International Journal of Business Quantitative Economics and Applied Management Research

ISSN: 2349-5677

Volume 1, Issue 6, November 2014

Lean, Six Sigma and Lean Six Sigma Overview

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***Abstract*— Lean is an approach that seeks to improve flow in the value stream and eliminate waste. It's about doing things quickly. Six Sigma uses a powerful framework (DMAIC) and statistical tools to uncover root causes to understand and reduce variation. It's about doing things right (defect free).A combination of both provides an over-arching improvement philosophy that incorporates powerful data-driven tools to solve problems and create rapid transformational improvement at lower cost.**

Index Terms— **lean, six sigma, lean six sigma, TQM, JIT, DMAIC, PDCA, PDSA, VVFPP ,VSM,7 wastes, 5S, SMED , SPC**

I. Lean And Six Sigma Overview

Two of the most popular continuous improvement programs are Six Sigma and lean management. Six Sigma was founded by Motorola Corporation and subsequently adopted by many US companies, including General Electrical GE and Allied Signal. Lean management originated at Toyota in Japan and has been implemented by many major US firms, including Danaher Corporation and Harley-Davidson. Six Sigma and lean management have diverse roots, (Arnheiter and Maleyeff, 2005).

Six sigma and lean are new methods, or if they are repackaged versions of previously popular methods – total quality management (TQM) and just-in-time (JIT), (Naslund, 2008).

Both Six Sigma and lean management have evolved into comprehensive management systems which clarify in lean six sigma methodology. In each case, their effective implementation involves cultural changes in organizations, new approaches to production and to servicing customers, and a high degree of training and education of employees, from upper management to the shop floor. As such, both systems have come to encompass common features, such as an emphasis on customer satisfaction, high quality, and comprehensive employee training and empowerment, (Arnheiter and Maleyeff, 2005).

Some elements to eliminate many misconceptions regarding Six Sigma and lean management by describing each system and the key concepts and techniques that underlie their implementation, (Arnheiter and Maleyeff, 2005).

International Journal of Business Quantitative Economics and Applied Management Research
ISSN: 2349-5677
Volume 1, Issue 6, November 2014

II. LEAN MANUFACTURING

2.1 Lean Definition

Lean defined as systematic approach to identifying and eliminating non value add (wastes) through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection.(Andersson, et al 2006)

"Lean production" term is a result of the benchmarking results from the IMVP. The word "lean" was suggested because the best assembly plants (the Japanese plants) (Womack et al., 1990, p. 13).(Dahlgaard, Park 2006),

2.2 Lean Overview

The concept of lean management can be traced to the Toyota production system (TPS), a manufacturing philosophy pioneered by the Japanese engineers TaiichiOhno andShigeo Shingo,(Arnheiter and Maleyeff,2005).

Toyota Production System (TPS) is recognized with being the birthplace of just-in-time (JIT)production methods, a key element of lean production, and for this reason the TPS remains a model of excellence for supportive of lean manage-ment,(Arnheiter and Maleyeff,2005).

TPS was the developed of manufacturing began shortly after the Second World War, pioneered by Taiichi Ohno and associates, while employed by the Toyota motor company. Forced by shortages in both capital and resources, Eiji Toyoda trained his workers to eliminate all types waste (seven wastes). Eiji defined the waste as "anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product" (Russell and Taylor, 2000, p. 737),(Pepper,Spedding ,2010).

The Toyota Production System (TPS) became the dominant production model to emerge from number of concepts around at the time (Katayama and Bennett, 1996; Bartezzaghi, 1999). As a result of the International Motor Vehicle Program (IMVP) benchmarking study, and the work of Womack et al. (1990), US and European companies began adapting the TPS under the title of just-in-time (JIT) to remain competitive with Japanese industry.(Pepper,Spedding ,2010).

Lean manufacturing is about controlling the resources in accordance with the customers' needs and to reduce unnecessary waste or non-value add (including the waste of time). The concept was introduced at a larger scale by Toyota in the 1950s, but not labeled lean manufacturing until the now famous book about the automobile appeared in 1990.(Andersson, Eriksson and Torstensson, 2006).

Lean manufacturing started in the form of the Toyota Production System has been around for decades, it did not get integrated with Six Sigma until the late 1990sand early 2000s (George, 2002, 2003). the approach in the areas where improvements could be identified and implemented quickly (one to four weeks), many of which involved the flow of information and materials through a process. Today Lean Six Sigma is the improvement approach of choice. (Snee, 2010).

The "birth" of the term "lean production" The IMVP Researcher John Krafcik originally coined the term "lean production". IMPV is an abbreviation of the International Motor Vehicle Program established at Massachusetts Institute of Technology in 1985. During the following 5 years, the IMVP staff carried out the world's most comprehensive benchmarking study ever seen.

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ISSN: 2349-5677
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The study collected data from automobile assembly plans all over the world in order to understand the differences in quality and productivity. The results of this benchmarking study were published in the well-known book The Machine that Changed the World (Womack et al., 1990), in which there is an exciting historical analysis of the machine called "the automobile(Dahlgaard ,Park 2006).

2.3 Lean manufacturing Objectives

The lean production goal of eliminating waste (muda in Japanese), so that all activities along the value stream create value, is known as perfection efforts focused on the reduction of waste are pursued through continuous improvement or kaizen events, as well as radical improvement activities, or kaikaku. Both kaizen and kaikaku reduce muda, although the term kaikaku is generally reserved for the initial rethinking of a process. Hence, perfection is the goal and the journey to per-fection is never ending,(Arnheiter and Maleyeff,2005).

Quality management practices in lean production emphasize the concept of zero quality control (ZQC). A ZQC system includes mistake proofing (poka-yoke), source inspection (operators checking their own work), automated 100 percent inspection, stopping operations instantly when a mistake is made, and ensuring setup quality,(Arnheiter and Maleyeff,2005).

The main objectives of lean is reduce the lead time of a process, one first analyses the customer's demands of the process to identify the value (first V in roadmap). Hence, the objectives of the improvement, besides reducing the lead time, are also to increase customer satisfaction. In addition, increased producivity and an inventory reduction are common effects of successful lean projects.(Andersson, et al2006).

Quality practices in batch-and-queue generally assure acceptance sampling performed by dedicated Quality inspectors, product quality audits, and statistical process control (SPC). Thus, for equivalent process levels of quality, poor quality in batch-and-queue system would result in high external failure costs, whereas poor quality in a lean production system would cause high internal failure costs and this is explained through the next Figure, (Arnheiter and Maleyeff,2005).

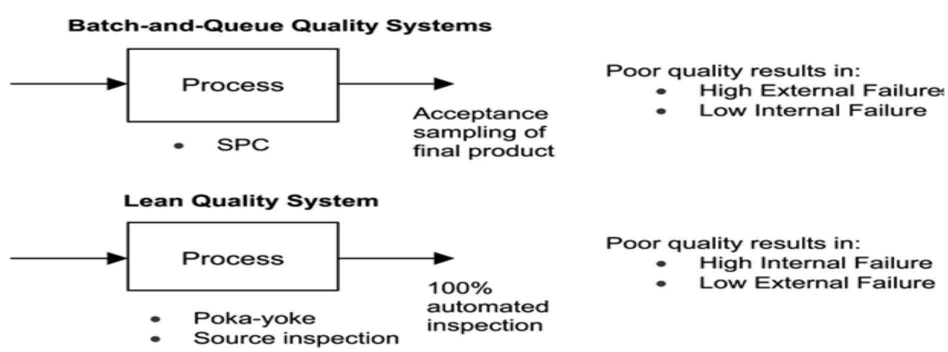

Fig.1Batch-and-queue versus lean quality systems

2.4 lean benefits

There are many reasons to launch lean techniques in an organization; as it may contribute substantially to eliminating costs and providing competitive advantages. Lean benefits include reduced work-in-process (WIP), increased inventory turns, increased capacity, cycle-time reduction and improved customer satisfaction.(Andersson, et al 2006).

Survey of 40 companies that had adopted lean manufacturing; typical improvements are visible in three areas. These improvement areas include: operational improvements (reduction of lead time, increase in productivity, reduction in work-in-process inventory, etc.), administrative improvements (reduction in order processing errors, streamlining of customer service functions so that customers are no longer placed on hold, etc.) and strategic improvements (reduced costs, etc.).(Andersson, et al 2006).

