1,5	27,2	28,7	28,7	27,2	14,8

Operational Performances	*Suppliers Integration*: Blanket Orders	TCO - Total Cost of Ownership	Kanban with suppliers	Free pass	Information sharing and mutual exchar	Supplier development	Supplier rationalization	*Total Productive Maintenance*: Autonomous Maintenance	Planned Maintenance	Proactive Maintenance	TPM Training	Maintenance Indexes utilization	*Employees Empowerment*: Training and Integration	Upkeep and Development	Multifunctional Workers	*Continuous Improvement*: Problem solving methodology	Standard work	Strategic planning	Tactical improvement	Daily Improvement	Organizational structure for continuous	***MEDIAN***
Turnover	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00	0,00	9,00	0,00	0,00	3,00	
Punctual deliveries	3,00	0,00	3,00	3,00	3,00	0,00	1,00	1,00	9,00	3,00	0,00	3,00	0,00	0,00	3,00	9,00	3,00	0,00	3,00	3,00	3,00	
Non-conformity	0,00	9,00	0,00	9,00	3,00	3,00	0,00	3,00	9,00	3,00	0,00	3,00	3,00	3,00	3,00	9,00	9,00	0,00	9,00	3,00	9,00	
Absenteeism	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	3,00	1,00	3,00	3,00	0,00	0,00	0,00	3,00	1,00	
Delivery time	0,00	0,00	9,00	3,00	3,00	0,00	1,00	0,00	3,00	3,00	0,00	3,00	0,00	0,00	3,00	9,00	3,00	0,00	3,00	3,00	9,00	
Worker Efficiency	0,00	0,00	3,00	1,00	0,00	0,00	0,00	9,00	3,00	3,00	3,00	3,00	9,00	9,00	9,00	9,00	9,00	0,00	3,00	9,00	3,00	
Product performance	0,00	0,00	0,00	0,00	0,00	9,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00	9,00	3,00	0,00	0,00	3,00	
Total	4,2	10,8	33,0	24,6	16,9	6,7	4,4	9,4	34,0	18,4	1,5	18,4	8,4	8,1	21,8	62,1	31,6	4,4	25,5	21,8	46,0	18,37

Figure 6.3 - the Performance-Practice Matrix

Step 7: The creation of the Priority Map

Having defined for each practice the degree of importance and the gap between current state and optimal profile, the last step of the proposed assessment tool regards the construction of the Priority Map (Figure 6.4) while the Table 6.7 shows the data coming from the previous steps and utilized as input for the Priority Map.

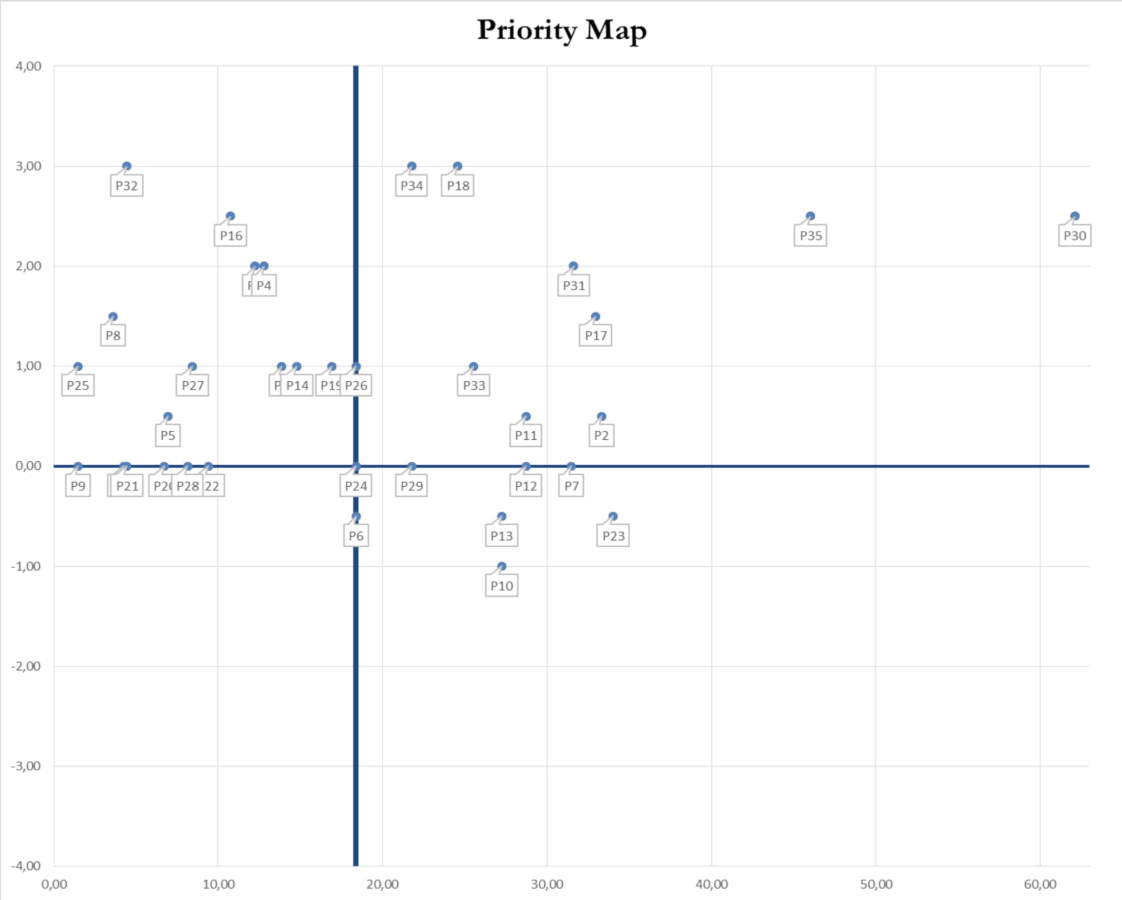


Figure 6.4 – The Priority Map for the Firm AAA

The Priority Map identifies in the right upper quadrant the LPs characterized by gaps in the implementation level and high importance in relation to relevant firm's performances. The threshold for identifying the LPs with high degree of importance is the Median value, in this case is equal to 18,37. The LP 2, 11 and 33 (Process oriented flow, Pull scheduling system and Tactical improvement) are the ones with high importance and low gap (between 0.5 and 1). These are the so called "Quick Win", namely the improvement that, if it is implemented, ensure enhancement with the minimum effort and in short time.

