

The Perplexing Enigma of Supply Chain Management: Literature Review

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ABSTRACT

The paper intends to explore the various developments that took place over the years in Supply Chain Management. It tries to delve deeper into this context and also highlights the imperative aspects pertinent to it by throwing light on the evolutionary aspects of concepts such as Six Sigma and others. In fact, it has tried to focus upon the innovative concept of Lean by describing in detail what it is about and how it can be very significant for the modern day large and complex forms of organizations. Details regarding this along with the methodology and its implications are also given. Furthermore, the assortment of Case Studies emphasizing its substance was also discussed with thorough analysis and illustrations with especial reference to successful lean implementation. It also draws attention to the pioneering idea of Lean manufacturing's integration with Six Sigma and consequently how it facilitates the process improvement. The instances of corporations such as Lockheed Martin and Bank One are also taken into consideration and especially included in this paper.

Keywords: Supply Chain, Six Sigma, Lean, Assortment, Substance

INTRODUCTION

Here in this chapter the developments in supply chain management and evolution of Six Sigma are described. Some details on what it is about and its methodology are also given. Some case studies to highlight its importance are also discussed in this literature review. While explaining the concept of lean, case studies of successful lean implementation are also illustrated. It will also brief about Lean manufacturing's integration with Six Sigma and how it helped in process improvement.

Douglas¹ (2004) said, "A streamlined process reduces the order-to-cash cycle which frees up capital, and reduces the delivery lead time which allows for reduced inventory levels."

DEFINING A SUPPLY CHAIN

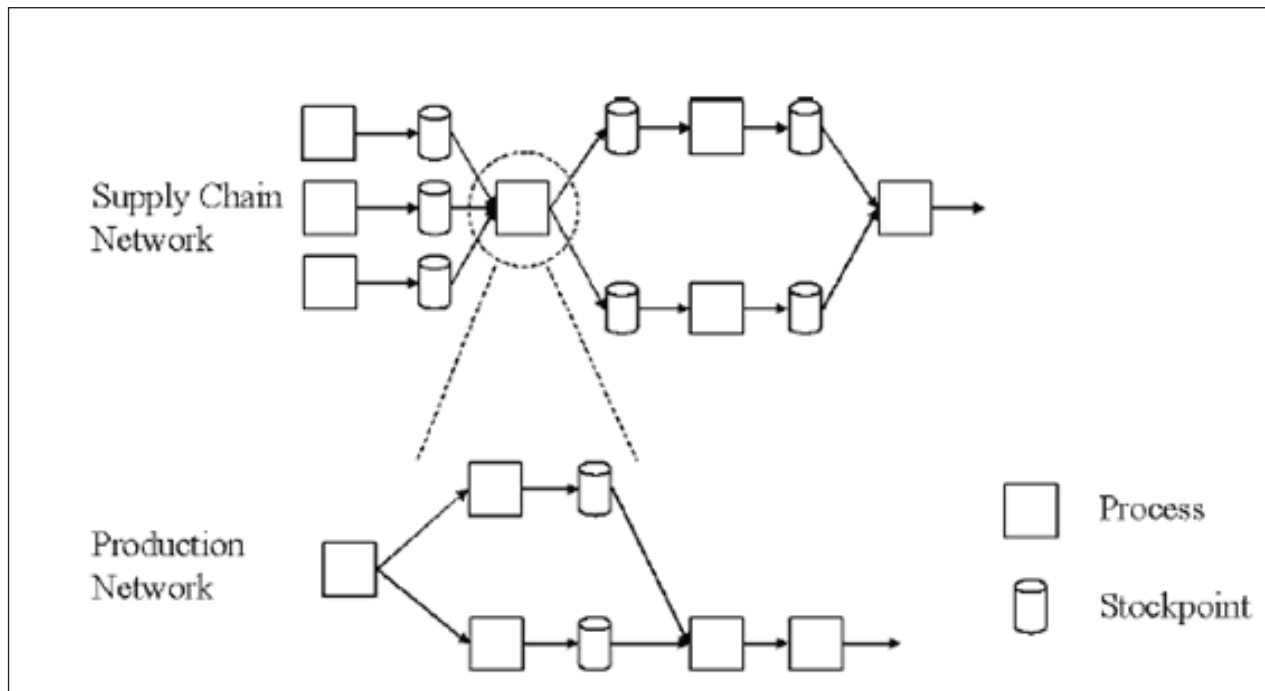
It is believed that by necessity science is reductionist. All real-world systems are too complex to study in their totality. So scientists reduce them to a manageable size by restricting their scope and by making simplifying assumptions. For example, all introductory physics students begin their study of mechanics by learning about

objects moving at sub-relativistic speeds in frictionless environments. Although almost all practical mechanical systems violate these conditions, the insights one gains from the stylised systems of classical mechanics are vital to the understanding of more realistic systems. Hence, the friction-free model of moving bodies satisfies the fundamental criterion of any scientific model-it captures an essential aspect of a real system in a form that is simple enough to be tractable and understandable.

To get anywhere with a science of supply chains we must first reduce the complex arrays of suppliers, plants, warehouses, customers, transportation networks and information systems that make up actual supply chains to structures that are simple enough to study rigorously. To do this, we must choose a level at which to model a supply chain. Clearly the level of the entire business is too high; the resulting models would be hopelessly complex and the details would obscure important commonalities between different supply chains. Similarly, the level of an individual operation is too low; while modeling a specific process (e.g., metal cutting) in detail may be tractable, it will give us little insight into what drives the performance metrics (e.g., profit) a manager cares about.

Definition (Supply Chain): A supply chain is a goal-oriented network of processes and stockpoints used to deliver goods and services to customers.

¹ Professor in Ohio State University of Supply Chain Management

Fig. 1: Supply Chain as Flow Networks

In this definition, processes represent the individual activities involved in producing and distributing goods and services. They could be manufacturing operations, service operations, engineering design functions or even legal proceedings.

But, since our focus is on the overall performance of the supply chain, we will concentrate primarily on the on the flow of goods and services. So we will usually view the processes in generic terms, with only as much specification as necessary to describe their effect on these flows. This perspective will enable us to apply our models across a broad range of industrial settings and adapt insights from one industry to another.

In addition to processes, our definition involves stock points, which represent locations in the supply chain where inventories are held. These inventories may be the result of deliberate policy decisions (e.g., as in the case of retail stocks) or the consequence of problems in the system (e.g., as in the case of a backlog of defective items awaiting repair). Because managing inventories is a key component of effective supply chain management, it is vital to include stock points in the definition of a supply chain.

Processes and stock points are connected by a network, which describes the various paths by which goods and services can flow through a supply chain. Fig.1 represents an example of such a network, but the number of possible

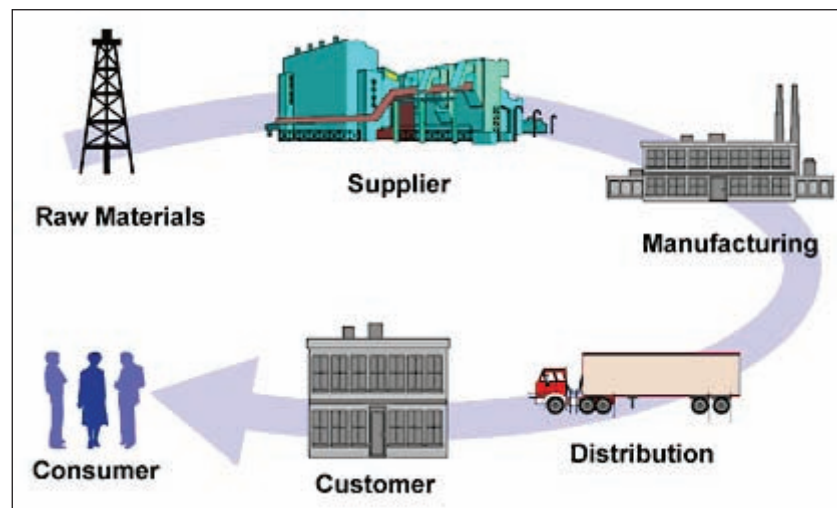
configurations is virtually unlimited. So, in the spirit of scientific reductionism, we will often find it useful to break down complex networks into simpler pieces. A feature of our definition that helps facilitate this is that, at this level of generality, supply chains and production operations are structurally similar.