2.5 Toyota Production System TPS and Seven Wastes

The beginning of TPS and JIT as shows next, The Toyota Production System (TPS) provided the basis for what is now known as lean thinking, as popularized by Womack and Jones (1996). And the main target of lean thinking seven forms of waste have been identified

(1) Over-production;
(2) Defects;
(3) Unnecessary inventory;
(4) Inappropriate processing;
(5) Excessive transportation;
(6) Waiting; and
(7) Unnecessary motion: (Pepper, Spedding, 2010)

2.6 Lean and Value of the customer

The first step in a lean transition is to identify value-added and non-value adding processes. The second step is Value stream mapping (VSM) and the benefits of VSM are many, including the provision of a common language when considering manufacturing processes. It also brings together all of the lean techniques, which helps practitioners avoid the temptation to cherry-pick one or two of the “easier "to implement. In fact, no other tool illustrates the linkages between information and material flow like VSM (Rother and Shook, 1999). (Pepper, Spedding, 2010).

VSM has its critics. suggested that the practical nature of VSM (i.e. the paper and pencil approach) limits the amount of detail collected and also detracts from the actual system workings (the action of using pencil and paper to draw the map may remove focus from the actual system being analyzed). This dynamic view looks beyond VSM as giving a quick, succinct overview of where “muda” is present, and develops the idea of the mapping process itself becoming a continuous tool, constantly being updated via software such as I grafix, when we are using software can increase the data that can be represented compared to paper and pencil. (Pepper, Spedding, 2010).

VSM needs to be methodically applied before other tools such as single minute exchange of die (SMED) and 5S. Perhaps the most widely used of the lean tools is 5S (concerned with a cultural change in the organization, making systematic and standardized processes normal routine, i.e. good housekeeping and not an exception).5S is seen as fundamental to achieving a lean business and is deemed equally also we can use VSM as powerful tool in lean six sigma methodology. (Pepper, Spedding, 2010)

2.7 Lean Manufacturing Roadmap

The lean principles are fundamentally customer value driven, which makes them appropriate for many manufacturing and distribution situations. Five basic principles of lean manufacturing are generally acknowledged and the lean roadmap called VVFPP as per clarify next:

(1) Understanding customer value (V). Only what the cus-tomers perceive as value is important and value meaning the needs and requirements.

(2) Value stream analysis (V). Having understood the value for the customers, the next step is to analyze the business pro-cesses to determine which ones actually add value. If an action does not add value, it should be modified or eliminated from the process. The VSM phase is important phase to determine the value adds and non value add and business value add in each process.

(3) Flow (F). Focus on organizing a continuous flow through the production or supply chain rather than moving commodities in large batches, in this phase we change the process to one piece flow to eliminate the wastes and work in process (WIP).

(4) Pull. (P) Demand chain management prevents from producing commodities to stock, i.e. customer demand pulls finished products through the system. No work is carried out unless the result of it is required downstream.

(5) Perfection. (P) The elimination of non-value-adding elements (waste) is a process of continuous improvement (CIP). “There is no end to reducing time, cost, space, mistakes, and effort”. (Andersson, et al 2006).

2.8 Lean Misconceptions

The misconceptions regarding lean management and six sigma, the Lean productions was derived from the need to increase product flow or decrease the production lead time through the elimination of all non-value-added activities and essential non value added activities . Six Sigma developed from the need to ensure final product quality by focusing on obtaining very high conformance at the OFD level. In order for proponents of one program to learn from the other program, some common misconceptions should be dispelled. The key misconceptions are described below, (Arnheiter and Maleyeff, 2005).

The Key misconceptions regarding lean management in four points as below.

1- Lean means layoffs Arnheiter and Maleyeff (2005) replay it is a misinterpretation of the term. In lean management, if workers were performing non-value-added activities within their job, management and the employee would work together to find a better way to perform the job to eliminate then on-value-added activities. Laying-off the employee would be counterproductive

International Journal of Business Quantitative Economics and Applied Management Research
ISSN: 2349-5677
Volume 1, Issue 6, November 2014

since knowledgeable person would no longer be available and the remaining employees would be disinclined to take part in future waste elimination projects. Arnheiter and Maleyeff (2005)cited(Emiliani, 2001).to replay on the wrong lean meaning, layoffs cannot take place in the context of lean management, unless it becomes an absolute necessity and every effort to re-assign or re-train the employee fails

2-Lean only works in Japan, because of their unique culture In fact, lean management is not a universalsystem in Japan and some of the most successful lean management implemen-tations have been within non-Japanese companies Arnheiter and Maleyeff (2005) cited(Emiliani, 2003). The source of the misconception may be the belief that Japanese workers are by nature more frugal than their international counterparts. Even if this statement were true, eliminating waste and being frugal often conflict, such as when an engineer designs an inferior part to save money.

3- Lean for manufacturing only Arnheiter and Maleyeff (2005) replay lean management views each step in the process as a service step, where customer value is added with minimal waste. Within this framework, processing claims in the insur-ance industry, evaluating loan applications at a bank, and treating patients in a hospital all involve performing activities synonymous with the lean management viewpoint. In any business where customers Batch-and-queue versus lean quali-ty systems exist and activities take place to satisfy those cus-tomers, lean management can be practiced successfully.

4- Lean only works within certain environments Arnheiter and Maleyeff (2005) replay this view is heard from managers in operations that are traditionally large batch operations as well as from managers of diverse job-shop operations. While these types of operations may never conform to the "lot size of one" principle, lean management encompasses much more than manufacturing process design. If attempts were made to identify and eliminate all non-value-added activities through-out the organization, these companies would be practicing important aspects of lean management. These companies could also pursue there elements of lean management, by continuously attempting to follow lean principles when adopting new manufacturing technologies (Arnheiter and Maleyeff, 2005).

2.9 Criticism of lean

The main criticism against lean is the lack of flexibility the concept offers, see Dove (1999), and that the concept actually can lead to delays for the customers, see Cushman (1994). There is also a discussion going on whether lean, which was developed for manufacturing and distribution situations, is applicable in all industries. Mast (2004).(Andersson, et al 2006).

There are two points which was considered as weak points in lean methodology (criticism) the two points shows below:

1- The lean organization may become very susceptible to the impact of changes. The leanness in itself leads to reduced flexibility and less ability to react to new conditions and circumstances (Dove, 1999).

2- JIT deliveries cause congestion in the supply chain, leading to delays, pollution, shortage of workers, etc. (Cush-man, 1994).(Andersson, et al 2006).

To overcome this, the lean approach must integrate the use of targeted data to make decisions and also adopt a more scientific approach to quality within the system. (Pepper, Spedding, 2010)

III. Six Sigma Methodology

3.1 Six sigma Definition

The six sigma define as business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction by some of its proponents.(Andersson, et al 2006).

The term "Six Sigma" refers to a statistical measure of defect rate within a system. supported by statistical techniques, it presents a structured and systematic approach to process improvement, aiming for a reduced defect rate of 3.4 defects for-ever million opportunities, or Six Sigma.(Pepper,Spedding,2010)

3.2 Six sigma History and Overview

The six-sigma methodology was developed at Motorola in 1987 in response to sub-standard product quality traced in many cases to decisions made by engineers when designing component parts. Traditionally, design engineers used the "three-sigma" rule when evaluating whether or not an acceptable proportion of manufactured components would be supposed to meet tolerances. When a component's tolerances were consistent with a spread of six standard deviation units of process variation, about 99.7 percent of the components for a centered process would be expected to conform to tolerances. That is, only 0.3 percent of parts would be nonconforming to tolerances, which means that to3,000 defected parts per mil-lion (DPPM),(Arnheiter and Maleyeff,2005).

The six sigma started by Motorola was the first company to launch a six sigma approach in the mid-1980sIn 1988, where the Motorola specialized in electronic products, Bill Smith1986 is engineer and statistician at Motorola, introduce the six sig-ma concept aiming to attack the existing quality problems in the company.

Motorola received the Malcolm Baldrige National Quality Award, which led to an increased interest of six sigma in other organizations, see Pyzdek (2001). Today, a number of global organizations have developed six sigma approach of their own and six sigma is now established in almost every industry. (Andersson, et al 2006).

At Motorola, when studying the relationship between the quality of component and the quality of final product it was discovered that, from lot-to-lot, a process tended to shift a maximum of 1.5 sigma units (McFadden, 1993). This concept is shown graphically in next Figure, which shows a centered process and processes, shifted 1.5 sigma units in both directions. Table provides the relationship between component quality and finalproduct quality, assuming that the full 1.5 sigma shift takes place. In next Table, Sigma level is the standardized process variation (see Figure), OFD quality is the NCPPM if the process shifts a full 1.5 sigma units, and the probabilities in the

International Journal of Business Quantitative Economics and Applied Management Research
ISSN: 2349-5677
Volume 1, Issue 6, November 2014

table provide the proportion of final products that will be free of defects. For example, if the company sets a goal for final product quality of 99.7 percent and prod-ucts include about 1,000 OFDs, then the 3.4 DPPM corresponding to the Six-Sigma methodology would became the standard against which all decisions were made,(Arnheiter and Maleyeff,2005).