Lean Practice	*LP#*	*LP Importance*	*LP Gap*
SMED	P1	13,86	1
Process oriented flow	P2	33,33	0,5
Poka Yoke	P3	12,22	2
Workplace organization and cleanliness	P4	12,78	2
Safety and ergonomics	P5	6,94	0,5
Point of use and Supermarket	P6	18,37	-0,5
Flexible equipment	P7	31,48	0
Visual control at workplace	P8	3,58	1,5
Levelled production	P9	1,47	0
Pull planning system	P10	27,24	-1
Pull scheduling system	P11	28,71	0,5
Synchronized production	P12	28,71	0
Small lot sizing	P13	27,24	-0,5
Zero Inventories	P14	14,79	1
Blanket Orders	P15	4,24	0
TCO - Total Cost of Ownership	P16	10,75	2,5
Kanban with suppliers	P17	32,95	1,5
Free pass	P18	24,57	3
Information sharing and mutual exchange	P19	16,91	1
Supplier development	P20	6,73	0
Supplier Rationalization	P21	4,44	0
Autonomous Maintenance	P22	9,40	0
Planned Maintenance	P23	34,03	-0,5
Proactive Maintenance	P24	18,37	0
TPM Training	P25	1,47	1
Maintenance Indexes utilization	P26	18,37	1
Training and Integration	P27	8,43	1
Upkeep and Development	P28	8,13	0
Multifunctional Workers	P29	21,76	0
Problem solving methodology	P30	62,11	2,5
Standard work	P31	31,62	2
Strategic planning	P32	4,44	3
Tactical improvement	P33	25,54	1
Daily Improvement	P34	21,76	3
Organizational structure for continuous improvement	P35	46,03	2,5

Table 6.7 – LPs importance level and gap for the priority map

On the other hand, other two LPs have a much higher level of importance: Problem solving methodology and Organizational structure for continuous improvement. These LPs have also a high gap of implementation; it means that company should invest more in terms of resources, efforts and time in order to obtain significant improvements. This is a decision for the assessed organization but, in this last steps, the tool proposes the improvement path to the company thanks to the maturity grids. In fact, to enhance a given LP from the actual level of maturity to the higher desired one, company should follow the description of the actions to undertake contained in the MG.

In this way, the tool has clearly provided to the firm AAA the main areas of interventions according to the firm characteristics and its own strategic objectives in terms of relevant practices; moreover, the tool provides to the firm AAA the improvement paths to reach the optimal level of implementation of LPs characterized by a high level of importance.

6.3 Results of the tool application

Stake (1995) suggests, in selecting the data source, that the main concern should be in understanding which data sources will help understand the case best. It implies that: in selecting cases for the study, the main criteria should not be to find cases representing the entire population but to find those cases that can maximise learning. For this reason, purposeful sampling is utilized in this research (Gummesson 2000, Ellram 1996). Purposeful sampling is generally chosen in case study and other qualitative research, since it provides the occasion to focus on sites and samples (or cases) that best support the accessibility to the type of phenomenon of interest (Lanning, 2001).

Therefore, the abovementioned sample has been chosen to evaluate the quality the research. In fact, the methodology chosen in formulating the construct defines clear criterion of judgment in order to ensure the quality of the research and these criteria have been evaluated in the sample. The data useful for this evaluation has been acquired during the application of the tool within sample's firms. The first source utilized is the available firm's documentation: it is can provide details to corroborate information from other sources (Lanning, 2001). Documents should always be viewed critically, because they do not always present and contain the absolute truth about the subject concerned, yet an investigator is easily prone to think like it. (Yin, 1984). Nevertheless this weakness, documentation is relevant in this research since the implementation of LPs produces a large amount of written documents in disparate production contexts (e.g. maintenance, production scheduling, etc.). Another important source are the direct observations. As stated by Lanning (2001): *"Crucial for observations is to bear in mind the issues of the research and to continuously direct observations towards them. Again, the researcher has to keep a good record of the events observed for further analysis and reporting of the case. These records may be either quantitative or qualitative in nature. In either case, however, observations and record keeping must be carefully planned and in line with the issues under study"*. In fact, thanks to the tool application activity carried out at the sample's firms, the author had the opportunity to track and record relevancies and feedbacks during the assessment sessions.

Company Name	Number of Participants	Role of Participants	Data Source
AAA	7	• Plant director • Two process engineers • Production planning office manager • Technical office manager • Packaging department floor manager • Maintenance technician	Both Documentations and Observations
BBB	4	• Plant director • Continuous Improvement manger • Shop floor team leader • Senior Buyer	Both Documentations and Observations
CCC	5	• Plant director • Continuous Improvement manger • Shop floor team leader • Senior Buyer • Shop floor worker	Observations Access to Documentations not allowed
DDD	4	• Kaizen Promotion Office manager • Senior process engineer • TPM manager • Junior process engineer	Observations Limited access to Documentations
EEE	5	• EEE production system manager • EEE production system team leader • Two Shop floor workers • Maintenance technician	Both Documentations and Observations
FFF	4	• Plant director • Production planning office manager • Shop floor team leader • Junior Buyer	Observations Limited access to Documentations
GGG	5	• Company's Owner • Kaizen Promotion Office manager • Two Shop floor workers • TPM manager	Both Documentations and Observations
HHH	4	• Plant director • Production planning office manager • Kaizen Promotion Office manager • Maintenance technician	Both Documentations and Observations

Table 6.8 - Data sources from the sample and session details

In the Table 6.8 are shown the data sources from the sample, in terms of number of employees participating to the sessions, their role in the firm and data sources specification.