Finally, note that our definition of a supply chain specifies that it is goal oriented.

Supply chains are not features of nature that we study for their own sake. They exist only to support business activities and therefore must be evaluated in business terms. Usually this means that the fundamental objective of a supply chain is to contribute to long term profitability. But profitability or cost effectiveness is too general to serve as a metric for guiding the design and control of supply chains. Therefore, a key starting point for a supply chain science is a description of the strategic objectives the system should support.

Supply Chain Management (SCM) is one of the most important aspects in any production system. Analytical decisions have to be taken to coordinate the supply and production of goods and services. Logical analysis followed by its implementation to manage inventory, vendor development to buy materials from, and how to feed to assemblies in the most cost-effective and timely manner.

Fig. 2: Supply Chain Management



Source:www.metalez.com

As per Siems²(n.d.), a supply chain of a manufacturing unit is made up of many interrelated vendors and transaction points. There are component and subassembly suppliers. Above in the chain we have suppliers of suppliers mentioned above which in turn finally reaching the raw materials suppliers at the tail of the chain.

Moving downstream, back towards the producing firm, the supply chain runs through the warehouses and distribution partners, and then through the retailers finally conceding to with the consumer.

The supply chain encapsulates all activities linked with the flow and mutation of goods and services right from the raw materials stage in beginning through to the customer at the end, including all intermediate parties with respective information flows.

SUPPLY CHAIN MANAGEMENT: IMPROVED, FAST AND CHEAP

Lee³(n.d) said that the best supply chains aren't just fast and cost-effective. They are also agile and adaptable, and they ensure that all their companies' interests stay aligned.

Supply chain management is talks about procuring the right things and then arranging the right things at the right place and that too at the right time in most profitable manner.

RIGHT THING ✓

RIGHT PLACE ✓

RIGHT TIME ✓

= PROFIT

Supply chain management as an integral part of trade is as old as trade itself. New Scientific technologies and research have revolutionised modern supply chains turning them better, faster, and cheaper.

As mentioned in earlier researches about Dell Supply chain where if one wants to buy a computer he has to get on Dell's website and do self-configure and system will generate the price for it. As soon as we submit the online order to Dell, Each downstream supplier of components and subparts will be notified of the sale and they have to arrange themselves so that we receive your computer within stipulated timeframe.

In comparison to direct sales model with the customer being exposed to already assembled product which Dell have thought that it will serve the customer need, the company has eliminated the middleman, and Dell have fine-tuned their upstream suppliers so that production and distribution flowing smoothly. This in fact will reduce the cost also.

Well-trimmed supply chain models, not only helps manufacturers but service providers also like Business Process Outsourcing (BPO), Knowledge Process Outsourcing (KPO), banking, and insurance sector.

Use of information technology has improved the pace of supply chain as there are no delays in transfer information, no inventory and delivery problems.

With the introduction of new technologies like Rail Roads², New Communication Mediums, Double Decker Trains, Scheduling algorithms³ have made supply chains faster, better and cheaper.

Referring to history of 19th century, Henry Ford thought of using scientific management methods to create the assembly line. He was able to show to stakeholders that the time in production of a car has been reduced from 728 hours to 1.5 hours, enabling his company to enter into mass production hence reducing the cost. American manufacturers brought the idea from Ford of mass production and fine-tuned their local supply chains with new operational research.

Later in the seventies, manufacturing in American companies faced problem of competition from foreign companies specially Japan on quality and price parameters which led them to concentrate on quality checking procedure and introduction of new ideas to reduce defects in their supply chains.

In the early 1970s Toyota in Japan introduced the concept of lean manufacturing to prefer flexibility and quality over the efficiency and quantity. Parameters in the lean manufacturing use to be quality checking based on six-sigma and quality management with just-in-time inventory.

In modern times organisations are improving their supply chains through better engineering of information and processes. With the advent of information technology as mentioned in case of Dell, organisation has introduced mass customised products with support of their up and downstream suppliers. This has resulted in better organisation visibility in customer's mind.

Organisations are using modern communication technique like the web, RFID⁴, Barcodes⁵ and wireless to improve handling, servicing, delivery processes. The communication can be secured through secure intranet connections, VPN⁶ (Virtual Private Networks) for business-to-business (B2B) e-commerce solutions. The main driver for the adoption of technology is to improve information management and integrating internal and

2 Convergence of Road and Railway to prevent loading and unloading and direct to and from warehouse

3 Steps generally used to write computer programs

4 Radio Frequency Tags to identify from distance

5 A series of parallel bars of different width having correlation with the text

6 Secured internet connection using public network

external systems. MarutiUdyog and Tata Motors have established VPN for its dealers, service centres, original equipment manufacturers (OEM), and component refurbishers. Also for example delivery of speed post can be tracked by its unique number on the web and similarly and product bought over on online websites like Ebay and Rediff can be tracked. These Internet e-commerce engines keep the manufactures and up-stream suppliers connected on real time basis to that all get synced to provide quality and faster solution to customer.

SUPPLY CHAIN COMPONENTS

Lavassani⁴(n.d.) has mentioned that there were six major movements which describe evolution of supply chain management studies.

- ◆ Creation
- ◆ Integration
- ◆ Globalisation
- ◆ Specialisation Phases One
- ◆ Specialisation Phase Two
- ◆ Supply Chain Management SCM 2.0

Creation Duration

The term supply chain management was first used in United States by a consultant in 1980. Conceptually the supply chain management was already existed earlier with special link with the assembly line manufacturing. The major aspects of this time period was the need for large-scale changes, re-engineering, downsizing and cost reduction programmes, and widespread emphasis on to the Japanese production and management techniques.

Integration Duration

Introduction of Electronic Data Interchange (EDI) systems followed by movement towards Enterprise Resource Planning⁷ (ERP) systems was the main outline of the duration. These processes and systems have continued to develop in 21st century also with the broadening of internet-based collaborative systems. This time period of supply chain evolution is known for value-adding as well as cost reductions via integration.

7 Planning across whole organisation

Globalisation Duration

The next duration was of globalisation which can be characterised by the emphasis given to global systems of producer supplier relationships as well as expanding of supply chains over national political boundaries. Although the use of global procurement was not new as international trade has flourished since centuries. In the late 1980s many organisations initiated the integration of global sourcing process with the core manufacturing and delivery process. This timeframe is known for the taking supply chain management across boundaries and no belief that no customer or vendor is left because of his locations disadvantage and certainly to be brought in to the system if he offers increasing their competitive advantage, value-addition, and reducing costs.

Specialisation Timeframe-Phase One

1990s was the time for industries to focus on core competency and specialisation. Companies left the vertical integration re-managed the non-core operations either through selling or having them off the specialised vendors to cater them. This management had to bring the supply chain partners under the same umbrella and utilising the same strategy as the master organisation is doing.

This transition also forced to re plan the fundamental perspectives of each partner organisation. Original Equipment Manufacturer⁸ (OEM) who aligned themselves with the master brand needs to understand the supply base more deeply. Master organisation need to supervise and control the entire supply chain from above instead of from within. Second level contractors have to check the BOM⁹ (bills of material) with different part numbering schemes and sequences from large number of OEMs and then have to support master through work -in-process plan and inventory managed by vendor.

In the specialisation model manufacturing and distribution networks are created which have multiple and individual supply chains which are product specific, suppliers, and customers. They join hands together to design then manufacture followed by distribution, marketing and servicing the product. Partners may differ depending on market, region and channel of deployment which results

⁸ Direct equipment supplier to a bigger or collaborative brand

⁹ list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture a product

in multiple trading partner environments which have their own characteristics and behavior patterns.

Specialisation Time Frame-Phase Two

Specialised supply chains brought concepts like warehouse management and handling, Transportation brokerages, and non-assisted carriers and which matured beyond simple transportation and logistics into ideas of supply and dispatch planning, tie-ups, execution and elevation of performance through quantitative measurement.