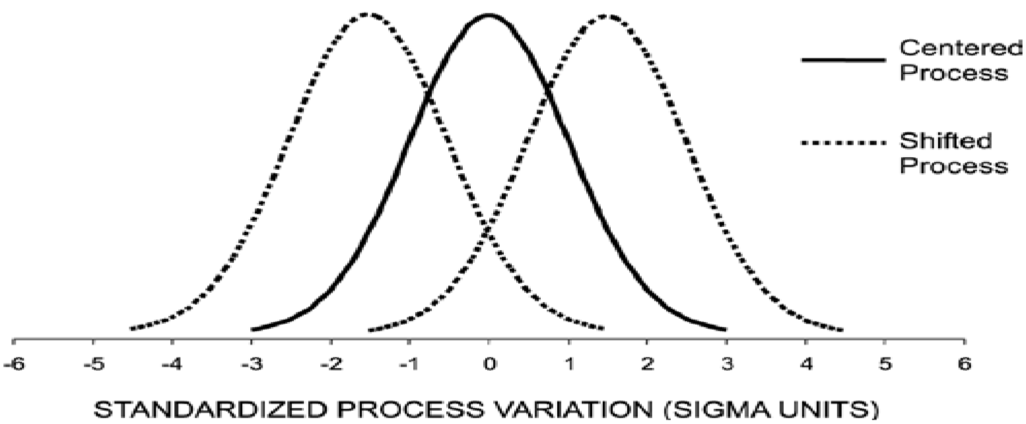

Fig.2 Process average shifting+/-1.5 Sigma units

Tab.1Final product quality level (percentage conforming)

		Number of OFDs per product				
Sigma level	OFD quality (NCPPM)	100 (%)	500 (%)	1,000 (%)	5,000 (%)	20,000 (%)
2.5	158,655	0.0	0.0	0.0	0.0	0.0
3.0	66,807	0.1	0.0	0.0	0.0	0.0
3.5	22,750	10.0	0.0	0.0	0.0	0.0
4.0	6,210	53.6	4.4	0.2	0.0	0.0
4.5	1,350	87.4	50.9	25.9	0.1	0.0
5.0	233	97.7	89.0	79.2	31.2	1.0
5.5	32	99.7	98.4	96.9	85.3	53.1
6.0	3.4	100.0	99.8	99.7	98.3	93.4
6.5	0.29	100.0	100.0	100.0	99.9	99.4
7.0	0.019	100.0	100.0	100.0	100.0	100.0
7.5	0.0010	100.0	100.0	100.0	100.0	100.0

Six Sigma was started and developed at Motorola by an engineer Bill Smith in the mid-1980s.Six Sigma is credited with playing a major role in the turnaround Motorola accomplished in their quality at the time culminating in Motorola winning the 1988 Balding National Quality Award.(Snee, 2010)

Six sigma established the power implementation and Sig-nificant deployments lead by the chief executive officers (CEOs) at AlliedSignal and general electric (GE) was the next major step for the approach. Welch promoted Six Sigma aggressively inside and outside GE. The initiative established major usage across business and industry; first in the USA and then globally. Most would agree that the state of "process excellence" is the ultimate goal of Six Sigma improvement.(Snee, 2010)

3.3 Six sigma successful companies

There are two successful companies in implementing six sigma programs.

The first case is Volvo Cars in Sweden claims that the six sigma program has donated with over 55 million euro to the bottom line during 2000 and 2002. And, another company is the Business Unit of Transmission & Transportation Networks at Ericsson located in Bora°s, Sweden. Ericsson in Bora°s has about 1,100 employees. According to Peter Ha¨yha¨nen, a promoter and educator at Ericsson, they established their six sigma programme in 1997. At Ericsson, in the first six sigma was used as methodology for solving problems. Today, they rather see six sigma as a business excellence model for con-crete areas and as a methodology in order to reach business goals. At Ericsson in Bora°s, around 50 Black Belt projects and 200 Yellow Belt projects have been executed between 1997and 2004, with total savings of approximately 200-300 million euro between 1997 and 2003.(Andersson, et al 2006).

3.4 Six sigma objectives

The six sigma consider as continuous improvement tool and as continuous improvement process for reducing varia-tion in process which meaning the defected products or de-fected service, which focuses on continuous and breakthrough improvements. Improvement projects are driven in a wide range of areas and at different levels of complexity, in order to reduce variation. The main purpose of reducing variation on a product or a service is to satisfy customers. The goal of six sigma is that only 3.4 of a million customers should be unsatis-fied and this is the six sigma target.(Andersson, et al 2006)

3.5 Six sigma Roadmap

There are two major improvement methodologies in six sigma, one for already existing processes and one for new pro-cesses. The first methodology used to improve an existing process can be divided into five phases and also we can callsix sigma roadmap. Which clarified in next points? (Andersson, et al 2006)

1. Define phase. In this phase we clarify the process or product that needs improvement. Define the most suitable team members to work with the improvement. Define the cus-tomers of the process which are the internal or external cus-tomers, their needs and requirements, and create a map of the process that should be improved.

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ISSN: 2349-5677
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2. Measure phase. Identify the key factors that have the most influence on the process, and decide upon how to meas-ure them and in this phase we can collect fresh data to clarify the sources of process variation.

3. Analyze phase. Analyse the factors that need im-provements and we can reduce the factors of process varia-tion.

4. Improve phase. Design and implement the most effec-tive solution. Cost-benefit analyses should be used to identify the best solution and hypothesis test to assure the improve-ment.

5. Control phase. Verify if the implementation was suc-cessful and ensure that the improvement sustains over time. So we can use control tools such as control plan. (Andersson, et al 2006)

Six Sigma brings structure to process improvement by providing the user with amore detailed outline of Deming's plan-do-check-act cycle by guiding the initiative through a five stage cycle of define-measure-analyze-improve-control (DMAIC); Each stage has a number of corresponding tools and techniques such as statistical process control, design of exper-iments and response surface methodology, providing the user with an extensive tool box of techniques, inorder to measure, analyze and improve critical processes in order to bring the systemunder control.(Pepper,Spedding ,2010)

By comparing these four simple but rigorous steps with Motorola's six steps tosix sigma quality it seems on the surface as if GE (or Jack Welch) in beginning oftheir six sigma journey focused only on Step 6 in Motorola's roadmap. Later on we-know that the sigma improvement process usually followed the so-called DMAICprocess, which is defined as follows

• Define. Identification of the process or product that needs improvement and identify the voice of the customers.

• Measure. Identify those characteristics of the product or process that are critical to the customer's requirements for quality performance and which contribute to customer satis-faction, in this phase we can collect the fresh data.

• Analyze. Evaluate the current operation of the pro-cess to determine the potential sources of variation for critical performance parameters.

• Improve. Select those product or process characteris-tics which must be improved to achieve the goal. Implement improvements.

• Control. Ensure that the new process conditions are documented and monitored via statistical process control methods (SPC). Depending on the outcome it may become necessary to revisit one or more of the preceding phas-es(Dahlgaard, Park 2006),

The six sigma road map and applying a step-by-step pro-cess based road map is a key success factor (KSF) inimple-menting any six sigma project regardless of the size or type of the business.Also this clarifying in the next ta-ble.(Nabhani,Shokri2009)

International Journal of Business Quantitative Economics and Applied Management Research
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Six sigma steps	Key processes
Define	Define the requirements and expectations of the customer Define the project boundaries Define the process by mapping the business flow
Measure	Measure the process to satisfy customer's needs Develop a data collection plan Collect and compare data to determine issues and shortfalls
Analyse	Analyse the causes of defects and sources of variation Determine the variations in the process Prioritise opportunities for future improvement
Improve	Improve the process to eliminate variations Develop creative alternatives and implement enhanced plan
Control	Control process variations to meet customer requirements Develop a strategy to monitor and control the improved process Implement the improvements of systems and structures

Source: Kwak and Anbari (2006)

Tab.2 Key steps of six sigma

3.6 Another six sigma roadmap (DMADV)

DMADV roadmapis often used when the existing process-es do not satisfy the external customers or isn't able to achieve strategic business objectives so we focused on design and veri-fication phases, this methodology can also be divided into five phases; define measure, analyze, design, verify. (Andersson, et al 2006)

3.7 Six sigma Misconceptions

The Key misconceptions regarding six sigma in three points as below:

1- Six Sigma is that it is the new flavor, pushed by quali-ty consultants in a way similar to the way Deming Manage-ment, TQM, business process reengineering (BPR), and ISO 9000 were pushed in the recent past. Unfortunately, there will

always be consultants who jump onto any bandwagon, take a seminar and proclaim themselves experts in a program Six Sigma is no exception to this phenomenon.

