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This is a refereed journal and all articles are professionally screened and reviewed **ORIGINAL ARTICLE**

Six Sigma Methodology and its Relationship with Lean Manufacturing System

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Hamid Tohidi, Kourosh KhedriLiraviasl; Six Sigma Methodology and its Relationship with Lean Manufacturing System

ABSTRACT

Purpose - Nowadays Six Sigma is known as the method with a strong and powerful principles and statistical tools to uncover root causes is to eliminate waste and reduce variation. On the other hand, by using Lean manufacturing we are going to gain rapid improvement of the increasing value and elimination the losses. Combination of Six Sigma and lean manufacturing will enable organizations to benefit from a powerful method with the practical tools for collecting data and solving problems, and also has the ability to accelerate the healing process. **Design/methodology/approach** - This article deals with introduces six sigma and lean manufacturing and implementation stages and advantages of each is expressed. Then Lean Six Sigma approach has been described that is the interaction between Six Sigma and lean production system. **Findings**- Experience in implementing Six Sigma in Iran has shown that the Six Sigma approach to problem solving is very effective for the Culture of Iran and the need to combine it with of lean production is sensing. **Practical implications** - This research will focus on "Six Sigma" and "Lean Production System" to discuss their integration based on the background and thoughts mentioned above. Six Sigma is one of the most popular quality initiatives recently. Lean Production System is the world famous production system developed and practiced by Toyota mobile company for a long time. Both are based on the variation in thinking in order to improve business process, enhance quality, production and competitive position. Besides, the integration of them is viewed as a new trend in the next management wave.

Key words: Six Sigma Methodology, Lean Manufacturing System, Continuous improvement, Lean Six Sigma

Introduction

Quality is Desirable of the customer's terms, it is always wishful. Quality as a customer forever lost among the multitude of Organization problems makes the hands and feet. Financial crises, warehouses full of parts and goods, Lack of workers motivation, inefficient systems, and dissatisfied customers are the Evidence that ignoring quality. The problems request to remove, but the inconsistency that quality is cost or profit, doesn't let it. History tells an important lesson: "the quality workers remain". Six Sigma as a technique, it is apparent Costly, But as a system, it's following the synergic value. Applying Six Sigma allows the organization that, identify the non-quality product sources and resolve this paradox to benefit of the survival of customers and organization finally.

Lean approach is a systemic approach to overcome problems in complex production systems and to gather various production tools so that to access three main goal of high quality, competitive cost and delivering the required amount and provides at the appropriate time. In this article we have introduces two approaches (Six Sigma and lean manufacturing); finally, we pay the interaction and integration of these two approaches.

The purpose of this literary review is to gain insight into lean manufacturing and six sigma; how they can be applied within a manufacturing environment. With global competition, it is important for manufacturers to remain competitive in their respective markets and to understand the principles of lean manufacturing and six sigma the steps to implement them to ensure that they are on the leading edge of manufacturing. This literary review describes these key principles.

1. Literature Review:

1.1. Six sigma:

In the 1980s and early 1990s, Motorola was one of many US and European corporation whose lunch was being eaten by Japanese competitors. Motorola's top leaders conceded that the quality of its products was awful. They were, to quote on Motorola Six Sigma veteran, "In a word of heart." Like many

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companies at the time, Motorola didn't have one "quality" program, it had several. But in 1987, a new approach came out of Motorola's Communication Sector – at the time headed by George Fisher, later top exec at Kodak. The innovative improvement concept was called "Six Sigma" [2]. Six Sigma is named after the process that has six standard deviations on each side of the specification window. Such a process produces 3.4 defects per one million opportunities in the long term . Based on Tong *et al*., six sigma has been initiated using statistical tools and techniques in business, transactional, and manufacturing process.

It has been proven to be successful in reducing costs, improving cycle times, eliminating defects, raising customer satisfaction, and significantly increasing profitability. In the first 5 years of Six sigma implementation, Motorola achieved saving of $US 2.2 billion. Other companies followed, e.g. GE, ABB, Bombardier and Allied Signal. According to Snee, R.D. and Hoerl, R.W. [22], the weeks correspond roughly to Measure, Analyze, Improve and control. (GE and others have added a "Define" phase at the beginning, to assure that the right projects are selected.) We will follow the improvement model is DMAIC:

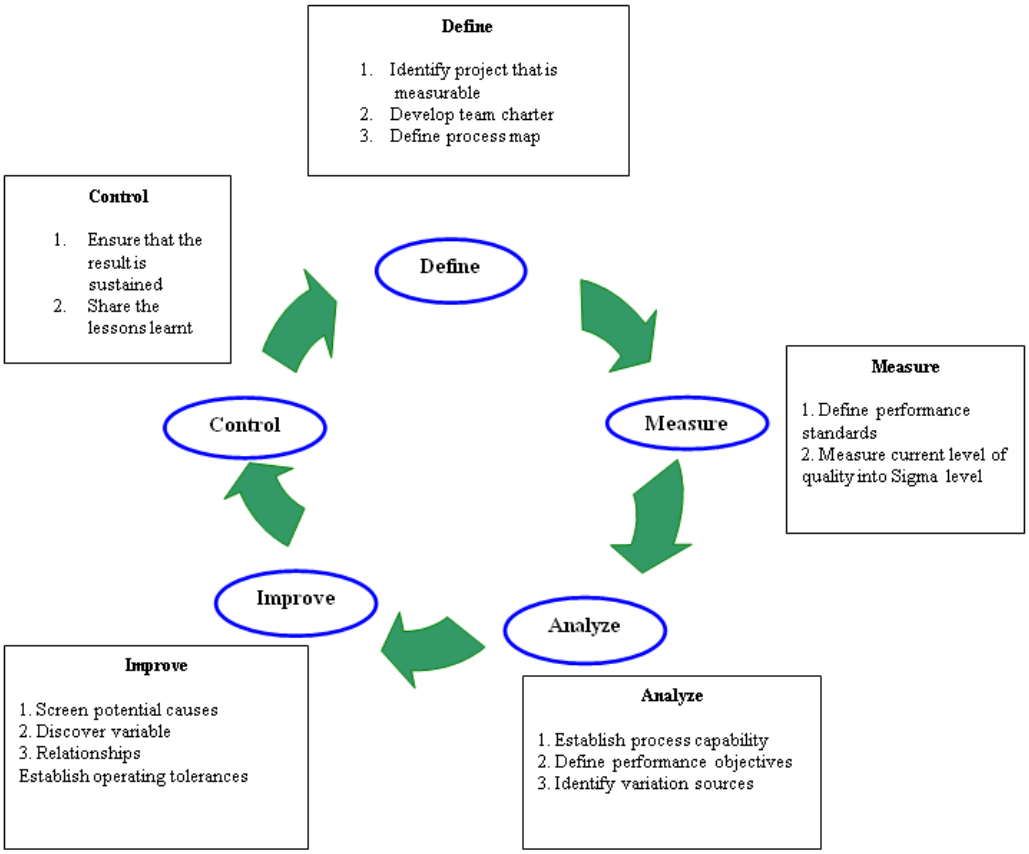


Fig. 1.1: DMAIC Cycle (Snee, R. D. and Hoerl, R.W. (2003)).

Origins of mass production and the birth of lean:

Fred Winslow Taylor, a foundry manager from Philadelphia, laid the foundation for mass production [26]. He was the first to systematically apply scientific principles to manufacturing. His many innovations included: Standardized work identifying the best and easiest way to do the job; reduced cycle time the time it takes for a given process; Time and motion study - a tool for developing standardized work; Measurement and analysis to continually improve the process. The key to mass production was not the assembly line [26]. Rather, it was the thorough interchangeability of parts and ease of assembly. These innovations, in turn, made the assembly line possible. Hemy Fords' conveyor system at the Ford plant, allowed for mass production [33]. The moving assembly line brought the car past the stationary worker [26]. The assembly line reduced walk time, and most importantly, linked sequential processes. Thus, slower workers sped up and faster workers slowed down. No other company had this technology and could not compete with the Ford plant [33]. Ford's system catapulted the company to industry leadership [26].

In the spring of 1950, a young Japanese engineer named Eiji Toyoda visited Ford's vast Rogue Plant in Detroit [26]. He studied every corner of the Rogue,

the world's biggest and most efficient manufacturing complex. Upon his return to Japan, Eiji and his production genius, TaiichiOhno, concluded that mass production would not work in Japan. TaiichiOhno already knew that workers were his most valuable resource. In the years to come, Ohno and his team developed activities to fully involve team members in improvement an utterly novel idea. The Toyota Production System, or lean production, was the solution to Toyota's problems [26]. Over the next thirty years, TaiichiOhno solved these problems one by one and pushed his system through Toyota. Today, the Toyota Production System (TPS) is used synonymously with "lean manufacturing" throughout the world [33]. But today we face the same daunting problems that Toyota faced a half century ago, Ohno's system is more relevant than ever [26].

Lean manufacturing is a philosophy which focuses on delivering high quality products at the lowest price and at the right time. Lean manufacturing focuses on eliminating waste or non-value added activities. According to Devane, leans basic value proposition is that principles for improving workflow, decreasing setup time, eliminating waste, and conducting preventive maintenance will speed up business processes and return quick financial gains.

In Black and Hunter, the authors propose a ten step process to achieve lean production. According to Black and Hunter, these ten steps were taken from hundreds of successful functional manufacturing systems conversations to lean manufacturing. These steps are numbered and the order of implementation should exactly follow the step order.

The ten steps and a brief description are given below:

Step 1: Reengineering the Manufacturing System

Restructure/reorganize fabrication and assembly systems into cells that produce families of parts/products. The cells should have one-piece parts movement within cells and small-lot movement between cells, achieved by creating a linked-cell system.

Step 2: Setup reduction and elimination

Setup time for a cell should be less than manual time, or the time a worker needs to load, unload, inspect, deburr etc.

Step 3: Integrate Quality Control into Manufacturing

The operation should be "Make-one, check-one, and move-on-one "type; and the quality of products output from the system should be 100%.