In order to evaluate the quality the research, the methodology chosen in the Chapter 4 defines clear criteria of judgment, these are dived in three main category as prescribed in the literature (Oyegoke, 2011; Lanning, 2001):

1. Use of the construct;
2. Usability of the construct;
3. Usefulness of the construct.

The Use of the construct concerns the practical relevance of the construct, while the Usability and the Usefulness are related to practical functionality of the construct. More in details, Usability refers to the aspects of the construct such as “it is simple and easy to use”, “it is user-friendly”, “it has to possibility to be modified” and “it is tempting”. Usefulness refers to other features of the construct: “it assists and supports in lean transformation program”, “it brings in effectiveness and efficiency”, it keeps the focus on the main critical actions in implementing LPs” and “it simplifies current issues”. The construct has been already tested and utilized in the sample’s firms, the results obtained from the data are summarized in the Table 6.9. This Table depicts as summary the perceived Usability and Usefulness and the intention of Use of the assessment tool. It is important to highlight same of the results: firm CCC evaluates the tool in negative way, the company do not consider the topic of the LPs assessment relevant for its LM program. On the other hand, even if same issues have been highlighted by the firm, the tool’s usefulness seems to be evaluate in a positive way. In addition, same firms suggested to amply the analysis of the tool adding new LPs related to different topics such as Product Development. Anyway, the Table 6.9 neither indicates if there is a causal relationship nor the order of causality between the data collected. Its purposes are only to provide evidences in terms of practical relevance and practical functionality of the construct. With this section, an important objective of this research is showed: the constructive methodology prescribed that the proposed construct should works providing a solution to the identified problem due to the applied nature of this research.

	AAA	BBB	CCC	DDD	EEE	FFF	GGG	HHH
USE of the construct	Firm declares that would like to use the tool in the future to assess again its lean journey	The plant director and the Continuous Improvement manger agreed to have other sessions of assessment	The company does not show enthusiasm in the lean assessment topic	Firm will evaluate to use the tool in the future to assess again its lean transformation program	The company has already developed an production system inspired to the TPS with a related assessment procedure	Firm use the tool as a reminder, a source of ideas and an aid for continuous improvement meeting preparation	Kaizen Promotion Office developed its own assessment tool, nevertheless it wants to use the tool to compare the results	Kaizen Promotion Office declares that the tool may be utilized for incoming Kaizen Weeks
USABILITY of the construct	The contents of the tool and the MGs are clear and useful, some important observations on the Performance-Practice Matrix	Some minor issues on the MGs corrected, the tool framework it clear	Low user friendliness	For the Firm necessities, another LP should be assessed: the practice of "go and see"	For the firm it is easier to use its own assessment model	The tool provides in a short time useful information as support for other activities	For the firm it is easy to use to tool and its own assessment model as well	The Performance-Practice Matrix it is not easy to fulfill by participants
USEFULNESS of the construct	The contents of the tool and the MGs capture the real issue related to the LPs implementation	The Continuous Improvement manager declares that the tool covers all main areas of interest, moreover it would be interesting to investigate the New Product Develop. In lean perspective	The tool cannot fit with the firm's needs in terms of lean implementation	The potential of the tool is great thanks to its two levels of contingency	Participants do not perceive the usefulness of the tool, since their assessment mode is based on paradigmatic approach	The participants state that the most relevant feature of the tool is only to identification of gap or overshooting implementing level	The tool provides valuable indications for the improvement paths thanks to the MGs	Tool is perceived useful in many ways. Obviously, it also had positive effect on Kaizen projects

Table 6.9 – Use, Usability and Usefulness of the proposed tool

6.4 Theoretical Contribution and Managerial Implications

6.4.1 Theoretical Contribution

In this section, the construct's connection to the existing theory and theoretical novelty is discussed. Regarding the existing theory in the problem domain, the connection of this research is provided thanks to the literature review described in Chapter 3 developed in accordance with the methodology of by Tranfield et al. (2003). The first outcome is a novel classification of 35 LPs in six Lean Operational Constructs divided in two categories: Primary and Support Practices. The second outcome of the literature review is the classification of existent LATs according to the assessment focus (practices rather than performances) and the method of assessment (subjective or objective). The third outcome is the evaluation of current LATs addressing the knowledge base incorporated in the tools according to the logic of conformity or coherence; this last classification highlights the absence of assessment tool for SMEs structured with a *normative-contingent* approach, in which the prescriptive requirements are situation-specific. In addition, the thematic literature review allows to define the necessary features for the proposed assessment tool with a theoretical grounded-based approach.

As prescribed by the adopted research methodology, the theoretical contributions of the proposed construct should be posited; it implies that its novelty and scope of application should be clearly stated (Oyegoke, 2011). Firstly, the assessment tool formulated in this research proposes 35 MGs for the evaluations of LPs implementation. The MGs are developed according to the methodology proposed by Maier et al. (2012), it unarguably adds to the body of lean practices maturity level evaluation knowledge. The MGs provide to theory, by one hand, a theoretical grounded instrument to evaluate the maturity level of selected LPs. On the other hand, the MGs are developed with a prescriptive approach. It means that specific and detailed courses of actions are suggested for each level. In this way, the MGs may be utilized by the firm to reach a higher-level just following the course of actions suggested. Furthermore, the assessment tool is formulated with a contingent approach based upon the logic of coherence, where requirements vary in relation to the contextual conditions internal and external to the organization. More specifically, the tool possesses two level of contingence: the first one consists in assessing the degree of LPs implementation considering the organizational/production context, the second one lies in defining improvement paths in line with strategic objective of the company.

In summary, considering the above conclusions the construct novelty in terms of practical and theoretical contribution is clear. It is the construct as a whole, that combines different elements from the QFD, AHP, maturity evaluation etc. It makes the assessment tool unique and different from other constructs. Both, the practical and theoretical novelty are thus discussed and demonstrated.