At any snapshot due to changing market conditions there are changes in functioning methodology and operating conditions of suppliers, logistics providers, locations and customers which affects the supply chain networks. These changing dynamics puts significant effects on the supply chain infrastructure right from the bottom of establishing and managing order and confirmation procedure between intermediate parties to more detailed requirements including the process tuning and work flow.

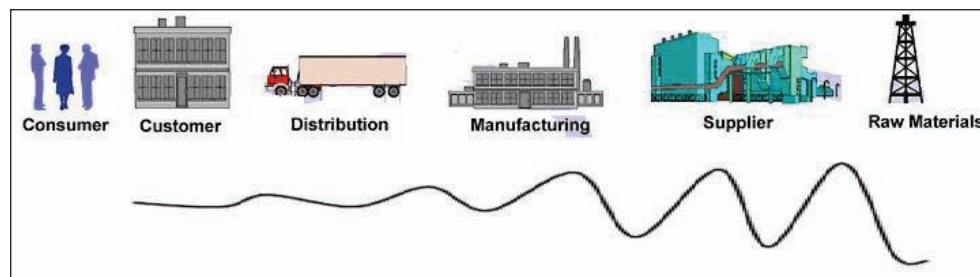
Supply chain methodology enables companies to improve their overall focus and enable the core competencies and the assembly systems and brings the total contribution from all the partners to enhance the value chain. These aspects often lead to increase in overall performance and efficiency.

Domain-specific supply chain knowledgebase can be deployed without maintaining high level of competencies and is the prime reason of supply chain specialisation is getting popular in small and medium enterprises.

Supply Chain Management version 2.0

Moving forward with globalisation and specialisation, term Supply chain management, SCM version 2.0 has been established to describe the changes in process and their evolutions with new tools to manage them.

Web 2.0 is the use of world wide web (WWW), for sharing and distributing information so that better business ecosystem can be created. The retrieval of relevant information out of the huge amount of data available on Internet is also a major attraction among corporate. It is like making a tunnel to the information right from the locator to information. SCM 2.0 follows this philosophy in supply chain operations. It is a tunnel towards SCM results with, set of the processes, methods, tools logic, and delivery methods to suggest to the companies to arrive to the results quickly. Arriving at the results and conclusions

Fig. 3: Bull Whip Effect

at a faster is needed because there are inherent variables which are beyond the control of organisations. Some of these are global, like oil and shipping prices or the ore or metal prices while there are some local issues like human resources issues, local shippers, local governance and laws which affect the business to a larger extent.

SCM 2.0 utilised modern algorithms which are designed to quickly deliver results with the precision to quickly manage future aspects for continuous variability and flexibility, value and success.

Competency networks delivers through supply chain domain expertise which understand various variable, both operationally and organisationally. They are some of the few critical ones who understand the nature, impact and fine tuning of the variables to achieve desired results.

Business process outsourcing, services management and providing SaaS¹⁰ (Software as a Service), or customised solutions are some way of participating in supply chain management in SCM2.0

COMPONENTS OF SUPPLY CHAIN

There are four basic components of Supply chain

Production: Which Answers Business Questions Like

- ◆ How much quantity to produce?
- ◆ Where and how to produce it?
- ◆ Which suppliers to use?

Inventory: Which Answers Business Questions Like

¹⁰ An arrangement where provider licenses an application to customers as a service on demand, through a subscription or a “pay-as-you-go” model

- ◆ Where to store their products?
- ◆ How much should be send to market?
- ◆ How much to store (Future Price Fluctuations)?

Distribution: Which Answers Business Questions Like

- ◆ How handling and forwarding should be done (retail logistics)?
- ◆ How retail storage has to be done?

Payments: Which answers business questions like

- ◆ What are best ways to pay suppliers?
- ◆ What are the best ways to received payments from customers?

The core of efficiency and effectiveness in any supply chain depends on the ability to handle important information related these components.

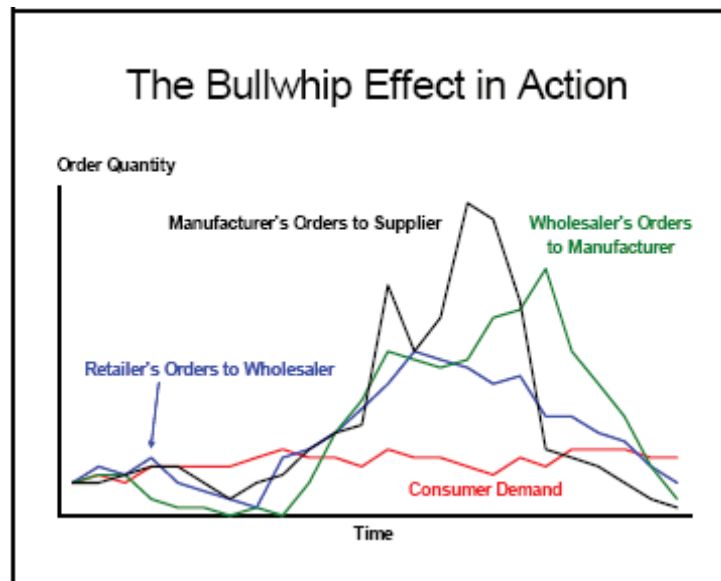
INFORMATION DISTORTIONS IN SUPPLY CHAIN

Bull Whip Effect

The shortage of information or distorted information is prime reason of bull whip effect which is named after the way amplitude of whip is represented as we move across the length.

It represents fluctuations in ordered quantities which become bigger at every upward step the supply chain starting from customer to the raw material vendor.

Fig.4: Bull Whip Effect in Action



Source: sloanreview.mit.edu

In the internal research of a famous FMCG company Proctor and Gamble (P&G), after studying the demand for disposable diapers it was thought that their use should be fairly constant and predictable against which the retail sales have to be uniform. But to the surprise it was detected that each retailer orders on his own, slightly exaggerated future demand and the real demand is not being reflected. Upwardly in the supply chain wholesaler also puts some addition to already exaggerated demand which in turn leads to P&G's ordering more than the real need to its suppliers.

Production

Let us see how bullwhip puts its effects on the production through checking the sales growth volatility on the customer side and comparing it with production growth volatility on the opposite end of the supply chain. Supply

chains which use proper information distributed on real time basis gets an information distortion bullwhip which looks like the shallower red line.

In the case of durable goods, production growth volatility comes near to growth volatility in sales. Major change in production growth volatility is because of improved process of manufacturing and quality control and the new information technologies tools.

For example, Reliance Petroleum has implemented a state of art information system that captures sales data directly at the Point of Sale level. Instead of using paper and pencil methods to forecast for the future demands forecasts are now based on algorithms.

For certain petroleum components sales forecasting and inventory management division have been outsourced to the foreign based component manufacturer. So now, a

Fig.5: Bull Whip Effect with Sales and Production Growth Volatility

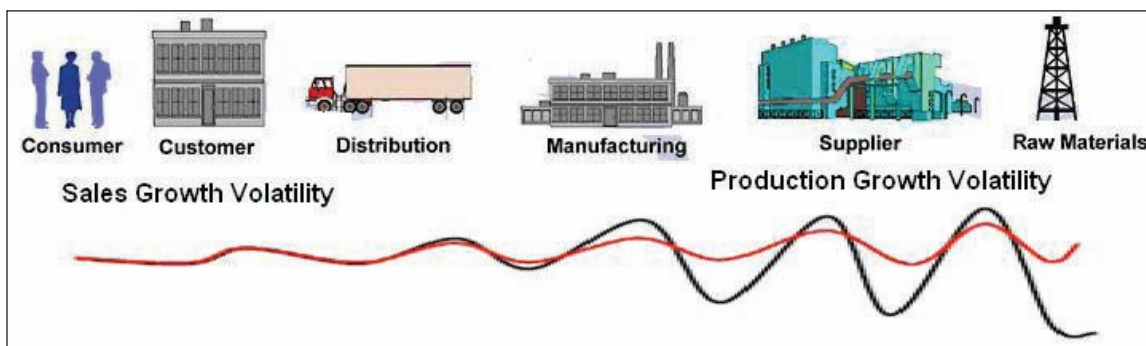
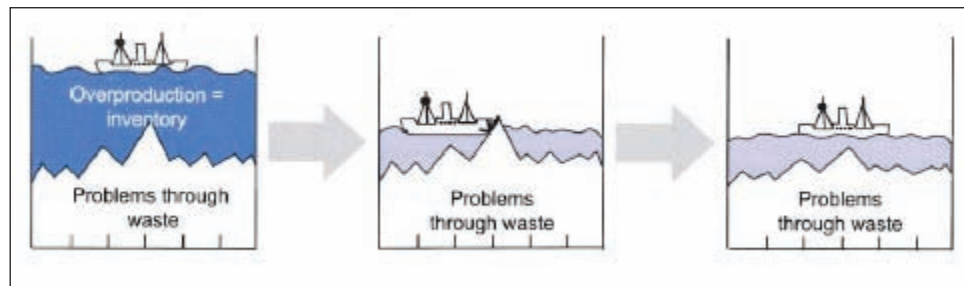