Step4: Integrate Preventive Maintenance into Manufacturing

There should be no equipment failure and the workers should be trained to perform routine low level process maintenance.

Step5: Level, Balance, Sequence and Synchronize

Fluctuations in final assembly should be eliminated, output from cells should be equal to the necessary demand for parts downstream and the cycle time should be equal to take time final assembly for final assembly.

Step6: Integrate Production Control into Manufacturing

Cells respond to demand by delivering parts and products only as they are needed, or just in time.

Step7: Reduce Work-In-Process (WIP)

Minimize the necessary WIP between cells, and parts are handled one at a time within cells.

Step8: integrate Suppliers

Reduce the number of suppliers and cultivate a single source for each purchased component or subassembly.

Step9: Autonomation

Inspection should become part of the production process (100% inspection) and there should be no overproduction.

Step 10: Computer-Integrated Manufacturing

Production system to be as free of waste as the manufacturing system.

These ten steps are used as the default methodology for lean implementation in this research.

1.3. Lean Six Sigma:

The term "Six Sigma" is a reference to a particular goal of reducing defects to zero [18], The sigma, or standard deviation, tells you how much variability there is within a group of items (the "population"), The more variation there is, the bigger the standard deviation, In statistical terms, therefore, the purpose of six sigma is to reduce variation to achieve very small standard deviations so that almost all of your products or services meet or exceed customer expectations. Lean Six sigma is a methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed, and invested capital [28] Since Lean Six Sigma starts with customers, its goal is clear - to eliminate anything that doesn't meet their needs [29]. What's also important in Lean Six Sigma is checking on the consistency in your products, services, and processes. How likely it is that customer will consistently get something they're happy with? If you deliver what they want one day, but not the next day, they may take their business elsewhere.

The Principle of Lean Six Sigma: The activities that cause the customer's critical-to-quality issues and create the longest time delays in any process other the greatest opportunity for improvement in cost, quality, capital, and lead time [9]. Though each piece of the Lean Six Sigma process can add value to your organization, the real gains will come from seeing the methods as a complete process that help you determine and implement clear direction from the board room to the frontline office or factory.

Lean Six Sigma combines the two most improvement trends of our time: making work better (using Six Sigma) and making work faster (using

lean principles) [29]. Establish metrics that are meaningful for the health of your business [34]. Metrics - measures against which current procedures and finished products can be compared - will be different for each organization. These metrics will be the goals that the company should always be working to achieve. If it matters, it will be measured.

2. Research Synthesis:

2.1. Six Sigma methodology:

Six Sigma is the major focus of many companies for its powerful breakthrough performance demonstrated in GE, Motorola etc. recently. Six Sigma can help companies to reduce cost, increase profits, keep current customers and create new customers. In brief, Six Sigma is a methodology to reduce the variation of every process and their interfaces to achieve a very high quality level.

In statistical theory, six sigma is an ideal target value, and expressed as: 6σ. It means when the process or product we observed under a normal distribution, the probability of a specific attribute value shifts from the mean about positive or negative six standard deviation would be 0.002 part per million (ppm). Motorola Company found a phenomenon that the process mean would shift around the center point of specifications in a long-term processing, and the shifting range would be about positive or negative 1.5 standard deviations from the center point of specifications.

Hence, Motorola Company modified the statistical meaning of six sigma. The definition can allow the sample mean shifts from the center of the population, and the observed process or product would out lie the six sigma limits only 3.4 times per million operations under the original specifications. In addition, the sigma performance can also be expressed by "Defect Per Million Operations (DPMO)" shown as Table 2.1.

Table 2.1: DPMO and Sigma Performance.

Yield	DPMO	Shift from Mean	Popular Age
6.68 %	933200	± 0σ	
30.9 %	690000	± 1σ	
69.2 %	308000	± 2σ	1970s
93.3 %	66800	± 3σ	1980s
99.4 %	6210	± 4σ	Early 1990s
99.98 %	320	± 5σ	Mid 1990s
99.9997 %	3.4	± 6σ	2000s

Six Sigma means the world leading quality level. More and more companies understand to use Six Sigma to improve the process quality so as to achieve the business dramatic performance. This is because Six Sigma requires the quantitative measurements and analyses of the core business processes as well as suppliers' involved processes.

Originally, Six Sigma methodology is applied to manufacturing industries. However, the applications of Six Sigma are no longer be limited in manufacturing processes today. Keim demonstrated Six Sigma is very suitable to improve the service performance by two real cases. Paul pointed that the recent trends in Six Sigma are: emphasis on cycle time reduction, smaller business deployment, and integration with other initiatives.

As the Six Sigma market grows, so does the availability of organizations to assist in deployment and integration. This availability of technical expertise allows smaller businesses realistically consider Six Sigma deployment with minimal economic investment. Besides, due to the central concern of Six Sigma is to pursue the customer satisfaction and business performance; we can view Six Sigma a main structure while integrating with other initiatives. As for the integrating initiatives such as Lean Production System, Total Quality Management or Quality Costs etc. depend on the different requirements of each company.