6.4.2 Managerial Implications

The managerial implications of the tools firstly arise from the analysis of the Table 6.9. In the Table 6.10 for each element of analysis (Use, Usability and Usefulness of the construct) relevant observation in terms of managerial implications are described.

	Managerial Implications
USE of the construct	As stated by the majority of firm analyses, the tools is in line with lean manufacturing transformation program and continuous improvement initiatives.
USABILITY of the construct	The assessment tool's elements are clear and ease to use; e.g. MGs provide important information for support activities. Nevertheless same important observations on the Performance-Practice Matrix that have been taken into account for improvement corrections.
USEFULNESS of the construct	The contents of the tool cover all main areas of interest and capture the real issue related to the LPs implementation. Several managers declare the potential of the tool is great thanks to its two levels of contingency.

Table 6.10 – Managerial Implications

The feedbacks obtained from the managers and participants have been considered for the refining and final formulation for the proposed assessment tool.

Moreover, the tool proposed has several elements that support the business activity:

1. MGs: this element provides an useful tool to assess the current level of LP implementation and describes at the same time the initiatives to implement in order to fill the gap to reach the optimal LP implementation;

2. Radar chart: it is an universal tool utilized in the business sector to show the current state and the future state to reach;
3. Priority Map: it provides in a clear and ease way a picture of LPs assessment within the firm according to two dimensions of analysis: the magnitude of implementation gap and the degree of LP importance referring to firm's characteristics and strategy. In addition, it provides improvement paths as described in the chapter 5.4.

Chapter 7: Conclusions

Nowadays, the small and medium-sized firms adopting the principles, methodologies, practices and tools developed within the lean manufacturing are facing the issue related to the lack of clear implementation processes and dedicated frameworks. In fact, even if the majority of firms obtain impressive initial gains, they are not able to sustain and/or to spread these gains to the entire productive organization.

Therefore, becomes vital for SMEs to review their Lean transformation program in order to create opportunities for continuous improvement, monitoring the path took and the direction to follow. It implies to act in-line with the value for the final customer and the strategic objectives of the company at same time, in order to identify the most urgent area to enhance according to firm's characteristics providing clear initiatives of improvement. In fact, the measure of lean practices implementation and the selection of right measuring metrics with appropriate implementation method are very crucial (Arif-Uz-Zaman, 2013). A clear understanding of these aspects helps to close the gap between theory and practice and provides an effective solution to SMEs of manufacturing sector.

Therefore, the first research question is: "*How a SME can assess the adoption of Lean accordingly to its own characteristics?".* The answer to the first research question is provided in Chapter 3. Thanks to the literature review, the evaluation of current lean assessment tools has been performed, highlighting the absence of tool for SMEs structured with a *normative-contingent* approach, in which the prescriptive requirements are situation-specific. In addition, the thematic literature review allows to define the characteristics of the current LATs identifying the necessary features for the proposed assessment tool.

The second research question is. *"Which are the methods and tools that can support SMEs in assessing the adoption of Lean?".* In the Chapter 4, the constructive research has been adopted to answer to this practical problem proposing an assessment tool for the evaluation of lean practices implementation. In fact, constructive research is about solving problems proposing a construct (e.g., a model, a plan, a tool or a framework). However, mere problem solving does not fulfil the requirements of producing scientific research. Furthermore, a crucial part of constructive research is to relate and compare the theoretical results with existing body of knowledge and to prove the novelty and usefulness of the construct (Lanning, 2001). This, however, brings along another challenge to constructive research: testing the use, the usability and the usefulness of the construct as done in the Chapter 6.

The third research question is: *"How can these methods and tools be applied for the improvement planning taking into account the strategic objectives of the company?".* In the Chapter 5, the assessment tool architecture structured with a *normative-contingent* approach is proposed, where requirements vary in relation to the contextual conditions internal and external to the organization. More specifically, the tool possesses two level of contingence: the first one consists in assessing the degree of LPs implementation considering the organizational/production context thanks to the Optimal Profile Generation Matrix. The second one lies in defining improvement paths in line with strategic objective of the company thanks the Performance-Practice Matrix, the Priority Map and the prescriptive approach of the MGs.

7.1 Limitations and issues for further research

There is always a limit to what a researcher can achieve during the research study. Identifying the limitations of a research strengthens the findings validity and the reliability of the research process.

The first limitation is concerned the fact that this research focuses only on firms that apply lean practices, tools and methodologies developed in manufacturing sector. In the last decade, the lean thinking has been expanding in new research streams such as product development, office, high education and health. This can limit the potential of generalising the results, but it is relevant to highlight that generalisability in qualitative research is not related to statistical sampling (e.g. the number of cases) but rather to theoretical replication (e.g. applicability of concepts in other environments and sectors).

The second limitation is that can be biases introduced by the data utilized for the evaluation of the proposed construct in terms of usability and usefulness. Firms' documentation and direct observations are not a limitation only for this research, rather for most of the qualitative research. However, due to the scope and the nature of this qualitative research, the researcher could not find any other kind of data collection that would avoid any sort of biases.

The third limitation is the geographical restriction for choosing the firm of the sample. As stated, the present research is financed by the Italian government with a strictly focus on the improvement of advanced manufacturing systems relevant for the "Made in Italy" industry. For these reason, the researcher identified a sample of eight firms in the Northeast region of Italy.

Moreover, as the study progressed, the researcher identified same areas for future investigations.

The first one is to identify the LPs developed in other context as product development, office, high education, health etc. With a theoretically grounded definitions of such LPs, researchers may adopt the approach of the tool proposed in this thesis to assess organizations in other sectors.

The second possible future investigation is to identify samples of firms from different geographical areas. It may be interesting to apply the proposed tool in other areas where the impact of different organisational culture and socio-economic context on the implementation of Lean practices could be investigated.

The last and more challenging investigation is how to succeed in introducing and applying over time the new construct of assessment in organizations. One topic for further research would be solving the problem of continuous use of proposed tool in organisation thanks to an innovative implementation procedure that combines the integration of the tool with IT solutions.