Fig. 6: Inventory as Safety Cushion



Problems are Concealed	Problems get Transparent	Elimination of Causes
Machine Breakdowns Missing Material Bottleneck in production Quality Problem	Quick Identification Necessarily of quick trouble-shooting by associates in area	Elimination of problem allows to run production with low inventory as well as sufficient agility and process stability

supplier in foreign land decides how many components to make with their specifications and sending them directly to Point of Sales (POS) and avoid large bureaucratic system of decision makers and already loaded warehouses.

Inventory

Incorrect information and over enthusiastic figures and because of bullwhip effect unnecessarily inventory gets piled up at every points along the supply chain.

Inventory is insurance against supply chain and price fluctuations. Non-Moving inventory comes with holding costs, warehouse storage costs, space at production site, insurance, obsolescence and damage costs.

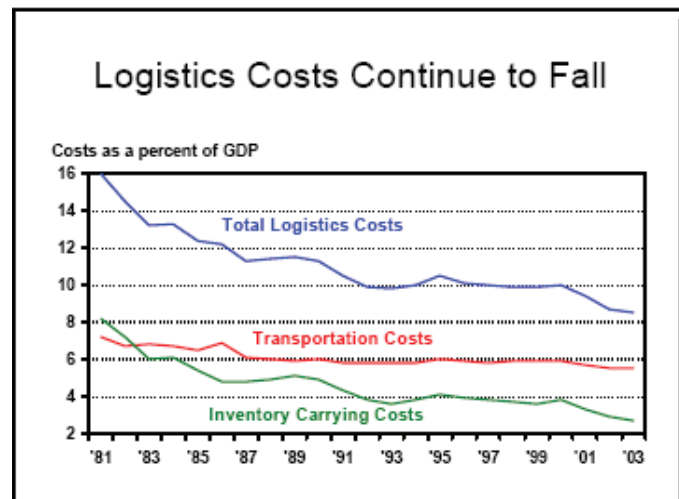
Meanwhile sufficient inventory levels have to be maintained so that demand and production can be smoothly handled out in synchronisation.

Seeing at the example of Dell, which has changed the traditional manufacturing process by adapting to the philosophy of not manufacturing anything till it has an order from a customer the inventory days were reduced from 31 to 4.

Distribution

Every product passes through many steps of transportations in forms of mode and hands before it finally reaches the customer. In the current scenario transportation and distribution of goods have to cover greater distances and requires better coordination.

Fig. 7: Logistics cost v/s Time Plot



Source: www.dallasfed.org

Logistics costs have moved southwards i.e. from about 16 percent in 1981 to 8.5 percent of GDP currently.

Logistics costs have declined mainly because

- ◆ Efficient of inventories
- ◆ Reduction in warehousing expenses
- ◆ Minimisation of risk
- ◆ Customised logistics solutions

Payments

Order placement, billing followed by payments can be done using computer systems eliminating human intervention and paper records.

Technology costs have fallen and companies have understood the benefits of electronic transactions. National Electronic Fund Transfer (NEFT)¹¹ and Real Time Gross Settlement (RTGS)¹² have become very popular in fund transfer. Companies have utilised B2B e-commerce systems to process payments and create an ecosystem of community for communicating with suppliers. This also ensures quick payment, its realisation and less revenue leakage. Cheque truncation system (CTS)¹³, Online Transfers over the internet and Magnetic Ink Character Recorder (MICR)¹⁴, are some technological adoptions in clearing payments.

All of these improvements have

- ◆ Reduced Production volatility
- ◆ Lower inventory levels
- ◆ Inexpensive logistics
- ◆ Reduced Payments hassles

This has been achieved as better methodologies and better technologies have managed information more efficiently and effectively. Business worldwide is reorganising their systems in line with modern information technology which has resulted in reduced prices, better quality products and greater variety for the customer.

Business challenges

As mentioned earlier, modern organisations faces many challenges to keep themselves in profitability zone, some of them are mentioned below

- ◆ Lower costs
- ◆ Improve customer service
- ◆ Accelerate cash
- ◆ Grow profitability
- ◆ Compete in changing market place
- ◆ Manage brand
- ◆ Attract, retain knowledge workers
- ◆ Supply chain challenges
- ◆ Growth in contract manufacturing

11 Online system for transferring funds of Indian financial institution to transfer funds below Rs. 1,00,000

12 Real Time transfer of money across Indian financial institutions above Rs. 1,00,000

13 Image based cheque clearing system

14 Character recognition technology used by the banking industry to facilitate the processing of cheques

- ◆ Shifting global manufacturing
- ◆ Unpredictable global demand
- ◆ Supply chain instability
- ◆ Increasing customer requirements

These challenges further raise many questions of doubts in our business

- ◆ Is our supply chain as lean as our manufacturing operation?
- ◆ Is it ready for next five years or based on history?
- ◆ Does it give us competitive advantage?
- ◆ Is it flexible enough to shift with the market?
- ◆ Is it responsive to customer requirements and their fluctuating demand?
- ◆ Does it make sense from a 'balance sheet' viewpoint?

BASIC OF SIX SIGMA

Sigma is a Greek alphabet (σ) which describes variability. Six Sigma is methodology to measures DPMO (Defects per Million Operations) as an index. It can include anything tangible things such as component, material, software line of code, BPO calls, banking transactions or services like Nutan Mumbai Tiffin Service alias Dabbawalas¹⁵.

According to Devane⁵(2004), Six Sigma's basic value proposition is that principles for process improvement, statistical methods, a customer focus, attention to processes, and a management system focusing on high-return improvement projects result in continuous improvement and significant financial gains.

According to George Michael L (2002), 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.

Urdhwaregeshe⁶(n.d.) said that Six Sigma is a highly disciplined approach used to achieve breakthrough improvements in manufacturing, engineering, and business processes. It reduces the process variations to the extent that the level of defects is drastically reduced to less than the 3.4 million processes, products or service opportunities defects per million (DPMO). Six Sigma projects are identified considering the strategic direction of the company initially and then the impact on the bottom-line next, and finally the impact of customer satisfaction.

15 A unique home cooked food delivering service in Mumbai working at Six Sigma level

As per Six Sigma Academy, Six Sigma is a continuous improvement methodology that focuses on the reduction of variation. Sigma represents the standard deviation, a unit of measurement that designates the distribution or spread about the mean of a process. Six Sigma as a business initiative was first taken by the Motorola Corporation in the early 1990s.

Six Sigma's roots can be traced back to the 1920s through the contributions of many mathematicians, statisticians, and quality specialists. These efforts cumulated in the analysis tools contained in Statistical Process Control (SPC) and were combined with analysis methods defined and refined by Six Sigma pioneers Harry and Smith. Six Sigma is defined as a statistic, a philosophy, and a methodology. As a statistic in the quality paradigm, it is 3.4 defects per 1 million opportunities and is related to the cost of quality as per Harry and Schroeder (n.d.). Table 1 provides a reference to how sigma levels have cost correlation.