2.2. Lean manufacturingprinciples:

Lean manufacturing can best be described as eliminating waste in a production process, Anything that does not add value to the end product is waste, Womak and Jones stated that lean thinking can be summarized in five principles: precisely specify value by specific product, identify the value stream for each product, make value flow without interruptions, let the customer pull value from the producer, and pursue perfection, The first requirement in making a successful transition to lean is to have a clear vision of what the company will become [30]. You can get there, there is no doubt, but the journey will take time and discipline. All the while you must hold tight to the vision and take consistent actions.

Essentially, lean manufacturing seeks to produce a product that is exactly what the customer wants, when the customer wants it, while minimizing all non-value added activities in production. In the literature, value is simply defined as what the customer is willing to pay for. Non-value added activities are generally understood to be either waste, or incidental activities that are necessary but add no value to the product. The best example of a non-value added activity is quality assurance. Quality inspections do not add value to a product; they merely detect defects before they reach the consumer. The foundation of the lean system is

stability and *standardization* [26]. The walls are *just-in-time* delivery of parts of products and *jidoka,* or automation with a human mind. The goal (roof) of the system is customer focus: to deliver the highest quality to the customer, at the lowest cost, in the shortest amount of time. The heart of the system is *involvement:* flexible motivated team members continually seeking a better way.

Very often, we tend to see business leaders, project managers getting honored by the Managing Director of an organization for completion of a successful project [32]. Good business results were achieved and there comes the CEO or Managing Director recognizing them in front of all the other top guns. That is good but isn't enough. The important point here is in order for a company to stay competitive and healthy in business, it does not only need the commitment and contribution from these top people, but the entire population of the organization. The population here is referred to the' line workers' that means the line operators, technicians or shop floor personnel. When the time comes to begin the transformation to lean, management will need to get people together and let them know what is going to happen, and what they can expect [30]. A meeting or series of meetings should be held in which plans, objectives, strategies, and the reasons for the transformation are communicated. The purpose of the meetings is to create a vision for the immediate future, a road map that will eliminate as much uncertainty as possible during what is sure to be an uncertain time in the company. People should understand why the decision to go lean has been made, that it is essential to remaining competitive, and that it is the only way to achieve the company's goals. They can expect the company to grow and expand which will create opportunities, some of which will flow to them. The lean transition is, at its core, an organizational culture transition and it follows that managing lean, particularly during the initial phases, is actually more about managing the change process than managing lean tools and techniques [25]. By initial phases we are referring to the time period in takes to create a culture that does not automatically revert back to the "old ways of doing work" when faced with a challenge. Until the desired new behaviors become firmly established, that is to say that the culture has been truly changed, they are at risk of being subordinated by the old behavior and disappearing. Culture change takes time; it cannot be accomplished overnight or in a few weeks. With hard work and determination combined with a little luck, significant culture change might be accomplished in a few years. The below Figure Shows the Hierarchical structure of Lean approach [17].

2.3. The seven types of waste in a manufacturing process:

The key principle of Lean is that waste ("muda") is the underlying driver of operational inefficiency. To become more efficient, companies should identify waste from the customer perspective and then determine how to eliminate it. Waste is defined in general terms as activities that do not add value to the product/service and that the customer would not want to pay for. Toyota has identified seven major types of non-value-adding waste in business or manufacturing processes, which are described in Table 1 [31]. These can be applied to product development, order taking, and the office, not just a production line.

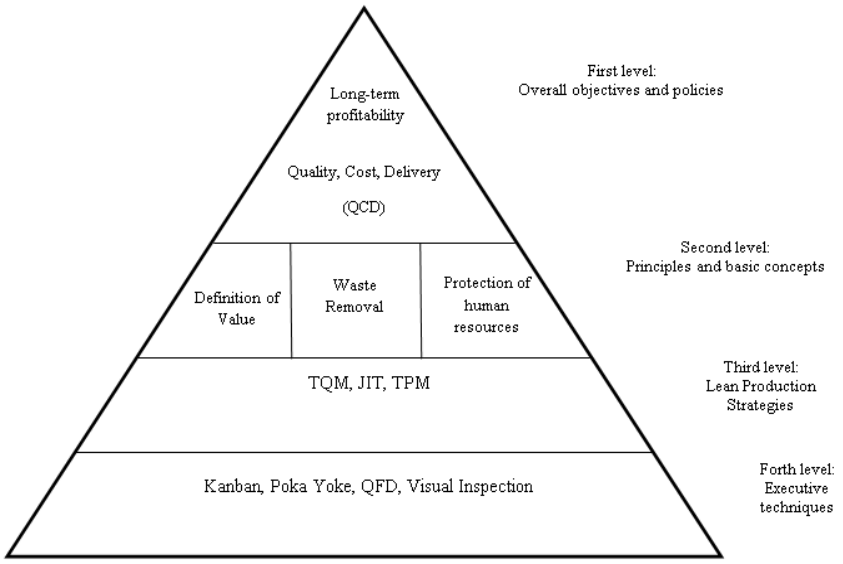


Fig. 2.1: The Hierarchical structure of Lean approach.