References

Achanga, P., Shehab, E., Roy, R., & Nelder, G. (2006). Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management*, *17*(4), 460-471.

Adams, R., Bessant, J., & Phelps, R. (2006). Innovation management measurement: A review. *International Journal of Management Reviews*, *8*(1), 21-47.

Agus, A., & Shukri Hajinoor, M. (2012). Lean production supply chain management as driver towards enhancing product quality and business performance: Case study of manufacturing companies in Malaysia. *International Journal of Quality & Reliability Management*, *29*(1), 92-121.

Allen, J., Stewart, D., & Robinson, C. (2001). *Lean Manufacturing: A plant floor guide*. Society of Manufacturing Engineers.

Anand, G., & Kodali, R. (2008). Selection of lean manufacturing systems using the PROMETHEE. *Journal of modelling in management*, *3*(1), 40-70.

Anvari AR, Mojahed M, Zulkifli N, Yusuff RM, Ismail Y, Hojjati SMH (2011) A group AHP-based tool to evaluate effective factors toward leanness in automotive industries. J Appl Sci. doi:10.3923/ jas.20ll

Anvari, A., Zulkifli, N., & Yusuff, R. M. (2013). A dynamic modeling to measure lean performance within lean attributes. *The International Journal of Advanced Manufacturing Technology*, 1-15.

Aoko, Y. (1990). Quality Function Deployment (QFD): Integrating customer requirements into product design.

Azadeh, A., Zarrin, M., Abdollahi, M., Noury, S., & Farahmand, S. (2015). Leanness assessment and optimization by fuzzy cognitive map and multivariate analysis. *Expert Systems with Applications*, *42*(15), 6050-6064.

Bayou, M. E., & De Korvin, A. (2008). Measuring the leanness of manufacturing systems—a case study of Ford Motor Company and General Motors. *Journal of Engineering and Technology Management*, *25*(4), 287-304.

Becheikh, N., Landry, R., & Amara, N. (2006). Lessons from innovation empirical studies in the manufacturing sector: A systematic review of the literature from 1993–2003. *Technovation*, *26*(5), 644-664.

Behrouzi, F., & Wong, K. Y. (2013). An integrated stochastic-fuzzy modeling approach for supply chain leanness evaluation. *The International Journal of Advanced Manufacturing Technology*, 68(5-8), 1677-1696.

Bhamu, J., & Singh Sangwan, K. (2014). Lean manufacturing: literature review and research issues. *International Journal of Operations & Production Management*, *34*(7), 876-940.

Bhasin, S. (2011). Measuring the Leanness of an organisation. *International Journal of Lean Six Sigma*, *2*(1), 55-74.

Biazzo S., de Crescenzo A.M., Panizzolo R., (2016), Towards the assessment of lean implementation in small and medium enterprises, 5th World conference on Production and Operations Management P&O M, September 6th-10th Havana, Cuba

Bowen, H. K., & Spear, S. (1999). Decoding the DNA of the Toyota production system. *Harvard Business Review*.

Brown, R., Lewis, A., & Mumby, A. (1996). Enhancing design effectiveness in very small companies. *Design Engineering Research Centre, Cardiff.*

Camacho-Miñano, M. D. M., Moyano-Fuentes, J., & Sacristan-Diaz, M. (2013). What can we learn from the evolution of research on lean management assessment? *International Journal of Production Research*, 51(4), 1098-1116.

Carter, C. R., & Liane Easton, P. (2011). Sustainable supply chain management: evolution and future directions. *International journal of physical distribution & logistics management*, *41*(1), 46-62.

Cawood, G. (1997). Design innovation and culture in SMEs. *Design Management Review*, *8*(4), 66-70.

Cezar Lucato, W., Araujo Calarge, F., Loureiro Junior, M., & Damasceno Calado, R. (2014). Performance evaluation of lean manufacturing implementation in Brazil. *International Journal of Productivity and Performance Management*, *63*(5), 529-549.

Chen, F. F. (2005, January). Quantifying Leanness and Agility of Manufacturing Systems. In *IIE Annual Conference. Proceedings* (p. 1). Institute of Industrial and Systems Engineers (IISE).

Chiva, R., & Alegre, J. (2004). Design management approaches in the Spanish ceramic sector: a comparative case study. *International Journal of Product Development*, *1*(2), 215-233.

Clough, P., & Nutbrown, C. (2012). *A student's guide to methodology*. Sage.

Collins, J., & Hussey, R. (2003). Business research. *A practical guide for undergraduate and postgraduate students, Polgrave Macmillan, New York*.

Comm, C. L., & Mathaisel, D. F. (2000). A paradigm for benchmarking lean initiatives for quality improvement. *Benchmarking: An International Journal*, *7*(2), 118-128.

Conner, G. (2001). *Lean manufacturing for the small shop*. Dearborn, MI: Society of Manufacturing Engineers

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. *International journal of operations & production management*, *22*(2), 220-240.

Crnkovic, G. (2010). Constructive research and info-computational knowledge generation. *Model-Based Reasoning in Science and Technology*, *314*, 359-380.

Cua, K. O., McKone, K. E., & Schroeder, R. G. (2001). Relationships between implementation of TQM, JIT, and TPM and manufacturing performance. *Journal of operations management*, *19*(6), 675-694.

Dahlgaard, J. J., & Mi Dahlgaard-Park, S. (2006). Lean production, six sigma quality, TQM and company culture. *The TQM magazine*, *18*(3), 263-281.

Dean, J. W., & Bowen, D. E. (1994). Management theory and total quality: improving research and practice through theory development. *Academy of management review*, *19*(3), 392-418.

Dennis, P. (2016). *Lean Production simplified: A plain-language guide to the world's most powerful production system*. Crc press.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). *The Sage handbook of qualitative research*. Sage.

Doolen, T. L., & Hacker, M. E. (2005). A review of lean assessment in organizations: an exploratory study of lean practices by electronics manufacturers. *Journal of Manufacturing systems*, *24*(1), 55-67.