Table 1: Table Cost of Quality as per Harry and Schroeder

Sigma Level	Defects Per Million Opportunities	Cost of Quality
2	308,357 (Noncompetitive companies)	Not applicable
3	66,807	25-40% of sales
4	6,210 (Industry average)	15-25% of sales
5	233	5-15% of sales
6	3.4 (World class)	<1% of sales
Each sigma shift provides a 10 percent net income improvement		

A sigma quality level is an index to denote how often defects may occur. High sigma quality level denotes a process which will create fewer defects. As Sigma level in quality increases, reliability of product improves which in turn decreases the testing and inspection effort, work in progress status decreases, duty cycle goes down, in turn costs go down which elevates the customer acceptance and satisfaction.

Nyman of GlobalTester Inc. said Six Sigma can and should be applied as a targeted approach. It involves asking operational questions from the concerned people as company movers towards the target of Six Sigma regime.

The History of Six Sigma

Six Sigma began at Motorola, and until 1987 it was merely a statistical term. Since then, the concept has

been adopted by many companies who had matured and saturated till a level and now wants to improve beyond their existing limits and who are continually striving for excellence.

Six Sigma has extended and evolved from a mere problem-solving technique to a quality oriented strategy thus leading to sophisticated quality philosophy. Jack Welch of General Electric, made it famous and trustworthy after his plan to make it across his business planning in 1995.

Mikel Harry⁷ is known to the world as the "Godfather" of Six Sigma and is considered as a leading figure and authority on theory and practice of Six Sigma. Though Six Sigma was not invented by him but the way it is being practiced has impression and impact of Harry ideas.

In the late 1970s, A Japanese company bought over television factory of Motorola and they made tremendous changes in factory operations. Japanese management was able to reduce the defects to one twentieth.

Motorola management impressed by the turn around in quality has decided to undertake the quality procedure more seriously.

Bill Smith termed as father of Six Sigma and Mikel Harry wrote a quality research report in which he drew correlation between product field performance and rework required in manufacturing process. They also said that products with less nonconformity performed better after customer delivery.

Although Smith's supposition was agreeable but the framework to eliminate the defects in practical was absent. Harry brought a concept of "logic filter" with Smith where they designed a four-stage approach towards problem resolution: Measure, Analyse, Improve, and Control (MAIC). MAIC system is broad road map for implementing Six Sigma in an organisation.

In 1987, Galvin¹⁶ came out with long term quality programme name as "The Six Sigma Quality Programme". It was a corporate programme to establish Six Sigma becoming required capability level to obtain the standard of 3.4 DPMO. This standard was then come to use universally in product, services, processes and administration.

In 1988, Motorola received the Malcolm Baldrige¹⁷ National Quality Award after implementing Six Sigma

¹⁶ CEO of Motorola from 1959 to 1986 who changed many practices at Motorola

¹⁷ A Quality preacher and former United States Secretary of Commerce

as disciplined problem solving strategy. Since then it has been an attraction for industries.

Harry was a martial arts lover and he thought that People in martial arts are incredibly disciplined and precisely skilled and have a razor cut command of tools, are very devoted with being humble and ready to learn. Based on these thoughts, Harry decided to designate those people with Six Sigma skills as “Black Belt”.

Later Harry as Head of Motorola’s Six Sigma Research Institute designed strategy for quality knowledge transfer and its quick circulation in short span. Harry Six Sigma implementation strategy attempted to put quality tools into the hands of large numbers of associates, workers and their managers across the organisation. Only Quality engineers were not having the Six Sigma skills, but they started flowing from quality circle to whole organisation.

It was realised that senior management is only interested in clear and quantifiable gains. It is generally business first approach instead of quality first in their mind but when the quality leads them to better business they will approach towards establishing quality circle. Harry tweaked the Six Sigma deployment methodology to produce changes in top line and bottom line of the company and established concepts like Champions, Master Black Belts, Black Belts, and Green Belts.

Seeing the success of Six Sigma at Motorola other companies, began a similar exercise and started seeing the effect in their business.

Jack Welch got impressed by Six Sigma and its achievement. Earlier it was felt that the Quality Systems are much more than quality programmes in terms of slogans and posters but couldn’t produce quantifiable and tangible results.

Jack Welch said, “The best Six Sigma project begins not inside the business but outside it, focuses on answering the question, how can we make the customer more competitive.”

General Electric did a cost-benefit analysis to check on Six Sigma implementation, which suggested that if GE, then operating at three to four sigma level want to raise its quality level to Six Sigma they will have opportunity to save 7 billion US dollars to 10 billion US dollars, which is 10 to 15 percent of sales which is a huge number.

There are two important lessons learnt from General Electric while they implemented Six Sigma.

- ◆ CEO demonstrated the great paradigm of leadership
- ◆ CEO established strong rewards system for participating in Six Sigma like
- ◆ 40 % of Incentive and Bonus compensation will depend on Six Sigma results which attracted General Electric employees serving aim of the management
- ◆ Promotions in General Electric will depend on Six Sigma and no management job will be filled without at least green belt training

Prof. Tony Bendell¹⁸ and Ted Marra¹⁹ said that Six Sigma delivers impressive reduction in cost and it also brings about improvements in customer satisfaction by increasing performance and reducing variation potentially but there is much more to Six Sigma than cost reduction.

Definition of Six Sigma

It is a management concept that tries to analyse and reduce the process variations and their negative effects. With the support of its trained professionals, it derives a problem-solving strategy and model along with process control customised utilities and statistical tools.

Joe Liddane²⁰ and John Hutchinson²¹ researched that the way to successful implementation of process is to recognise that every improvement opportunity requires unique approach and form a toolkit of activities that address different issues in different times.

The DMAIC is an outline explained in step by step way which makes the process drivers to understand and then improve logic to reduce process variation and approach towards achieving Six Sigma Quality.

Jane Erwin²² said achieving Six Sigma takes some vision; you may have a plan, necessary resources and commitment of everyone and uncompromising matrices. Then an aggressive goal can be set up keep people accountable.

The main principle of Six Sigma is variation reduction. Theoretically if there is reduction of variation in processes, then implementation of more accurate and reliable process will be established which enhances customer satisfaction and also reduce the waste or leftovers. As an example in

18 Managing Director of onsixsigma.com

19 Director, Centre for Innovation Management Europe

20 Chartered Accountant and financial advisor at SetantaUK

21 Director at SetantaUK

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Bosch, the purchase order-delivery cycle required for the supplier in Germany is 30 days and the general average is also 30 days but some of the products arrive in 15 days and others arrive in 45 days where we have maintained the average but the variation has resulted into complex situation and inventory management becomes tough. This will lead to increased transportation cost because of pressure, out of stocks situation and non-confidence of stakeholders and worse case is unpredictable inventory.

Major Themes of Six-Sigma

- ◆ **Customer-Focused:** The value which Stakeholder incurs is the trigger point for all Six Sigma implementations
- ◆ **Process-Focused:** Running through business processes creates competitive advantage and enhancing value to customers
- ◆ **Fact-driven:** Decisions taken in Six Sigma are fact driven and not biased
- ◆ **Standardised and Repeatable:** Consistent processes with precise repetitions are key aspects of Six Sigma
- ◆ **Contribution:** Six Sigma propagate the opportunities for people to learn and work beyond their boundaries for better and bigger picture of organisation
- ◆ **Perfection Driven with failure tolerance:** Environment to all stakeholder of higher precision and lowering the failure but within acceptable limits

Six Sigma Success Factors

Marjorie Green and Mischa Dick²³ said for the successful execution of a Six Sigma project, it is important to have a well laid out infrastructure in place namely project identification process, leadership training, practitioner training and project tracking and support.

It has been outcome of the researches that following factors are responsible for successful Six Sigma implementation:

1. Commitment and leadership of Top management
2. Well-deployed customer management system
3. Constant skill up-gradation and training system
4. Well-deployed information and decision making reporting system

²³ Co-Founders of Operational Performance in Health sector HEI

5. Well-deployed process management system
6. Well-deployed strategic planning system
7. Well deployed supplier management system
8. Working knowledge of the quality processes and tools
9. Well-established human resource management system
10. Well-deployed benchmarking system

Gary A. Gack and Kyle Robinson²⁴ said that success in Six Sigma requires more than just an understanding of the Six Sigma philosophy and tools as it requires how the philosophy and tools would get applied in specific business area.