Table 2.2: Definitions for the seven types of waste in a manufacturing process.

Type of Waste	Description
Overproduction	Producing items for which there are no orders, which generates such wastes as overstaffing and storage and transportation costs because of excess inventory.
Waiting (time on hand)	Workers merely serving to watch an automated machine or having to stand around waiting for the next processing step, tool, supply, part, etc., or just plain having no work because of stock outs, lot processing delays, equipment downtime, and capacity bottlenecks.
Unnecessary transport or conveyance	Carrying work in process long distances, creating inefficient transport, or moving materials, parts, or finished goods into or out of storage or between processes.
Over-processing or incorrect processing	Taking unneeded steps to process the parts. Inefficiently processing or due to poor tool and product design, causing unnecessary motion and producing defects. Waste is generated when providing higher-quality products than is necessary.
Excess inventory	Excess raw material, work-in-process, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and Excess inventory storage costs, and delay. Also, extra inventory hides problems such as production imbalance, late deliveries from suppliers, defects, equipment downtime, and long setup times.
Unnecessary movement	Any wasted motion employees have to perform during the course of their work, such as looking for, reaching for, or stacking parts, tools, etc. Also, walking is waste.
Defects	Production of defective parts or correction. Repair or rework, scrap, replacement production, and inspection mean wasteful handling, time, and effort.

When these elements of waste exist, all they do is increase costs and add zero value to the manufacturing process. Ohno considered the fundamental waste to be overproduction [31]. Producing more than the customer wants by any operation in the manufacturing process necessarily leads to a build-up of inventory somewhere down stream: the material is just sitting around waiting to be processed in the next operation.

Lean organizations are adept at processing only what the subsequent step in the process requires. The processing is done when it is needed and at the right quality levels. By identifying and eliminating waste, the remaining work is only what is needed to convert the product or service into a form that the customer is willing to pay for. An implicit assumption with this approach is that eliminating waste reduces cost.

2.4. Steps to eliminate waste in a manufacturing process:

Process improvement is the only way to improve the results that your company wants to improve [29]. You have to examine how work flows from one person or workstation to the next you have to look at variation and how it affects the process. A good place for any company to begin the journey to lean is to create continuous flow wherever applicable in its core manufacturing and service processes [31]. Flow is at the heart of the lean message that shortening the elapsed time from raw materials to finished goods (or services) will lead to the best quality, lowest cost, and shortest delivery time. Flow also tends to force the implementation of a lot of the other lean tools and philosophies such as preventive maintenance and built-in quality. A lean process is one in which the value-added time in the process is more than 25% of the total lead time of that process [9]. To get to world class, the value added time divided by the total lead time must equal 25% or greater.

The goal of lean is to virtually eliminate wait time [9]. In order to eliminate the waste and eliminate the wait time, the company has to be able to look at the value stream of the manufacturing process. What is it that adds value to the product and what is it that does not add value to the product. This process is known as the value-stream. The value-stream is simply going through the entire manufacturing process and looking at the things that add value to the product and the things that do not. Once those key factors are determined, the process of eliminating waste can begin by concentrating on those things that do not add value. From a lean perspective, the first thing you should do in approaching any process is to map the value stream following the circuitous path of material (or paper or information) through your process [31]. It is best to walk the actual path to get the full experience. You can draw this path on a layout and calculate the time and distances traveled and then give it the highly technical term of "spaghetti diagram". A "spaghetti diagram" is a very useful tool in that it gives the true path of how material is flowing through the process. Once this diagram is on paper, it gives people a good visual understanding as to the path the material is flowing and how much distance is wasted during the transfer of material. With this visual tool, it allows people the opportunity to start working towards a more efficient flow of material and eliminate the unnecessary travel distance that is currently in their

system. With this knowledge, we can manage decision points, form a future roadmap for implementation, and identify opportunity areas [9]. Value stream mapping also provides a communication tool to stimulate ideas by capturing critical organization knowledge and identifying locations for data gathering and process measurement. The key insight is that a lot of non-value-added costs are in fact required to move the product through the "molasses "flow.

You can't remove these costs until you remove the underlying causes; trying to do so will just create greater costs in the long run. You will have identified your discreet value streams early in the lean implementation process; it is within these value streams that we apply lean tools to reduce lot sizes, lead time, and inventory and cost [27]. One vital step toward excellence is the co-location of process elements in the value stream, which is a layout issue. Until we physically isolate the value streams, we are quite limited in our ability to remove waste. On the other hand, when we have "shuffled the furniture" to create cells and focused factories, we have set the stage for major waste reduction. We can now foster a lean culture characterized by an abiding commitment to continuous improvement. Just as activities that can't be measured can't be properly managed, the activities necessary to create, order, and produce a specific product which can't be precisely identified, analyzed, and linked together cannot be challenged, improved (or eliminated altogether), and, eventually, perfected. Lean benchmarkers who discover their performance is superior to their competitors' have a natural tendency to relax while mass producers discovering that their performance is inferior often have a hard time understanding why. They tend to get distracted by easy-to-measure or impossible-to-emulate differences in factor costs, scale, or "culture"' when the really important differences lie in the harder-to-see ways value-creating activities are created. Don't worry about your competitors; compete against perfection by identifying all activities that are waste and eliminate them. You will become a World Class performer one Kaizen event at a time [27]. Use resources who know how to structure and facilitate effective events, as well as help develop in- house people, it is critical to use report-outs at the end of each Kaizen event to educate management and recognize efforts.