Dunning, J. H. (1979). Explaining changing patterns of international production: in defence of the eclectic theory. *Oxford bulletin of economics and statistics*, *41*(4), 269-295.

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2012). *Management research*. Sage.

Eden, C., & Huxham, C. (1996). Action research for management research. *British Journal of Management*, *7*(1), 75-86.

Edwards, S. (2009). *Understanding the Three Basic Elements of Manufacturing Costs.* Source available on 17/03/2017 at: https://www.schneiderdowns.com/our-thoughts-on/manufacturing/Understanding_and_Controlling_the_Three_Basic_Elements_of_Manufacturing_Costs

El-Haik, B., & Al-Aomar, R. (2006). *Simulation-based lean six-sigma and design for six-sigma*. John Wiley & Sons.

Ellram, L. M. (1996). The use of the case study method in logistics research. *Journal of business logistics*, *17*(2), 93.

Emiliani, M. L. (2000). Cracking the code of business. *Management Decision*, *38*(2), 60-79.

Farris, W. W. (2006). *Japan's medieval population: famine, fertility, and warfare in a transformative age*. University of Hawaii Press.

Feld, W. M. (2000). *Lean manufacturing: tools, techniques, and how to use them*. CRC Press.

Filson, A., & Lewis, A. (2000). Barriers between design and business strategy. *Design Management Review*, *11*(4), 48-52.

Flynn, B. B., Sakakibara, S., & Schroeder, R. G. (1995). Relationship between JIT and TQM: practices and performance. *Academy of management Journal*, *38*(5), 1325-1360.

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. *Decision sciences*, *26*(5), 659-691.

Freel, M. S. (2000). Barriers to product innovation in small manufacturing firms. *International Small Business Journal*, *18*(2), 60-80.

Fuss, M. A., & Waverman, L. (1985). Productivity Growth in the Automobile Industry, 1970-1980: A Comparisonof Canada, Japan and the United States.

Garengo, P., Biazzo, S., & Bititci, U. S. (2005). Performance measurement systems in SMEs: A review for a research agenda. *International journal of management reviews*, *7*(1), 25-47.

Ghosh, M. (2012). Lean manufacturing performance in Indian manufacturing plants. *Journal of Manufacturing Technology Management*, *24*(1), 113-122.

Gnanaraj, S. M., Devadasan, S. R., Murugesh, R., & Shalij, P. R. (2010). DOLADMAICS: a model for implementing Lean Six Sigma in contemporary SMEs. *International Journal of Services and Operations Management*, *7*(4), 440-464.

Gomes, J., Weerd–Nederhof, D., Petra, C., Pearson, A., & Fisscher, O. A. (2001). Senior management support in the new product development process. *Creativity and Innovation Management*, *10*(4), 234-242.

Goodson, R. E. (2002). Read a plant-fast. *Harvard business review*, *80*(5), 105-113.

Gummesson, E. (2000). *Qualitative methods in management research*. Sage, London.

Hadjimanolis, A. (2000). A resource-based view of innovativeness in small firms. *Technology analysis & Strategic management*, *12*(2), 263-281.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International journal of operations & production management*, *17*(1), 46-64.

Hines, P., Holweg, M., & Rich, N. (2004). Learning to evolve: a review of contemporary lean thinking. *International journal of operations & production management*, *24*(10), 994-1011.

Hino, S. (2006). Inside the mind of Toyota. *Management Principles for Enduring Growth, New York*.

Hirano, H. (1995). *5 pillars of the visual workplace*. CRC Press.

Hu, Q., Mason, R., Williams, S. J. and Found, P. (2015), "Lean implementation within SMEs: a literature review", *Journal of Manufacturing Technology Management*, Vol. *26*, No.7, pp. 980-1012.

Huang, X., Soutar, G. N., & Brown, A. (2002). New product development processes in small and medium-sized enterprises: some Australian evidence. *Journal of Small Business Management*, *40*(1), 27-42.

James-Moore, S. M., & Gibbons, A. (1997). Is lean manufacture universally relevant? An investigative methodology. *International Journal of Operations & Production Management*, *17*(9), 899-911.

Jasti, N. V. K., & Kodali, R. (2015). Lean production: literature review and trends. *International Journal of Production Research*, *53*(3), 867-885.

Jordan, J. A., & Michel, F. J. (2001). *The lean company: making the right choices*. Society of Manufacturing Engineers.

Karim, A., & Arif-Uz-Zaman, K. (2013). A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations. *Business Process Management Journal*, *19*(1), 169-196.

Karlsson, C., & Åhlström, P. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management*, *16*(2), 24-41.

Kasanen, E., Lukka, K., & Siitonen, A. (1991). The Constructive Research Approach in Economics. *The Finnish Journal of Business Economics*, *40*, 301-329.

Kim, W. C., & Mauborgne, R. (2005). Blue Ocean Strategy: How to Create Uncontested Market Space and Make Competition Irrelevant: Harvard Business School Press. *Boston, MA*.

Kochan, T. A., Lansbury, R. D. and Macduffie, J. P. (Eds.). (1997), *After lean production: Evolving employment practices in the world auto industry* (No. 33). Cornell University Press.

Krafcik, J. F. (1988). Triumph of the lean production system. *MIT Sloan Management Review*, *30*(1), 41.

Lanning, H. (2001). *Planning and implementing change in organisations: a construct for managing chance projects*. Helsinki University of Technology.

Lewin, K. (1946). Action research and minority problems. *Journal of social issues*, *2*(4), 34-46.

Li, J. (2013). Continuous improvement at Toyota manufacturing plant: applications of production systems engineering methods. *International Journal of Production Research*, *51*(23-24), 7235-7249.

Liker, J. K. (1997). *Becoming lean: Inside stories of US manufacturers*. CRC Press.

Long, R. G., White, M. C., Friedman, W. H., & Brazeal, D. V. (2000). The Qualitative Versus Quantitative Research Debate: A Question of Metaphorical Assumptions? *International Journal of Value-Based Management*, *13*(2), 189-197.