2- Six Sigma is that the goal of 3.4 NCPPM is absolute andshould be applied to every opportunity tolerance and specification, regardless of its ultimate importance in the cus-tomer's value expression. While the 3.4 NCPPM wasderived at Motorola based on the characteristics of its products.

3- Six Sigma is that it is a quality only program. As de-scribed earlier, the concept of Six Sigma "quality" relates to the entire customer value equation.

International Journal of Business Quantitative Economics and Applied Management Research
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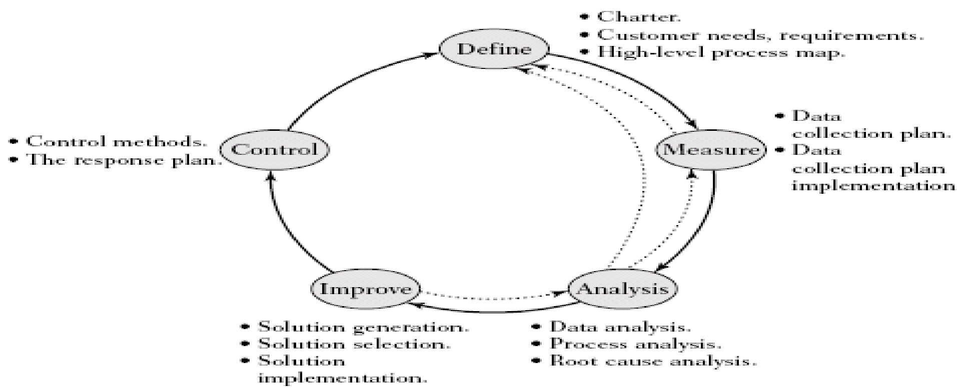

Fig.3High-level DMAIC improvement methodologies.

3.8Criticism of six sigma

The six sigma has the same common features as TQM and that six sigma does not, in principle, contain anything new. In more detail, they state that six sigma is a highly disciplined, data-oriented, top-down approach, which typically includes four stages (measure, analyze, improve and control) and the use of statistical decision tools. The new thing concerning six sigma is the clear linking of the tactical and the strategic, For example, statistical techniques are used in a systematic way to reduce variation and improve processes, and there is a strong-er focus on results, including customer needs.(Andersson, et al 2006)

There is a complexity in six sigmaapproach to exceed and achieved the customer's needs and hence increase the custom-er satisfaction. So to avoid this problem some companies use voice of the customer tools (VOC) in their define phase claim that six sigma approach fail to create conditions in order to involve everyone, which is more emphasized in the TQM. Furthermore, in six sigma training programmes one can on-ly start a project which gives a certain amount of savings. This project is often executed in the department of the project members. The project normally leads to an improvement in the department of the project members, but due to the per-formed change another department can experience deteriora-tion. As a result, six sigma is sometimes accused for not hav-ing a system view.(Andersson, et al 2006).

Six Sigma needs to adopt a wider systems approach, con-sidering the effects of muda on the system as a whole; and therefore quality and variation levels. Figure (2.4) shows how each approach can gain from being seen as a single frame-work, andalso the balance that may be reached if effectively brought together. (Pepper, Spedding, 2010)

3.9 Similarities between Six Sigma and Lean Manu-facturing

The Similarities between Six Sigma and Lean Manufactur-ing as below:

1. Both require a high level of management commit-ment.
2. Both implemented as part of a strategic plan.
3. 3-Both represent a culture change for the organiza-tion.

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ISSN: 2349-5677
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4. Both require input from all levels of the organization (especially shop floor).
5. Both have systematic structures.
6. 6-Both concerned with elimination of waste. (Breyfogle, 2003)

3.10 Dissimilarities between Lean and Six Sigma

The dissimilarities between lean manufacturing and six sigma approach as noted below

1. Lean focuses on improving manufacturing operations in variation, quality and productivity. However, Six Sigma focuses not only on manufacturing operations, but also on all possible processes including R&D or design process which is cover in DMADV roadmap and service areas.

2. Lean approach attacks variation differently than a Six Sigma system does. Lean tackles the most common form of process noise by aligning the organization in such a way that it can begin working as a coherent whole instead of as sepa-rate units. Lean seeks to co-locate, in sequential order, all the processes required to produce a product. Instead of focusing on the part number, Lean focuses on product flow and on the operator. Setup time, machine maintenance, TAKT time, OEE and routing of processes are important measures in Lean. However, Six Sigma focuses on defective rates, defects prod-ucts or service and costs of poor quality due to part variation and process variation based on measured data.

3. The data-driven nature of Six Sigma problem-solving lends itself well to lean standardization and the physical rear-rangement of the factory. Lean provides a solid foundation for Six Sigma problem-solving where the system is measured by deviation from and improvements to the standard.

4. While Lean emphasizes standardization and produc-tivity, Six Sigma can be more effective at tackling process noise and cost of poor quality. (Breyfogle, 2003)

The next table clarifies the comparison between lean manu-facturing and six sigma (Nave, 2002)

Tab.3 comparisons between six sigma and lean thinking

	Six sigma	Lean
Benefits- primary ef-fects	Uniform process out-put	Reduced flow time
Benefits- secondary effects	Less waste , Fast throughput, Less inventory, Fluctuation-Performance measures for manag-ers , Improved quality	Less variation Uniform output Less inventory New accounting system Flow-performance measure for managers Improved quali-ty
Theory and objective	Reduce variation	Remove waste
Focus	Problem focused	Flow focused

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Assumptions	A problem exists fig-ures and numbers are valued system out-puts improves if vari-ation in all processes reduced	Waste removal will improve business per-formance. many small improve-ments are better than system analysis
Application Guideline	Define Measure Analysis Improve Control	Identify value Identify value stream Flow Pull Perfection
Tools	Flow chart, control chart, graphical chart ,	5S,VSM,Kanban,
Criticisms	System interaction not considered processes improved inde-pendently	Statistical or sys-tem analysis not valued

IV. Lean Six Sigma

4.1 Lean six sigma definitions

The integration between six sigma and lean manufacturing, Hoerl, (2004) said that there is an ongoing trend of integrating Lean and Six Sigma by adding Six Sigma projects to a Lean initiative. Antony et al.(2003) highlight the strengths of the two initiatives and discuss theoretical synergies of using both. The synergies can be summarized as if a combination would be beneficial in providing focus on flow, value streams and waste reduction, as well as focus on variation reduction through structured problem solving and application of statis-tical tools and techniques.(Assarlindet al 2012)

The integration of lean and Six Sigma, The phrase “lean Six Sigma” is used to describe the integration of lean and Six Sig-ma philosophies.(Pepper,Spedding ,2010)

The concept of lean Six Sigma as an approach to process improvement has yet tofully mature into a specific area of ac-ademic research (Bendell, 2006). (Pepper,Spedding ,2010)

Lean Six Sigma is a business strategy and methodology that increases processperformance resulting in enhanced customer satisfaction and improved bottomline results ($). It is also be-ing widely recognized that Lean Six Sigma is an effective lead-ershipdevelopment tool. Welch and Welch (2005) points out that “Perhaps the biggest but mostunheralded benefit of Six Sigma is its capacity to develop a cadre of great leaders.”(Snee, 2010)

Lean six sigma methodology that, there have been attempts to combine the two methodologies under titles such as “Lean Six Sigma” or “Lean Sigma”. Often, this alleged combination is no more than a “philosophical” or near-religious argument about professed compatibility of approaches. In reality these are practical examples of incompatibility and even conflicts between the approaches that have lead to bad processes and process improvement approach. (Bendell, 2006)

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The Lean Six Sigma helps companies flourish in a new world where customers expect no defects and fast delivery at the minimal cost. Magnusson et al. (2003) also state that many companies have merged six sigma andlean manufacturing practices. The merger can be traced back to early develop-ments atGeneral Electric's where they realized that the two concepts complemented each other very well, i.e. lean manu-facturing addresses process flow and waste whereas six sigma addresses variation and design (Andersson, et al2006).