3. Methodology:

3.1. Combining six sigma to Lean Production:

According to George, the principle of lean six sigma is that activities that cause the customer's critical-to-quality issues and create the longest time delays in any process offer the greatest opportunity for improvement in cost, quality, capital, and lead time. Table 3 shows the fundamental differences between six sigma and lean production methodologies.

Table 3.1: Fundamental differences between six sigma and lean production methodologies.

Issues/problems/objectives	Six Sigma	Lean Production
Focuses on customer value stream	No	Yes
Focuses on creating a visual workplace	No	Yes
Creates standard work sheets	No	Yes
Attacks work-in-process inventory	No	Yes
Focuses on good house keeping	No	Yes
Process control planning and monitoring	Yes	No
Focuses on reducing variation and achieve uniform process outputs	Yes	No
Focuses heavily on the application of statistical tools and techniques	Yes	No
Employs a structured, rigorous and well planned problem solving methodology	Yes	No
Attacks waste due to waiting, over processing, motion, over production, etc.	No	Yes

According to George, Six Sigma does not directly address process speed and so the lack of improvement in lead-time in companies applying six sigma methods alone is understandable. In a similar manner, those companies engaged in Lean methodology alone show limited improvements across the organization due to the absence of six sigma cultural infrastructure. According to Smith, six sigma projects take months to finish, and they produce elite black belts who are disconnected from the shop floor, while, lean boost productivity but does not provide any tool to fix unseen quality issue. According to Smith, lean brings action and intuition to the table, quickly attacking low hanging fruit with kaizen events, while six sigma uses statistical tools to uncover root causes and provide metrics as mile markers.

According to Devane, a pure six sigma approach lacks three desirable lean characteristics:

1. No direct focus on improving the speed of a process
2. No direct attention to reductions in the amount of inventory investment
3. No quick financial gains due to the time required to learn and apply its methods and tools for data collection and analysis.

According to Devane, shortcomings of a pure lean improvement effort:

1. Processes are not brought under statistical control
2. There is no focus on evaluating variations in measurement systems used for decisions
3. No process improvement practices link quality and advanced Mathematical tools to diagnose process problems that remain once the obvious waste has

been removed. According to Smith, when run separately, such programs will naturally collide with each other. In contrast, a combination of lean and six sigma has a positive impact on employee morale, inspiring change in the workplace culture because teams see the results of their efforts put to work almost immediately. According to George, lean six sigma directly attacks the manufacturing overhead and quality costs more effectively than any previous improvement methodology because it comprehends both quality and speed. Thus an obvious solution is to develop an integrated approach that will produce greater solutions in search of business and operational excellence, hence lean six sigma.

The focus of current research in many academic and research institutions today is to integrate lean principles and six sigma methodology for achieving greater operational efficiency.

According to Devane, the key concepts of lean six sigma are the following:

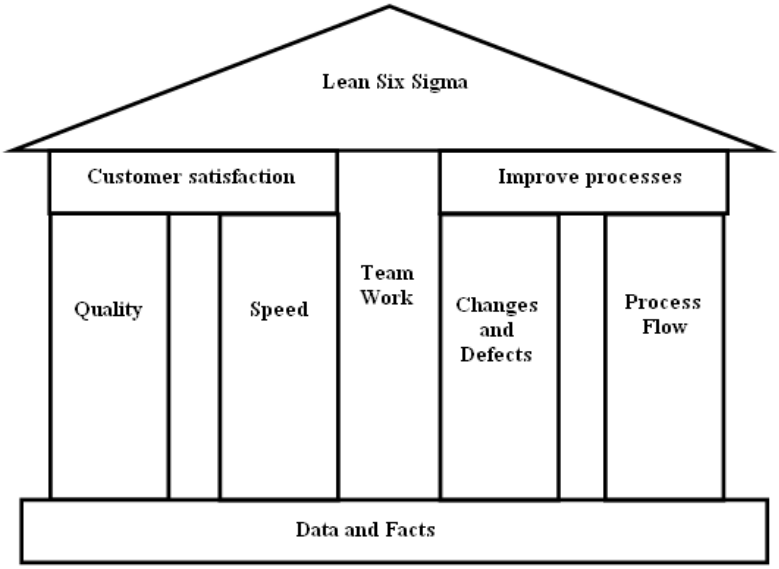
1. The voice of the customer and "CTQ".
2. The six sigma metric.
3. Elimination of waste and non-value added activities.
4. Process.
5. Unintended variation is the enemy.
6. Value Streams.
7. The "DMAIC" improvement process.