Macpherson, A., & Holt, R. (2007). Knowledge, learning and small firm growth: A systematic review of the evidence. *Research policy*, *36*(2), 172-192.

Maier, A. M., Moultrie, J., & Clarkson, P. J. (2012). Assessing organizational capabilities: reviewing and guiding the development of maturity grids. *IEEE Transactions on Engineering Management*, *59*(1), 138-159.

Mann, D. (2014), *Creating a lean culture: tools to sustain lean conversions*, CRC Press.

March-Chorda, I., Gunasekaran, A., & Lloria-Aramburo, B. (2002). Product development process in Spanish SMEs: an empirical research. *Technovation*, *22*(5), 301-312.

Marchini I. (1998), Il governo della piccola impresa, Vol. III – *La gestione delle funzioni, Genova, Aspi/Ins-Edit.*

Maritan, D. (2015). *Practical Manual of Quality Function Deployment*. Springer.

Mazzi, C. (2011). Family business and financial performance: Current state of knowledge and future research challenges. *Journal of Family Business Strategy*, *2*(3), 166-181.

McIvor, R. (2001). Lean supply: the design and cost reduction dimensions. *European Journal of Purchasing & Supply Management*, *7*(4), 227-242.

McLachlin, R. (1997). Management initiatives and just-in-time manufacturing. *Journal of Operations Management*, *15*(4), 271-292.

Millward, H., & Lewis, A. (2005). Barriers to successful new product development within small manufacturing companies. *Journal of Small Business and Enterprise Development*, *12*(3), 379-394.

Monden, Y. (1981). Adaptable Kanban system helps Toyota maintain just-in-time production. *Industrial Engineering*, *13*(5), 29.

Monden, Y. (1986). Applying Just in Time: The American-Japanese Experience. Industrial Engineering and Management Press, Institute of Industrial Engineers.

Monden, Y., (1998). *Toyota Production System: an Integrated Approach to Just-in-Time*, 3rd ed.,

Motwani, J. (2003). A business process change framework for examining lean manufacturing: a case study. *Industrial Management & Data Systems*, *103*(5), 339-346.

Moyano-Fuentes, J., & Sacristán-Díaz, M. (2012). Learning on lean: a review of thinking and research. *International Journal of Operations & Production Management*, *32*(5), 551-582.

Nabhani, F., & Shokri, A. (2009). Reducing the delivery lead time in a food distribution SME through the implementation of six sigma methodology. *Journal of manufacturing technology Management*, *20*(7), 957-974.

Nasab, H. H., & Zare, H. K. (2012). Finding a probabilistic approach to analyze lean manufacturing. Journal of Cleaner Production, 29, 73-81.

Naylor, J. B., Naim, M. M., & Berry, D. (1999). Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of production economics*, *62*(1), 107-118.

Nightingale, D. (2001). LESAT: The Lean Enterprise Self Assessment Tool.

Ohno, T. (1988). *Toyota production system: beyond large-scale production*. crc Press.

Oyegoke, A. (2011). The constructive research approach in project management research. *International Journal of Managing Projects in Business*, *4*(4), 573-595.

Pakdil, F., & Leonard, K. M. (2014). Criteria for a lean organisation: development of a lean assessment tool. *International Journal of Production Research*, *52*(15), 4587-4607.

Panizzolo, R. (1998). Applying the lessons learned from 27 lean manufacturers.: The relevance of relationships management. *International journal of production economics*, *55*(3), 223-240.

Panizzolo, R., Biazzo, S., & Garengo, P. (2010). New product development assessment: towards a normative-contingent audit. *Benchmarking: An International Journal*, *17*(2), 173-194.

Panizzolo, R., Garengo, P., Sharma, M. K., & Gore, A. (2012). Lean manufacturing in developing countries: evidence from Indian SMEs. *Production Planning & Control*, *23*(10-11), 769-788.

Pavnaskar, S. J., Gershenson, J. K. and Jambekar, A. B. (2003), "Classification scheme for lean manufacturing tools", *International Journal of Production Research*, Vol. *41*, No.13, pp. 3075-3090.

Petersen, K. (2010). Is lean agile and agile lean. *Modern Software Engineering Concepts and Practices: Advanced Approaches*, 19.

Phelps, R., Adams, R., & Bessant, J. (2007). Life cycles of growing organizations: A review with implications for knowledge and learning. *International Journal of Management Reviews*, *9*(1), 1-30.

Philips, E. (2002). Pros and cons of lean manufacturing. *Forming and Fabricating*, *9*(10), 1-5.

Radnor, Z. J., & Boaden, R. (2004). Developing an understanding of corporate anorexia. *International Journal of Operations & Production Management*, *24*(4), 424-440.

Rapoport, R. N. (1970). Three dilemmas in action research: with special reference to the Tavistock experience. *Human relations*, *23*(6), 499-513.

Röglinger, M., Pöppelbuß, J., & Becker, J. (2012). Maturity models in business process management. *Business Process Management Journal*, *18*(2), 328-346.

Romano, C. A. (1990). Identifying factors which influence product innovation: a case study approach. *Journal of Management Studies*, *27*(1), 75-95.

Ross, J. E., & Perry, S. (1999). *Total quality management: Text, cases, and readings*. CRC Press.

Rother, M., & Shook, J. (2003). *Learning to see: value stream mapping to add value and eliminate muda*. Lean Enterprise Institute.

Saaty, T. L. (1980). The Analytic Hierarchy Process, NY. *McGraw-Hill, USA. Cook WD and Seiford LM. (1978). Priority ranking and consensus formation, Management Science*, *24*, 1721-1732.

Sakakibara, S., Flynn, B. B., & Schroeder, R. G. (1993). A framework and measurement instrument for just- in- time manufacturing. *Production and Operations Management*, *2*(3), 177-194.

Sakakibara, S., Flynn, B. B., Schroeder, R. G., & Morris, W. T. (1997). The impact of just-in-time manufacturing and its infrastructure on manufacturing performance. *Management Science*, *43*(9), 1246-1257.