Jack Welch said that the Six Sigma approach has taught GE employees about the importance of fulfilling and surpassing customer expectation.

Jane Erwin said that the Six Sigma projects instead of product they should be customer focused. Management should look towards shift from an organisational focus to a customer focus.

Improvements can really begin once companies assessed the defects levels of their customer's experience, and the internal defects, which require rework, and additional inspections. This would hold the key to success for any Six Sigma initiatives.

Understanding Sigma Level

Process capability can be represented in two ways namely

- ◆ Short term
- ◆ Long term

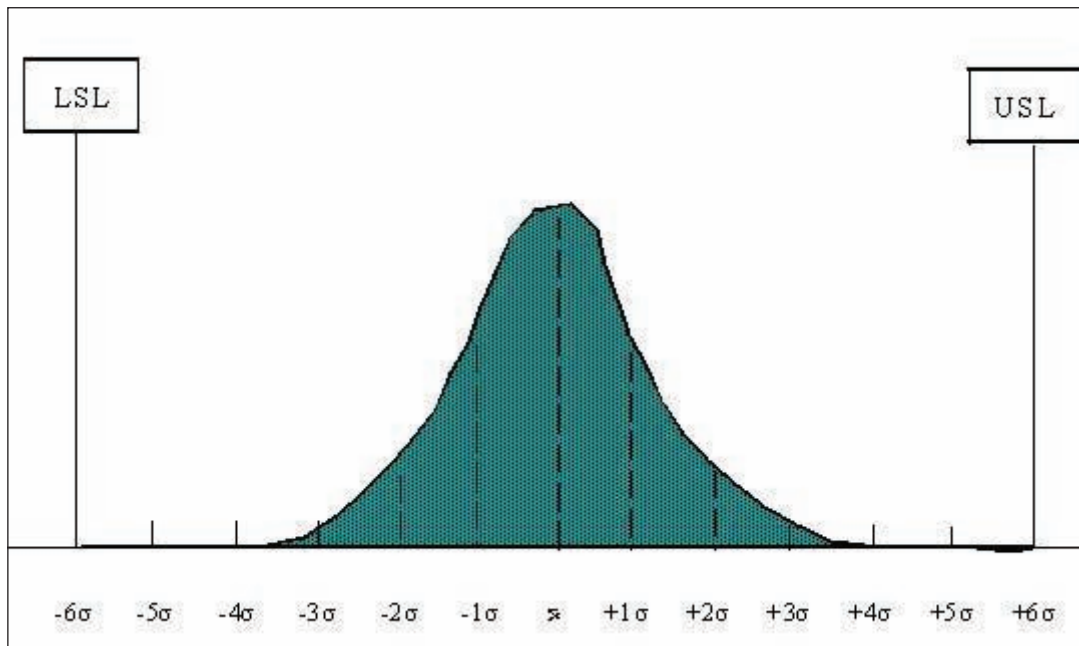
Short-Term Process Capability

Any product will be considered as defective in case the measurement is outside the prescribed range of upper specification limit (USL) and lower specification limit (LSL). Customer often defines a target value which is midpoint of USL and LSL.

Normally after sampling in a short-term process capability view a Six Sigma process producing parts will show a normal distribution (see Fig.8). Table 2 explains short-term process capability across various sigma levels.

²⁴ Six Sigma consultants

Fig. 8: Short -Term Six Sigma Performance for a Single Process



Source:www.pqa.net

Table 2: Short-Term Process Capability at Various Sigma Quality Levels

Sigma Level	% Good	PPM/DPMO
2	95.45	45500
3	99.73	2700
4	99.9937	63
5	99.999943	0.57
6	99.999998	0.002

Long-Term Process Capability

While considering long term process because of the nature of the process, there is shifting and drifting of the mean of the distribution because of many reasons like tool wear or gradual shift, minor changes in raw material or their suppliers.

D.H. Evans²⁵ suggested that 1.5s should be used as the standard-deviation²⁶ while calculating the percentage of out of tolerance results.

M.J. Harry²⁷ has said that a typical process at any frame

of time may deviate from its natural centre condition by around 1.5 standard deviations.

It is always better to take the consideration on long term as meaningful results are being identified. As the process by virtue of its nature long-term drifting, can be taken in account because of many parameters. Long term results are more genuine and come close to real picture of operations.

Keeping this principle in mind, logical estimation can be done in the long-term process capability keeping in mind the short-term process capability (see Fig.9). Table 3 explains long-term process capability in various sigma levels.

Table 3: Long-Term Process Capability in Various sigma Levels

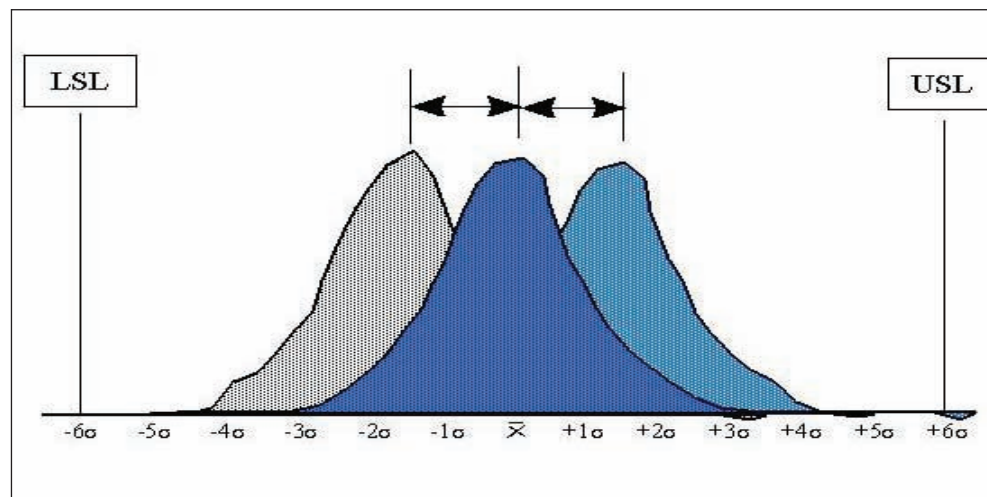
Sigma Level	% Good	PPM/DPMO
2	69.15	308,537
3	93.32	66,807
4	99.379	6,210
5	99.9676	233
6	99.99966	3.4

²⁵ Famous writer of books on Six Sigma, TQM, Production Engineering

²⁶ Square root of its variance

²⁷ Consultant at SixSigmaAcademy which is a known author-

ity on Six Sigma practices

Fig.9: Long-Term Six Sigma Performance for a Single Process (Shifted 1.5 σ)

Source:www.pqa.net

Six Sigma Working

Six Sigma is a quality level system which lays emphasis on disciplined and quantitative approach which needs erecting a system and design process for the improvement in defined variables during manufacturing, services, or financial processes.

The methodology is to evaluate and select right projects and their right processes based on business goals of the organisation. This also encapsulates the selection and training of the right people to become torch bearer of Six Sigma and perform their task according to new laid down procedure and obtain the results. The selected projects follows a defined discipline in the processes which all the four major phases in MAIC.

Daryl Dickman and Colm Doran in their research talk about the key factors in selecting project for Six Sigma in which they said that the key factors for selecting a Six Sigma project are vagueness of scope, lack of resource availability, no upfront buy in, misalignment with company objectives, low priority and data unavailability as these are difficult to deal with, the Six Sigma projects that work the best are “Just do it” projects or projects done to justify preconceived solutions, as they don’t have to use any DMAIC tools.

PHASES OF MAIC

There are four well demarcated phases of MAIC namely

Measure Phase

The goal is to measure system variables and to create a validated reliable metrics. This metrics monitor the progress to achieve sigma levels. Error Condition or “Not according to the specification” logic needs to be properly listed.

Identification and description of the potential critical processes/products

It is the enlisting with description of the potential critical processes after having discussion with the participants during brainstorming sessions, collecting historical records, yield reports, product failure analysis data, line fallout data.