4.2 Integration between lean and six sigma

The key lean implementation steps, along with the Six Sig-matools that can be used as an aid to achieve each task. It can be seen here, that lean andSix Sigma are ideally suited to be used in a comprehensive methodology incorporat-ing.(Pepper,Spedding ,2010)

Tab.3Synergies between lean and Six Sigma (Source: Adapted from Pyzdek (2000))

Lean	Six Sigma
Establish methodology for improvement	Policy deployment method-ology
Focus on customer value stream	Customer requirements measurement, cross func-tional management
Use a project-based imple-mentation	Project management skills
Understand current condi-tions	Knowledge discovery
Collect product and produc-tion data	Data collection and analysis tools
Document current layout and flow	Process mapping and flowcharting
Time the process	Data collection tools and techniques, SPC
Calculate process capacity and Takt time	Data collection tools and techniques, SPC
Create standard work combi-nation sheets	Process control planning
Evaluate the options	Cause-and-effect, FMEA
Plan new layouts	Team skills, project man-agement
Test to confirm improvement	Statistical methods for valid comparison, SPC
Reduce cycle times, product defects, changeover time, equipment failures, etc.	Seven management tools, seven quality control tools, design of experiments

4.3 The Competitive advantage of lean, Six Sigma and lean Six Sigma

The key concept for the integration of the two continuous improvement approaches (lean manufacturing and six sigma methodology), as a state of equilibrium needs to be achieved between the two, moving away from a inflexible approach in any one direction, risking becoming

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too lean and therefore rigid in responses to the market and subsequently impacting on value creation. The other extreme is to concentrate too much on reducing variation beyond the requirements of the customer, and therefore wasting unnecessary resources in the pursuit of zero variation. The balance lies in creating sufficient value from the customer's viewpoint, so that market share is maintained, while at the same time reducing variation to ac-ceptable levels so as to lower costs incurred, without over-engineering the processes.(Pepper,Spedding2010).

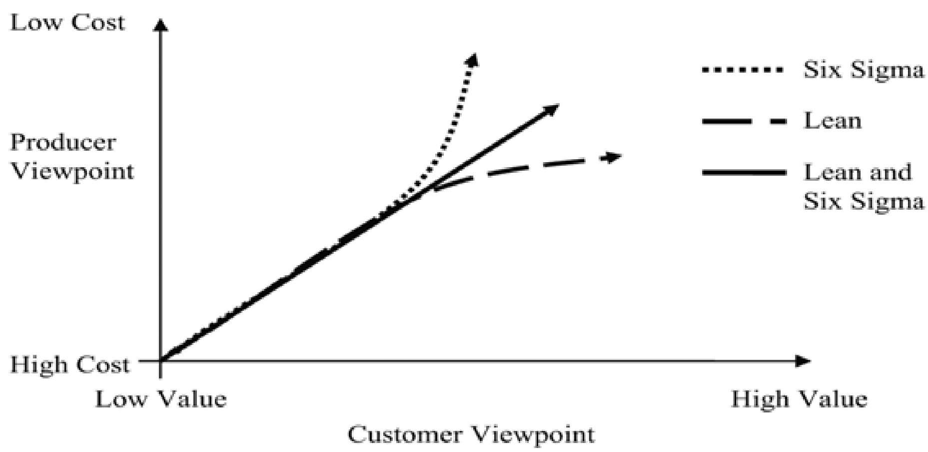

Fig.4 Competitive advantage of lean, Six Sigma and lean Six Sigma

There are two currently "hot" process improvement ap-proaches are six sigma and lean manufacturing. The two are related, but dissimilar.

The six sigma focuses on the reduction and removal of var-iation by the application of an extensive set of statistical tools and supporting software, whilst lean thinking focuses on the reduction and removal of waste by process and value analysis.

4.4 Lean Six Sigma history and overview

Lean Six Sigma is the latest generation of improvement ap-proaches. I argue that improvement approaches are not fads but steps along the way in evolution of business improvement methodology. Each approach builds on previous approaches adopting the effective aspects of previous approaches and adding new concepts, methods and tools to remove limitations that have been identified.(Snee, 2010)

Some articles and journal to clarifying a brief overview of some of the central components of Lean Six Sigma's twound-erlying concepts is provided as a background to discussions. The components havebeen derived theoretically, which is one of the several possible ways to deconstructSix Sigma and Lean.Six Sigma can be broken down into seven parts: DMAIC (Hoerl, 2004), Six Sigmatoolbox (Magnusson et al., 2003), Six Sigma organisation (Hoerl, 2004; Bergman andKlefsjo¨, 2003; Magnusson et al., 2003), reduction of variation (Nave, 2002; Na¨slund, 2008;Bertels, 2008), customer focus (Bergman and Klefsjo¨, 2003), decisions based on facts(Goh and Xie, 2004) and bottom line focus (Goh, 2002). Similarly, Lean can be said to bebased on the four following concepts: Lean tools and techniques – notably value streammapping (Womack, 2006; Alukal, 2003), the involvement of people (Holbeche, 1997), continuous improvement (Ricondo and Viles, 2005) and re-moval of waste (Spector, 2006;Alukal, 2003; Na¨slund, 2008). The concepts of lean Six Sigma have mainly swapped the concepts of JIT and TQM. He added that Lean and Six Sigma (LSS) are basically newer versions of JIT and TQM. The sys-tematic approach to organizational change and improvement as a critical success factor seem to be the difference between lean six sigma and both JIT and TQM, (Naslund, 2008).

4.5 The Difference between LSS and other continuous improvement tools

Lean Six Sigmaworks better thanprevious approaches such as lean , TQM and six sigma …etc because it integrates the humanand process aspects of process improvement as clari-fied in next Table (2.5).(Snee, 2010)

Tab.4 Human and process aspects of improvement

Human issues	Process issues
Bottom line focus ($	Process improvement
Management leadership	Analysis of variation
Sense of urgency	Disciplined approach
Customer focus	Quantitative measures
Project teams	Statistical thinking and meth-ods
Culture change	Process management

4.6 Lean Six Sigma benefits

The Lean Six Sigma projects category is conspicuously ab-sent from this frame work. That is because in a holistic im-provement methodology, in which the overarching goal is improvement – no matter how it is achieved – all projects are, in effect, Lean Six Sigma projects. They draw on a common toolbox that contains tools that have in the past been kept apart. Also the lean six sigma cover all type of continuous im-provement projects (Byrne et al, 2007)

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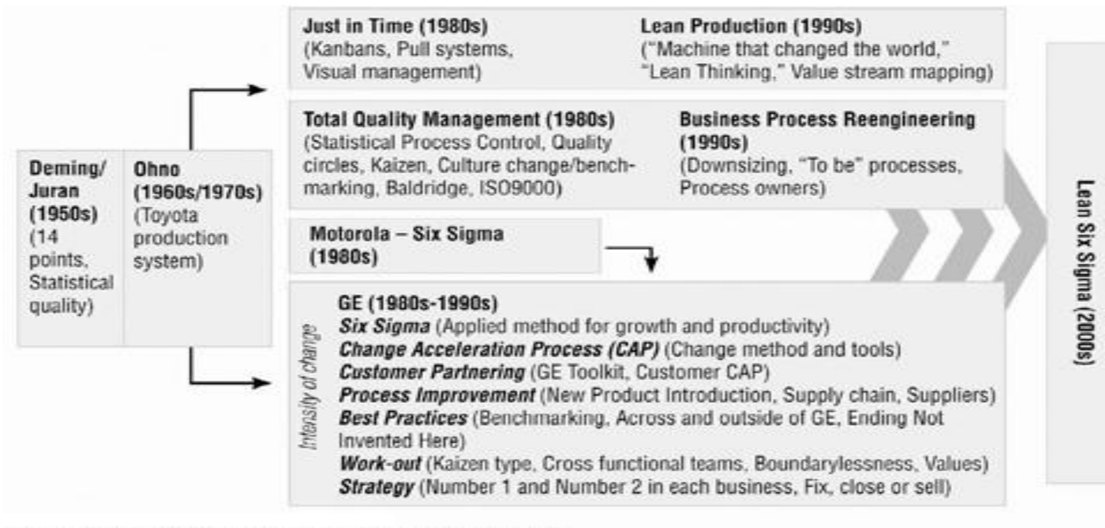

Source: IBM Global Business Services analysis

Lean Six Sigma approach draws on the philosophies, prin-ciples and tools of both. However, lean Six Sigma's goal is growth, not just cost-cutting. Its aim is effectiveness, not just efficiency.(Byrne et al, 2007) Fig.4 Lean six sigma builds on the practical lessons learned from previous eras of operational improvement

The joint implementation of the programs will result in a lean, Six Sigma (LSS) organization, overcoming the boundaries of each program when implemented in isolation. A thorough analysis of the two programs provides some likely reasons why the programs alone may fail to achieve absolute perfec-tion,(Arnheiter and Maleyeff,2005).