According to Smith, lean brings action and intuition to the table. Based on the principles of Toyota Production System and Kaizen (Continuous improvement) breakthrough methodology, lean focuses on creating one-piece flow with just-in-time management of inventory and materials. Using five-day kaizen events, cross functional groups improve lead time and reduce inventory on the spot, attacking the kind of quality and flow issues referred to as "low hanging fruit". The idea is to implement a culture of continuous improvement. Using the six sigma kaizen team based approach; results are implemented faster with the participation of teams of employees from the shop floor to the executive suite.

According to George, it really does not matter whether lean enterprise methodologies or six sigma approaches is used first – rather the approach should be based on the personnel preference of the six sigma black belt who is leading the team. Also, the slow rate of corporate improvement is not due to lack of knowledge of six sigma or lean. Rather, the fault lies in making the transition from theory to implementation. Managers need a step-by-step, unambiguous roadmap of improvement that leads to predictable results. This roadmap provides the self-confidence, punch, and power necessary for action.

An unambiguous roadmap towards lean six sigma has still not been proposed; this roadmap provides a step by step process towards achieving lean six sigma. This roadmap should also provide to the managers the necessary toolsets that could be used to achieve any particular step. This roadmap should also be flexible enough to adapt as the learning curve within the organization improves; by providing access to theoretical implementation processes and practical results within the organization or between multiple organizations. The roadmap should also be capable of guiding the implementation team to certain specific steps that needs immediate attention based on the team's current level of implementation. In essence, there is an urgent necessity for a roadmap that tells the lean six sigma implementation team "what to do?", "How to do?" and help them in doing it.

The below Figure (Fig.3.1) shows the key concepts of lean six sigma. [29]



3.2.Lean Six Sigma Process Tools:

"Process Improvement" refers to a strategy of finding solutions to eliminate the root cause of performance problems in processes that already exist in your company. Process Improvement efforts seek to fix problems by eliminating the causes of variation in the process while leaving the basic process intact. In Six Sigma terms, Process Improvement teams find the critical Xs (causes) that create the unwanted Ys (defects) produced by the process.

5S is a set of techniques, all beginning with the letter "s" [35]. They are used to improve workplace practices that facilitate visual control and lean implementation. The 5Ss are: Separate, Set to order, Shine, Standardize, Sustain. George, *et al*, state that 5S enables anyone to distinguish between normal and abnormal conditions at a glance. 5S is the foundation for continuous improvement, zero defects, cost reduction, and a safe work area and is a systematic way to improve the workplace, processes, and products through production line employee involvement. As defined by George, *et al* the 5S definitions are as follows in Table 4.

DMAIC (Define, Measure, Analyze, Improve, and Control) is a structured problem-solving methodology widely used in business. These phases lead a team logically from defining a problem through implementation solutions linked to underlying causes, and establishing best practices to make sure the solutions stay in place.

These tools are worth the effort [9]. They have been proven in practice, time and again, that they can bring nearly miraculous progress to what you thought were "intractable" problems. They are the tools that can achieve breakthrough performance improvements in quality, cost, and lead time.

Table 3.2: Definition of 5S.

Term	Definition
Sort	Clearly distinguish needed items from unneeded items and eliminate the latter.
Set in order	Keep needed items in the correct place to allow for easy and immediate retrieval.
Shine	Keep the work area swept and clean.
Standardize	Standardize cleanup
Sustain	Make a habit of maintaining established procedures

Table 3.3: Definition of the DMAIC process.

Term	Definition
Define	Define Review project charter, validate problem statement and goals, validate voice of the customer, validate financial benefits, create communication plan, select and launch team, develop project schedule, complete define gate.
Measure	Value Stream Map for deeper understanding, identify key metrics, develop operational definitions, develop data collection plan, collect baseline data, determine process capability, complete measure gate.
Analyze	Determine critical inputs, identify potential root cause, reduce list of potential root causes, prioritize root cause, complete analyze gate.
Improve	Develop potential solutions, evaluate and select best solutions, develop and implement pilot solution, develop full scale implementation plan, complete improve gate.
Control	Implement mistake proofing, implement SOP's and process controls, implement solution and ongoing process measurements, complete control gate, transition monitoring/control to process owner.

You should apply the concepts of Lean Six Sigma to build upon your existing development capabilities and provide your design teams the knowledge and tools to help them generate more profitable products faster to grow your business.

There are no shortcuts to "world class" [11]. Bringing the tools of Lean Enterprise into an organization requires commitment and culture change. There is no more powerful tool in an organization than the excitement of its employees.

3.3. Interaction techniques of Six Sigma and lean manufacturing:

Implementation of Six Sigma and lean manufacturing methodologies are required to apply the various techniques. Some of these techniques are unique to each approach and both are common in some other form. This is shown in the figure below. [42].

Also the below figure indicates that the integration of Six Sigma and lean manufacturing can bring added value and improve flow of lubricant, it also reduces variation and changes.

3.4. House without waste:

In this section we take attention to a model home with no waste. The interaction of Six Sigma and lean manufacturing in order to create an environment free from any lesion shows.