Analysis of Perform measurement system

This determines precision, needed accuracy, ability of each instrument to repeat and reproduce so that their capability is checked.

Edwards W. Deming said, “If you don’t measure it, you won’t improve it.”

Perhaps one of his most important contributions to the business community was to clearly demonstrate that most, if not all, business performance improvement efforts begin with measurements of the current situation.

Analyse Phase

System analysis is done to check and locate the methods to close the gap between the existing performance level and the desired goal level. Underlying reasons for the defects gets located. Statistical tools examine variables which affect the outcome potentially and search for the root cause. Then all factors are being listed prioritised on the desired outcome.

Isolation and Verification of the Critical Processes

Multiple iterations are done to zeroing over few potential problems out of many. Then correlation is being done with respect to these problems between input and output. Then specific problems gets listed and later they are verified their probable causes and their through impact on the product.

Conduct the Process and Measure System Capability Studies

Limitations of the processes are identified and defined. Processes should be able to reach optimal level and it should be ensured. All the special cases are identified and removed to minimum variation. Realistic specifications and confidence intervals are determined. A process is called as capable when there is finite prediction of controllability and stability.

Improve Phase

Optimal solution is sought and development and testing of the plan for action for implementation and confirmation of the solutions are done. The process methodology is fine-tuned and gradually modified and the results determine whether at that point method produced results as per expectations of customer.

Experiment Design

Selection of design of experiments is done with various factors and levels. Planning of experiment executions locate the most significant factor.

Implementation of variability reduction designs and assessments

Implementation of permanent and corrective action plan is done for avoiding the variation due to special causes.

Also demonstration of stability and predictability of the process is being done.

Control Phase

New system needs to be controllable and measures are deployed to avoid reoccurrences of problems. The systems are established and benchmarked through modification of policies, procedures, working instructions.

Description of Process Control Method

Establishment of regular controls for the process depending on prevention of special variation and its causes, by use of statistical process control methods.

Documentation of the Process Improvement

Record and well document the processes/steps of improvement phase with decision tree, decision graphs, and reaction plan.

SIX SIGMA IMPLEMENTATION

In implementation of Six Sigma, a well-defined structure is developed which has:

Team Structure

1. Core Team

- ◆ The Core Team defines the reviewer of progress and project leader which removes the obstacles for rest of the team.

2. Master Black Belts

- ◆ The Master Black Belt is the technical leader which infuses the knowledge of quality tools in the project team. Generally for 1000 employees there is one Master Black Belt, which is sufficient as per norms.

3. Black Belts

- ◆ The Black Belt is controller of the project. Normally 10 to 20 Black Belts are sufficient for 1,000 employees.

4. Green Belts

- ◆ The Green Belt provides support to Black Belts. Generally there are 3 to 5 Green Belts in the team working with the Black Belt and normally 300 Green Belts are sufficient for 1,000 employees.

5. Yellow Belts

- ◆ Yellow Belts are the remaining of the team members who provide information and support which can later rise up to green belts.

6. Discipline for MAIC

- ◆ The MAIC discipline is being established to define protocol for internal communication.

7. Incentive system

- ◆ The incentive system to promote the acceptability of Six Sigma.

Core Team

Six Sigma is the change carrier which changed value steams across the organisations to achiever organisation's strategic goals. Commitment and involvement of Top management's are critical aspects in Six Sigma implementation. Often, the Top management forms and supports the core team. The main responsibility is in selection of high financial impact projects, which are in line with the strategic plan. During the phase of implementation, the work is regularly reviews the projects. It is suggested to adopt a training module consisting following modules to enhance the understanding of the participants:

- ◆ Overview and implementation of Six Sigma
- ◆ Process improvement and Knowledge-centered activity
- ◆ Measurement, Statistics and experimentation overview
- ◆ Learning Six Sigma Success Factors and their deployment

Master Black Belts

It is the highest technical and organisational proficiency level. There main role is to provide technical leadership who also ensure smooth functioning during the phase of implementation. In-house expertise is being developed in various Six Sigma tools, processes and methodology. They play following role:

- ◆ Coaching and supporting projects members for results
- ◆ Six Sigma training content development and execution
- ◆ Project identification assistance

- ◆ Partnership with Six Sigma Champions

- ◆ Identification and deployment of best practices

Black Belts

Black Belts establish the improvement and methodologies and act as change agents for percolating the six concepts in the organisation. They play following roles:

- ◆ Leader of high impact and strategic process improvement projects
- ◆ Technical supervision of quality tools and statistics
- ◆ Carrier agent of measurement, analytical, improvement and control techniques

Green Belts

They are experts of technical process and change agents with following roles:

- ◆ Leader in process improvement processes and projects
- ◆ Assist Black Belts in their area
- ◆ Establish continuous process improvement

Yellow Belts

They are rest of participants. They are adequately trained to make them understand and apply basic concepts and formulae used in problem solving. They assist Six Sigma team and often contribute in coming to conclusion on root causes.

Six Sigma Tools

There are many tools and templates used in implementation of Six Sigma, some of them are as follows

Overall Equipment Effectiveness (OEE)

It is excel template of Total Productive Maintenance (TPM) by which we can maximise the effectiveness of bottlenecking resources and issues.

SIPOC Diagram

SIPOC template is used to identify and eliminate wastes in the systems. The waste can be of any type scrap, heat or energy, packaging, routes.

The acronym SIPOC stands for suppliers, inputs, process, outputs, and customers. This template is the starting item for a Value Stream Mapping Team. It clearly defines the extent of the value stream segment which is being mapped.

Failure Modes and Effects Analysis (FMEA)

It is a powerful template in DMAIC Lean Six Sigma tool through which quality problems can be anticipated and corrective action can be identified to minimise the risk. FMEA analysis is used

1. To do initial designing any system, product, or process
2. To revise the system, product, or process
3. To declare already visible risks
4. To keep handle on key process variables and visibility of their impacts
5. To register and analyse the effectiveness of trials to control variability

Root Cause Analysis tools

It is a template to analyse the root cause of problems and derive the create ideas for solving the. Cause and Effect Diagram and Ishikawa Fishbone Diagram serve the same purpose.

Root cause analysis template provides:

1. Record ideas from people quickly and present them in a readable format.
2. Arrive at the problem's root causes by keeping on asking the reason for the problem and their sub problems till the root of problem is dugout. This is also known as "5 whys", as it is said if 5 times "why" is asked, it is most likely help to arrive at cause of the problem.
3. Easy arrangement of ideas logically which help in forking new and better ideas.

Shigeo Shingo⁹ said, "A relentless barrage of 'why's' is the best way to prepare your mind to pierce the clouded veil of thinking caused by the status quo. Use it often."

Brainstorming Group Tool

It is a template to list and quickly organise brainstorm ideas and distribute them to participating teams in such a

way that it leads to generate more ideas

Thought Map Relation Diagrams

These diagrams identify root causes of a nonlinear complex problem. For less complex and linear problems Cause and Effect Fish Bone Diagram is used.

Customer Segmentation Worksheet

This Template identifies and addresses the sub-segments of customers, which are most valuable with respect to the product or service.

Voice of the Customer Data Collection Worksheet

This worksheet collects and arranges customer data from existing data, conducting and recording surveys group meetings and interviews as well as personal observation.

Kano Analysis and translation of Customer Requirements

This template translates vague and versatile customer comments into measurable functional parameters which will increase the delivery and design team to come close to customer expectation.

House of Quality - Quality Functional Deployment Matrix

It is guiding structure for multi-functional team to design the new product or services. This serves as starting guideline for converting an idea into a product or locating a solution for customer specific need from scratch.

Pareto Chart

Pareto Chart template identifies the 20% issues which affect 80% of work so that areas of improvement can be prioritised.