Lean six Sigma (LSS) organization would take advantage of on the strengths oflean management and Six Sigma methodology, (Arn-heiter and Maleyeff,2005).

4.7 The sources of Lean six sigma projects

The importance of placing organizational change and im-provement methods in general under a systemic (process management) umbrella.Hence, organizational readiness for change will be increased and thus, increase probability of im-plementation success so the organizational change is first fac-tor to success the LSS implementation, (Naslund, 2008).

The next figure all the different types of projects are gener-ated directly or indirectlyfrom business goals or performance gaps. A top-down approach employs business goalsto gener-ate projects, while the bottom-up approach addresses perfor-mance gaps that arisefrom within the operations of the organ-ization.(Snee, 2010)

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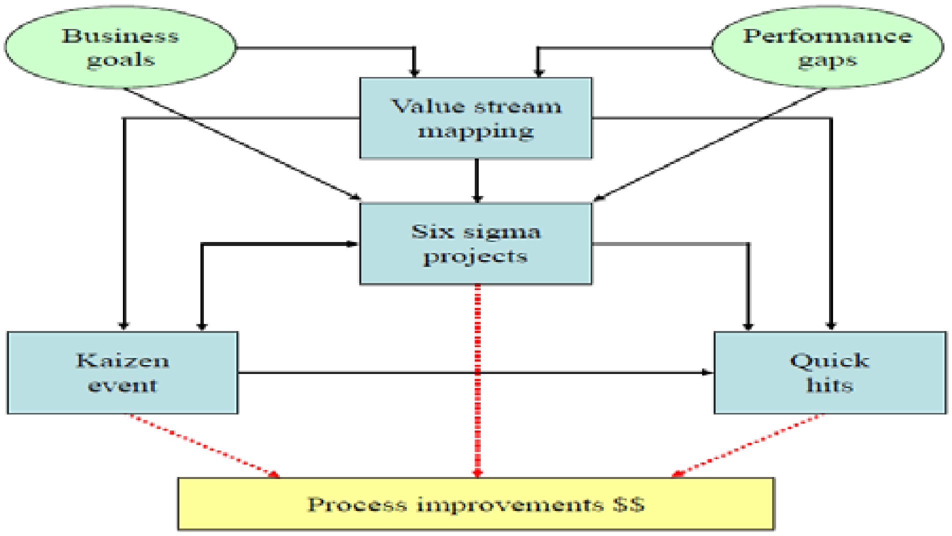

Fig.5 Improvement project selections

a.Source Snee and Hoerl, 2007

In the previous schematically figure a novel and powerful approach to selecting the rightprojects that includes elements both of Six Sigma and lean, all with the vital goal ofachieving maximum sustainable process improvements Although there are many types of improvement projects, process improve-mentstypically result from three major types of projects, re-quiring varying amounts of time for completion:

(1) Quick-hit projects can be accomplished almost immedi-ately and, should theyfail, cost little in lost time and resources.

(2) Kaizen projects, sometimes called rapid improvement projects, are typicallycompleted in 30 days or less.

(3) Six Sigma projects are typically completed in three to six months but are oftencompleted more quickly.(Snee, 2010)

The explanation of previous figure where business goals and performance gaps can directly generate Six Sigma pro-jects, goals and gaps can also provide inputs for value stream mapping (VSM), a technique often employed in lean that can also be used to generate Six Sigma projects, A Six Sigma pro-ject might uncover quick hits or generate Kaizen projects in the course of its execution. If VSM uncovers non-value-added activity for which lean tools might be appropriate, then a Kai-zen event might be convened to brainstorm solutions.(Snee, 2010)

4.8 Criticism of LSS Projects

Lean Six Sigma projects category is clearly absent from this framework.That is because in a holistic improvement method-ology, in which the main goalis improvement – no matter how it is achieved – all projects are, in effect, Lean SixSigma pro-jects. They draw on a common toolbox that contains tools that have in thepast been kept apart.Improvement objectives and needs of an organization are clarified in next Figure. Depend-ing on the nature of the problem, of course, tools

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traditionally regarded aslean or tools associated with Six Sigma may domi-nate. For example, the typesof commonly encountered im-provement needs, including the need to:

1. Streamline process flow to reduce complication, de-crease downtime, shorten cycle
2. Time and reduce waste;
3. Improve product quality;
4. Achieve consistency in product delivery;
5. Reduce process and product costs;
6. Reduce process variation to reduce waste (such as the waste of defective products);
7. Improve process control to maintain stable and pre-dictable processes;
8. Find the sweet spot in the process operating window; and
9. Achieve process and product robustness (Snee, 2010)

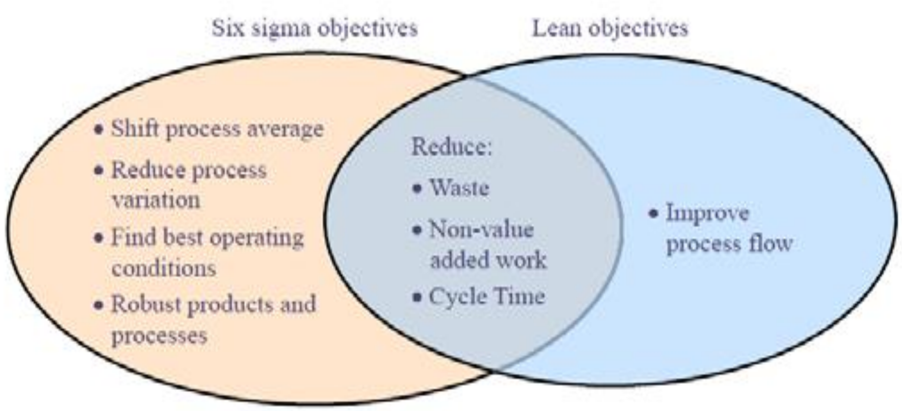

Fig.6.Improvement objectives (Snee, 2010)

4.9 Lean and six sigma as business process

Both six sigma and lean have at heart the business process and the process improvement approaches. A holistic model and methodology should thus retain this at its heart next Fig-ure. The route through their approaches should depend pri-marily upon the issues that the organization is facing and its nature, as well as being influenced by the organization's and individual's aspirations and perceptions(Bendell, 2006)

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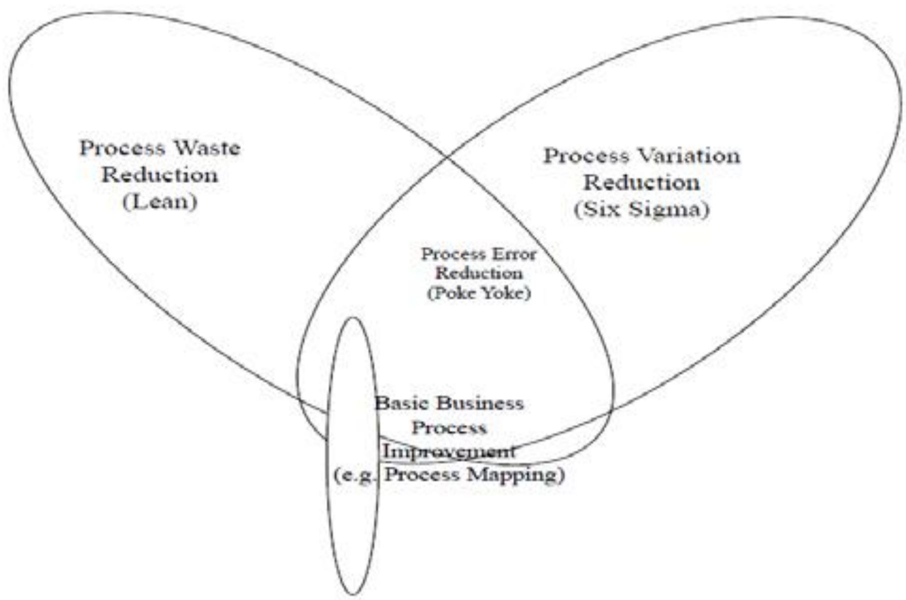