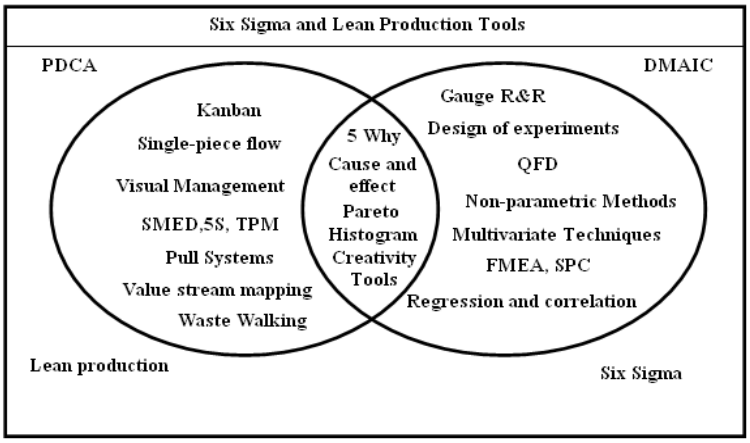
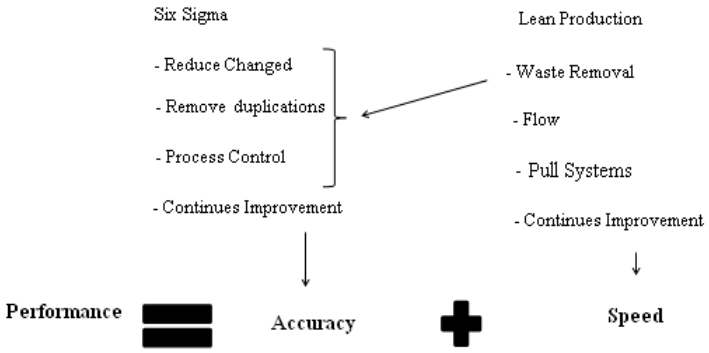


Fig. 3.2: Interaction techniques of Six Sigma and lean manufacturing [42].



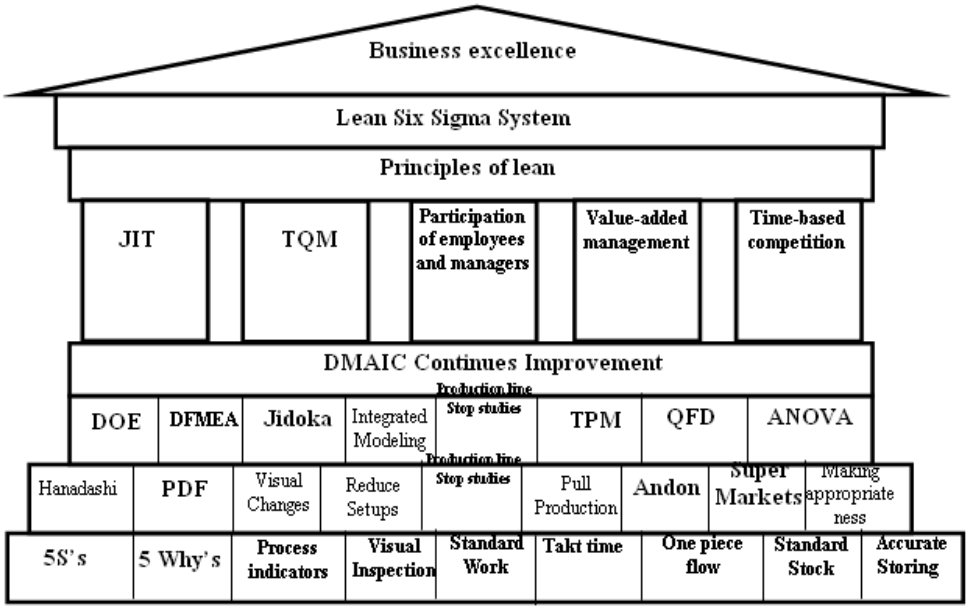


Fig. 3.3: House without waste.

Conclusion:

Two basic strategies can be proposed for improving manufacturing operations, one of them is Lean Production and the other is six sigma. Lean Manufacturing evaluate all of the operation of a plant and review and restructuring manufacturing and construction methods to reduce the additional activities such as loss of time, waiting, transportation and replacement of inappropriate material, equipment and over- production of the required puts. It also reduces the variance associated with conventional methods of producing, transporting and working with materials, warehousing and storage, lack of communication that will produce a non-continuous flow. On the other hand, six sigma tools usually focus on special part or stages to reduce variance. Combination of these two methods is a hard and strong barrier against the dispersion that includes plant layout and concern on special stages.

Lean manufacturing and Six Sigma have emerged as the different mechanisms and processes of thought. The detailed inspections have shown that both strategies are against the one enemy raided yet and linked together as chains which make both mechanisms are dependent on each other to achieve success. Both campaign against Bending and scattered, but each has its own style and with two different points. Integration of lean manufacturing and Six Sigma methods included both instrumental and powerful method in solving problems and it will form a powerful combination. This approach should be viewed as complementary to each other not as similar methods and replace each other.

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