Salavou, H., & Lioukas, S. (2003). Radical product innovations in SMEs: the dominance of entrepreneurial orientation. *Creativity and innovation management*, *12*(2), 94-108.

Sanati, F., & Seyedhoseini, S. M. (2008). New concept in leanness development and assessment in plant life cycle (PLC). *International Journal of Industrial Engineering & Production Research*, *19*(1), 57-65.

Sánchez, A., & Pérez, M. (2001). Lean indicators and manufacturing strategies. *International Journal of Operations & Production Management*, *21*(11), 1433-1452.

Saurin, T. A., G. A. Marodin, and J. L. D. Ribeiro. 2011. "A Framework for Assessing the Use of Lean Production Practices in Manufacturing Cells." *International Journal of Production Research* 49: 3211–3230.

Seyedhosseini, S. M., Taleghani, A. E., Bakhsha, A., & Partovi, S. (2011). Extracting leanness criteria by employing the concept of Balanced Scorecard. *Expert Systems with Applications*, *38*(8), 10454-10461.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of operations management*, *21*(2), 129-149.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of operations management*, *25*(4), 785-805.

Shah, R., Goldstein, S. M., Unger, B. T., & Henry, T. D. (2008). Explaining anomalous high performance in a health care supply chain. *Decision Sciences*, *39*(4), 759-789.

Shepherd, C., & Günter, H. (2006). Measuring supply chain performance: current research and future directions. *International Journal of Productivity and Performance Management*, *55*(3/4), 242-258.

Shingo, S. (1985). *A revolution in manufacturing: the SMED system*. CRC Press.

Shingo, S. (1989), A Study of the Toyota Production System from an Industrial Engineering Viewpoint, Productivity Press, Portland, OR.

Sign (2004). Systematic literature review. In A Guideline Developers' Handbook; SIGN Publication No. 50.

Sitkin, S. B., Sutcliffe, K. M., & Schroeder, R. G. (1994). Distinguishing control from learning in total quality management: A contingency perspective. *Academy of management review*, *19*(3), 537-564.

Slack, N., Brandon-Jones, A., & Johnston, R. (2013). *Operations management*. Pearson Ed.

Slack, R. A. (1999). *The lean value principle in military aerospace product development*.

Soriano-Meier, H., & Forrester, P. L. (2002). A model for evaluating the degree of leanness of manufacturing firms. *Integrated Manufacturing Systems*, *13*(2), 104-109.

Srinivasaraghavan, J., & Allada, V. (2006). Application of mahalanobis distance as a lean assessment metric. *The International Journal of Advanced Manufacturing Technology*, *29*(11), 1159-1168.

Stake, R. E. (1995). *The art of case study research*. Sage Publications, London.

Stuart, I., & Boyle, T. (2007). Advancing the adoption of 'Lean' in Canadian SMEs. *Ivey Business Journal*, *71*(3), 1-5.

Suárez-Barraza, M. F., Smith, T., & Dahlgaard-Park, S. M. (2012). Lean Service: A literature analysis and classification. *Total Quality Management & Business Excellence*, *23*(3-4), 359-380.

Sugimori, Y., Kusunoki, K., Cho, F., & Uchikawa, S. (1977). Toyota production system and kanban system materialization of just-in-time and respect-for-human system. *The International Journal of Production Research*, *15*(6), 553-564.

Thorpe, R., Holt, R., Macpherson, A., & Pittaway, L. (2005). Using knowledge within small and medium-sized firms: A systematic review of the evidence. *International Journal of Management Reviews*, *7*(4), 257-281.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222.

Vimal, K. E. K., & Vinodh, S. (2012). Leanness evaluation using IF–THEN rules. *The International Journal of Advanced Manufacturing Technology*, *63*(1-4), 407-413.

Vimal, K. E. K., & Vinodh, S. (2013). Application of artificial neural network for fuzzy logic based leanness assessment. *Journal of Manufacturing Technology Management*, *24*(2), 274-292.

Vinodh, S., & Balaji, S. R. (2011). Fuzzy logic based leanness assessment and its decision support system. *International Journal of Production Research*, *49*(13), 4027-4041.

Vinodh, S., & Kumar Chintha, S. (2011). Application of fuzzy QFD for enabling leanness in a manufacturing organisation. *International Journal of Production Research*, *49*(6), 1627-1644.

Vinodh S, Chintha SK (2011) Leanness assessment using multi-grade fuzzy approach. *International Journal of Production Research,* 49(2):431–445

Vinodh, S., & Vimal, K. E. K. (2012). Thirty criteria based leanness assessment using fuzzy logic approach. *The International Journal of Advanced Manufacturing Technology*, *60*(9-12), 1185-1195.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International journal of operations & production management*, *22*(2), 195-219.

Wan, H. D., & Frank Chen, F. (2008). A leanness measure of manufacturing systems for quantifying impacts of lean initiatives. *International Journal of Production Research*, *46*(23), 6567-6584.

Wilson, L. (2010). *How To Implementing Lean Manufacturing and The Toyota Production System*. New York: Mc-Graw Hill

Wilson, M. M., & Roy, R. N. (2009). Enabling lean procurement: a consolidation model for small-and medium-sized enterprises. *Journal of Manufacturing Technology Management*, *20*(6), 817-833.

Womack, J. P., & Jones, D. T. (1996). Lean thinking: Banish waste and create wealth in your organisation. *Simon and Shuster, New York, NY*, *397*.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *Machine that changed the world*. Simon and Schuster.

Wong, W. P., Ignatius, J., & Soh, K. L. (2014). What is the leanness level of your organisation in lean transformation implementation? An integrated lean index using ANP approach. *Production Planning & Control*, *25*(4), 273-287.

Woodcock, D. J., Mosey, S. P., & Wood, T. B. W. (2000). New product development in British SMEs. *European Journal of Innovation Management*, *3*(4), 212-222.

Yin, R. K. (1994). *Case study research: Design and methods*. Sage Publications, London.