Fig.7 a holistic model for business process improvement

4.10 Lean organization and six sigma organization

In the next figure the business process improvement for many organizations, a natural starting point for business pro-cess improvement as been simple process thinking and map-ping as a bonus for improvement. Customeror market pres-sure may require ISO9001:2000 certification. Concern as to adequate qualified human resource to support process deliv-ery may simply pursuit of a standard such as Investors in People; whilst six sigma and lean are natural solutions to key questions as to whether chronic waste or variation problems are dominate. The directions shown in next Figure aren't of course, mutually exclusive. However, the diagnostic questions are useful to help identify the likely primary direction. The-route chosen should reflect primary needs.(Bendell, 2006)

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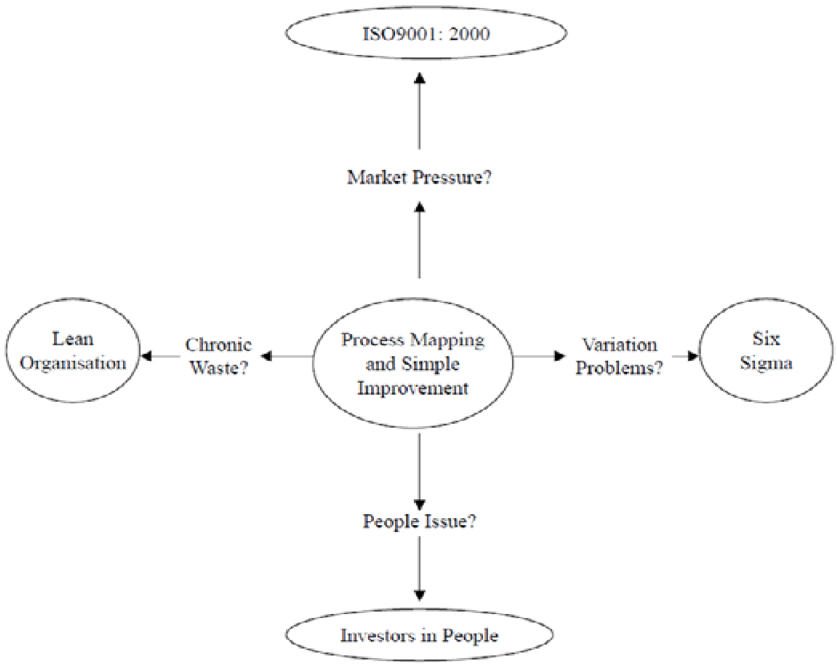

Fig.8 Typical "Six Sigma – Lean" organizational route map

4.11 Roles the Leadership in lean six sigma implemen-tation

Define the leaders; enable an organization to move from one paradigm to another; from oneway of working to another way of working. In making these shifts, work processes ofall kinds get changed. Lean Six Sigma provides the concepts, methods and tools forchanging processes. Lean Six Sigma is thus an effective leadership development tool inthat it pre-pares leaders for their role, leading change.

Lean Six Sigma is required because organizations and indi-viduals need amethodology for improvement and problem solving. Processes do not get better bythemselves. In fact, if not improved on some periodic basis, processes deteriorate over time.(Snee, 2010) The Lean Six Sigma a builds on the knowledge, methods and tools derived from decades of operational improvement research and implementation,Byrne et al (2007) concludes in the below figure the lean and six sigma progress and history, in the first Lean approaches focus on reducing cost through process optimization. Whilst sixsigma is about meeting cus-tomer requirements, stakeholder expectations and improving quality by measuring and eliminating defects. (Byrne et al 2007)

4.12 Technique of Lean six sigma deployment

The lean six Sigma incorporates key methods from its predeces-sors, which is clear identified in the next figure. Where in this figure shows the road map for lean and six sigma implementation. (Byrne et al 2007)

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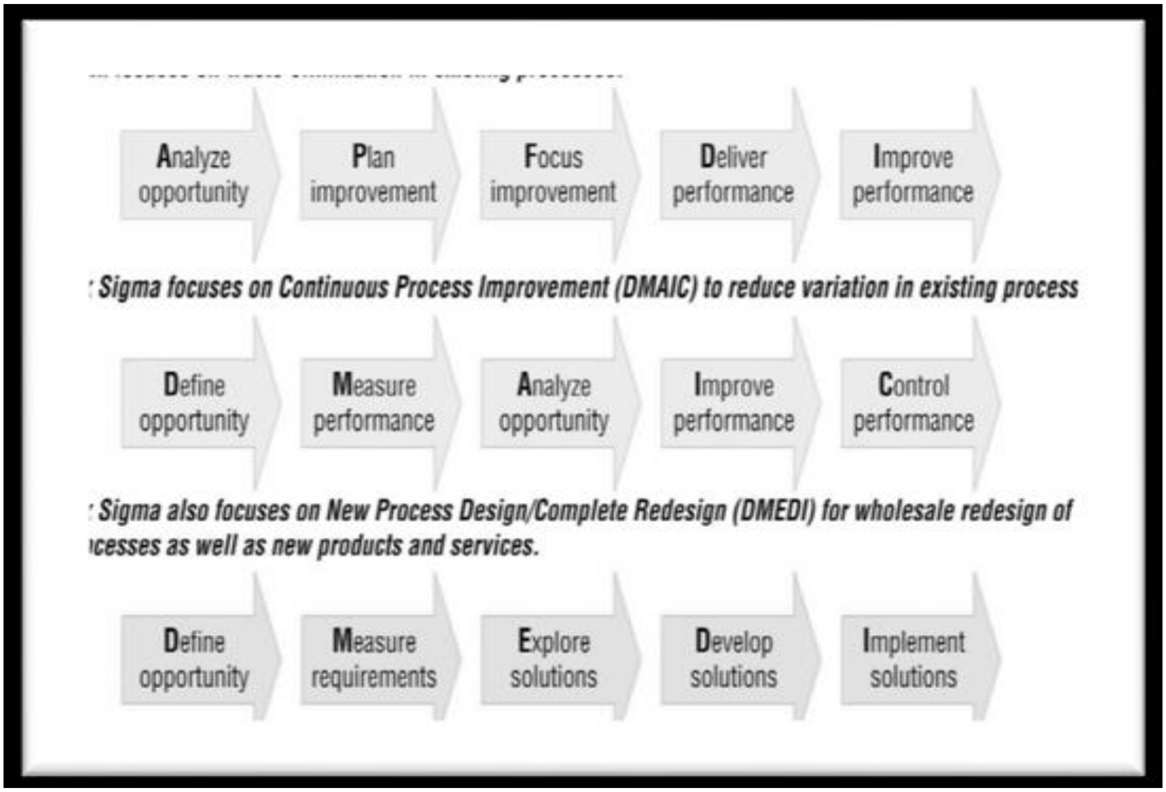

Fig.9 Lean Six Sigma incorporates, and deploys, the key methods, tools and techniques of its predecessors

4.13 Similarities between lean and six sigma approaches

The contents of Motorola's "six steps to six sigma" in the next table. By comparing Motorola's quality improvement process with the five principles oflean production it may, on the surface, look like, that there are not big differences.If there are differences they seem especially to be related to the lean production principles make the value flow without interrup-tions; and let the customer pull value from the produc-er.(Dahlgaard, Park 2006),

Tab.5 Motorola's quality improvement process "six steps to six sigma"
b. Source Motorola Material, Fukuda (1983)

Manufacturing (manu-factured products)	Non-manufacturing (administration/office/service)
1. Identify physical and functional requirements of the customers	1. Identify the product you create or the service you provide to external or internal customers

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2- Determine the critical characteristics of Produce	2. Identify the customer for your product or service, and determine what he or she considers important (your customer will tell you what they require to be satisfied. Failure to meet the customer's critical re-quirements is a defect
3. Determine for each characteristic, whether controlled by part, pro-cess or both	3. Identify your needs (including needs from your suppliers) to pro-vide product or service so thatit satisfies the customer
Determine maximum range of each characteristics	4. Define the process for doing the work (map the process)
5. Determine process variation for each characteristics	5. Mistake-proof the process and eliminate wasted effort and delays
6. If process capability (Cp) is less than two then redesign materials, product, process as required	6. Ensure continuous improve-ments by measuring, analyzing, and controlling the improved pro- cess (establish quality and cycle time measurements and improve-ment goals. The common quality metric is number of defects per unit of work

4.14 The similarities between PDCA and DMAIC ap-proaches

DMAIC process may be viewed as a short version of the following Quality Storywhich was developed in Japan in the 1960s as a standard for QC-circle presentations (PDCA cycle), but later on became an important quality improvement stand-ard (Dahlgaard et al.,1998a):

Plan:
(1) Decide on a theme (establish goals).
(2) Clarify the reasons this particular theme is chosen.
(3) Assess the present situation.
(4) Analysis (identify the causes).
(5) Establish corrective measures.
Do:
(6) Implementation.
Check:
(7) Evaluate the results.
Action:
(8) Standardization.
(9) After-thought and reflection, consideration of remaining problems.
(10) Planning for the future

Kheradia, (2011) cited American Society for Quality, ASQ, 2010b; American Society for Quality, ASQ, 2010c;Tague, 2004 emphasizes that the relation between PDCA or PDSA and DMAIC as the shown in the next table (Kheradia, 2011)

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Tab.6PDCA cycle and DMAICmethodology – therelation source ASQ 2010

PDSA cycle	DMAIC methodology
PLAN: recognize an improvement opportunity and plan a change	DEFINE: identify the prob-lem or the improvement opportunity
DO: test the change by carrying out a small-scale study program	MEASURE: set process performance in terms of sigma level i.e. DPMO
STUDY: review the test, analyze the results and identify the lessons learned	ANALYZE: determine the root causes of poor performance and whether the process can be improved or redesigned
ACT: take action based on what you learned in the study step	IMPROVE and CON-TROL: improve the process by attacking root causes and sustain using a control plan

4.15 The integration cycle between lean and six sigma (DMAIC)

In the below figure the DMAIC roadmap in ten step and overlap between six sigma approach and lean manufacturing methodology , DMAIC process is employed as the main func-tional system for the implementation of lean six sigma (LSS) approach. The blowcycle shows the conceptual development of the LSS framework. The main phases of the integrated LSS approach are:

(1) Define – what is the problem? Does it exist?
(2) Measure – how is the process measured? How is it per-forming?
(3) Analyse – what are the most important causes of de-fects?
(4) Improve – how do we remove the causes of the defects?
(5) Control – how can we maintain the improvements?
(6) Implement 5S technique.
(7) Application of value stream mapping (VSM).
(8) Redesign to remove waste and improve value stream.
(9) Redesign manufacturing system to achieve single unit flow (SUF).
(10) Apply total productive maintenance (TPM) to support manufacturing functions (Thomas et al., 2008)

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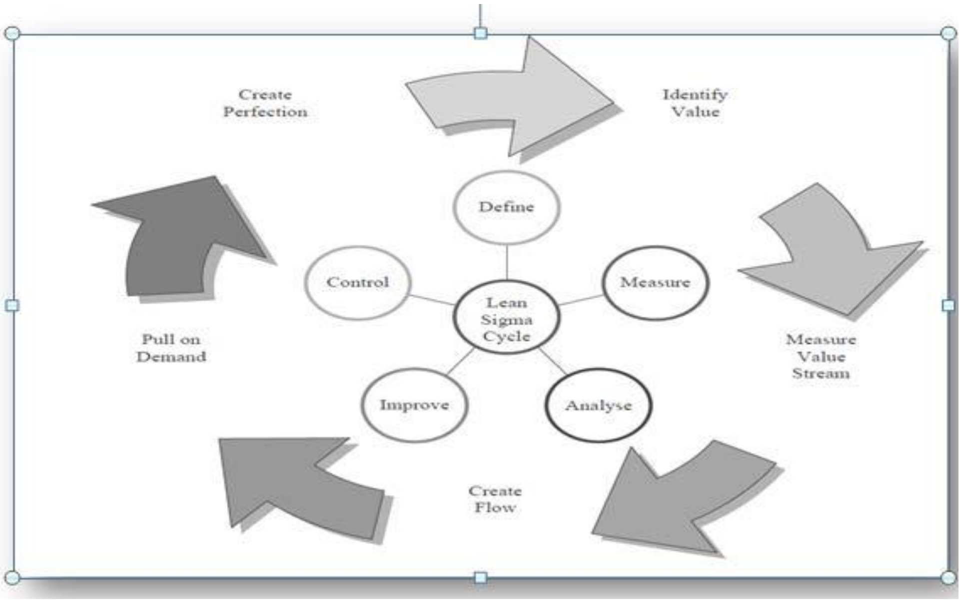

Fig.10 Outline approach to LSS

4.16 Conceptual model for lean Six Sigma

In the next Figure how both lean and SixSigma can be inte-grated together to form a coherent management tool for busi-nessprocess improvement. Lean philosophy underpins the framework, providing strategicdirection and a foundation for improvement, orientating the general dynamics of thesystem by informing the current state of operations. From this, lean thinking identifieskey areas for improvement ("hot spots"). Once these hot spots have been identified, SixSigma provides a focused, project based improvement methodology to target these hotspots and ultimately drive the system towards th desired future state (Pepper ,Spedding 2010)

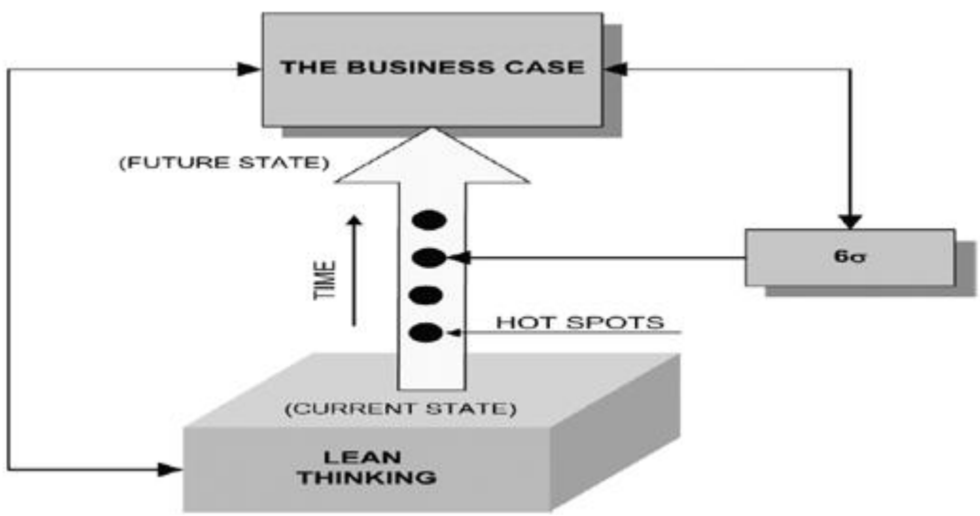

Fig.11 Conceptual model for lean Six Sigma

c. Source (Pepper M, Spedding T, (2010))

V. CONCLUSIONS

The Lean Six Sigma application, in the form of different packages used in a wide range of projects at various levels, is interesting. However, it is not feasible to adopt the same approach for incremental micro-projects performed at the lowest level by small improvement teams as for extensive projects performed by highly trained improvement experts. Reasons for this include the different problem-solving tools and expert resources that are needed. For larger improvement projects, therefore, a more complex traditional Six Sigma method may be appropriate. In such cases, the standard DMAIC cycle may provide structure and ensure that each step is performed thoroughly, thereby aiding the success of the project. Lean can contribute to these projects by staking out the direction; that is, indicating where to start, for example through the use of value stream mapping (V phase) where the process is reviewed in order to find waste .The Lean Six Sigma application studied here does not point towards one well-defined Lean Six Sigma approach; the company does not adopt any particular standardized approach to larger improvement projects. Instead, the company supports the integration at this level by ensuring that their improvement specialists are widely trained in both Lean-and Six Sigma, as integration at this level is ultimately up to the individuals. In the improvement teams on the other hand, the dominance of Lean is obvious, although Six Sigma's influence can be seen in the idea of a ubiquitous DMAIC.

However, this is not to say that the company does not gain complementary benefits from the two improvement initiatives, as both methodologies definitely exist and thrive within the company boundary, also must insert inside DMAIC roadmap. First, selection phase (S phase) to collect the projects, the second insertion is value stream map (V phase), third insertion is replication phase (R Phase).

There is also clear interaction between Lean and Six Sigma, particularly as projects are passed back and forth between one and the other. Having studied this application, it is our view that the benefits of Lean and Six Sigma can be achieved with-out the need for a standardized approach of an integrated Lean Six Sigma concept.

Refer to Lean Six Sigma as an integrated entity that exploits the benefits of both Lean and Six Sigma. One rationale for implementing both systems in the case study company was to gain the benefits of continuous improvement, for example by waste elimination, as well as breakthrough improvements through larger improvement projects. At a company level, it can be said; therefore, that integrated use of Lean and Six Sigma does exist, although not always in individual projects. Lean and Six Sigma could be said to provide complementary rather than synergistic benefits. Instead of discussing whether to implement "Lean Six Sigma", the company has selected the parts of Lean and Six Sigma that are the most appropriate for their business and adopted them into their production system.

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