To summarise the above tools and techniques referred above, we also see below:

Fig. 10: Pareto Chart



Table 4: Companies adopted Six Sigma

3M	General Electric	Patheon
Acme Markets	General Dynamics	Penske Truck Leasing
Advanced Micro Devices	Generali Group	PepsiCo
Agilent Technologies	Genpact	Quest Diagnostics
Air Canada	GlaxoSmithKline	Raytheon
ALCAN	HCL Technologies	Samsung Group
Amazon.com	Heinz Co.	Sears
AXA	Honeywell	SGL Group
BAE Systems	Hertel	Shinhan Bank
Bank of America	HSBC Group	Shop Direct Group
BD Medical	Ingram Micro	Siemens AG
Bechtel Corporation	Intrawest ULC	SKF
Boeing	Inventec	Staples Inc.
Canada Post	ITC, India	Sterlite
Caterpillar	JEA	Target Corporation
CIGNA	Korea Telecom	Teradyne
Cintas Uniforms	KINDUZ	Trane
Cognizant	LG Group	Textron
CSC	Lilly Pharmaceuticals	The Hertz Corporation
Cummins Inc.	Lockheed Martin	TRW
Deere & Company	Maple Leaf Foods	TSYS
Dell	Merrill Lynch	Tyco International
Delphi Corporation	Motorola	Ueki Corporation
Denso	Mumbai Dabbawalas	Unipart
Deutsche Telekom	Network Rail	United States Air Force
Dominion Resources	NewPage Corporation	United States Army
Dow Chemical Company	Nielsen Company	US Marine Corps
DSB Bank	Nortel Networks	United States Navy
DuPont	Northrop Grumman	UnitedHealth Group
Eastman Kodak Company	Organo Corporation	Vodafone
EMC	Owens-Illinois	Wipro
Flextronics	PIA	Tata Steel
Ford Motor Company	PakistanState Oil	Xerox

- ◆ **Define:** Benchmarking, Task Appraisal / Task Summary, Quality Function Deployment, SIPOC Model, Project Charter, Kano's Model, Voice of Customer, FMEA, IPO Diagram, Value Stream Mapping, Knowledge Based Mgt
- ◆ **Measure:** Process Flow Diagram, Confidence Intervals, Measurement System Analysis, Value Stream Mapping, Nominal Group Technique, Measurement System Analysis, Process Capability

Analysis, Nominal Group Technique, Process Observation, Time Value Map, Physical Process Flow, Waste Analysis

- ◆ **Analyse :** Affinity, Diagram, Brainstorming, Fault Tree Analysis, Cause & Effect Diagram, e-test, F-test, Historical Data Analysis, FMEA, Scatter Diagram, Thematic Content Analysis, Histogram, t-test, Regression Analysis, Pareto Chart, Reality Tree, 5 Whys, Tukey End Count Test

- ◆ **Improve:** DOE, Mistake Proofing, 5S Workplace Organisation, Kanban, Standard Work, DFSS, Visual Management, Theory of Constraints, Work Cell Design, PF/CE/CNX/SOP, Total Productive Maintenance, Takt Time
- ◆ **Control:** Control Charts, Run Charts, Standard Operating Procedures, Control Plan, Reaction Plan

Industrial Adoption of Six Sigma

Following are the companies out of many who have adopted Six Sigma principles and have improved performance:

Criticism of Six Sigma

Lack of Originality

Joseph M. Juran, a senior quality expert described Six Sigma as basic and simple version of quality improvement and he stated that nothing new was there. Six Sigma used flamboyant terms like belts and colors but they are mere quality facilitators.

Role of Consultants

The need of consultants for guiding and implementing the Six Sigma as well as having “Black Belts” as one of the major change agents has developed training and certification Industry which charges abnormal fees. Six Sigma has been over sold by consulting firms which lack real knowledge of the tools as well as the techniques required.

Negative Effects

Charles Holland of consulting firm Qualpro in his analysis stated that most of the large companies, who have adopted or announced Six Sigma programmes, have lost stock prices on exchanges. Six Sigma is effective in fixing an existing process but doesn't lead to develop new products or high end technologies. In other words, Six Sigma is highly localised in its effect. People favouring Six Sigma notions that these findings are ambiguous and full of error as well as they are not well educated and informed so their critic's results and observations are not well established against the favourable results.

Based on Arbitrary Standards

It is true that 3.4 defects per million opportunities are acceptable for certain products/processes but it may not be optimal or cost effective to others. A life-saving drug manufacturer or rocket components manufacturing process might need higher standards while routine calls in call centers may be fine with lower standards.

Basis of choosing 6 and not others as number for standard deviation is also not clear and explained. This model also assumes that the process data will always adhere and conform to the normal distribution. Defect rate calculations in the event of not application of normal distribution are also unexplained.

Criticism of the 1.5 sigma shift

Donald J. Wheeler has criticised and said that the 1.5 sigma shift is ambiguous and uncertain because of its arbitrary nature and its universal applicability.

The short term view, rather than the long term has made 1.5 sigma shift contentious. A process that has long-term defect levels equivalent to 4.5 sigma performance equated technically to Six Sigma convention, which is described as a “6 sigma process.”

Six Sigma has been treated by many experts as a confidence enhancing trick of statisticians. Six Sigma scoring system in its current situation, cannot be matched with probabilities of actual normal distribution for the prescribed number of standard deviations. It is not clear that a “6 sigma” process will definitely show long-term defect rates corresponding to performance at 4.5 sigma rather than actual 6 sigma performance.

Six Sigma Myths

In the minds of management and process engineers there are some myths about Six Sigma practices, which don't hold any ground. Some of these inhibitions are as follows

- ◆ Minimum Quality level; a prerequisite
- ◆ Too much of statistics
- ◆ High % of Training
- ◆ Black Belt is first step
- ◆ Long Journey
- ◆ Only for Manufacturing
- ◆ Only for few; not for everyone

LEAN MANUFACTURING

What is Lean?

Lean is regime which focuses on the elimination of waste with increase in speed and flow.

History of Lean Manufacturing

It is believed it was the Toyota manufacturing system for which that lean manufacturing concepts and practices were developed but Lean manufacturing concepts were already in use at some other companies in their manufacturing. Ford in United States was incorporated similar concepts in manufacturing model T automobile. Ford's methodologies of continuous assembly lines and linear flow systems have very high importance in lean manufacturing.

In late 1940's industries in Japan were facing very tough time as their economy vanished because of World War II. They had problems in supply of raw materials, labour issues and shortage of capital. While automobile industry could not compete with the already existing companies of the rest of the world. Established companies like Ford, simply out performed small Japanese manufacturers like Toyota making impossible for them to compete in the overseas markets.

Taichii Ohno¹⁰ was asked to develop and implement strategy to handle the situation. Ohno and his colleague Shingo developed a manufacturing system known as Toyota Production System (TPS).

The basic principles were derived from the Ford's system but it is not the copy of it. They investigated and searches for positives and negative aspects in Ford system and they adopted the positive and forward looking concepts and eliminated the negative ones. Juran and Deming who worked for Ford system had put lot of influence on the Toyota production system.

From the mid-1940s to 1970s, Toyota production system evolved continuously giving encouraging results. In 1974 when many Japanese companies were making losses, Toyota was an exception. This resulted into the changed mindset of Japanese manufacturers to check for TPS benefits over their system and that led to gaining popularity of TPS and Just in Time (JIT).

While in US who were unaware of Japanese TPS and JIT were amazed with the growth of Japanese industry. Then

Norman Bodek published the English version of Ohno and Shingo work which made US manufacturers learn about lean manufacturing.

After that Lean from their onwards became a common term in manufacturing. Later many US manufacturers used lean manufacturing with encouraging results.

Lately lean manufacturing has got the one step further in its evolution cycle and came with the concept of lean enterprises. Lean manufacturing is linked with from the factory to all of stake holders which include suppliers, customers.

Lean enterprise strives for getting best possible value from all participants in the supply chain from their collective effort.

Charles Darwin said, "It is not the strongest of the species that survive, or the most intelligent, but the one most responsive to change". This feeling is well reflected in the companies which managed to sail through tough times taking advance steps.

Lean Manufacturing Goals

As per Richard MacInnes, lean goals are

- ◆ Improving quality
- ◆ Eliminating waste
- ◆ Reducing lead time
- ◆ Reducing total cost of a process

The goal of improving quality is to align the process with the customer's needs or desires. Either the processes or the product can be the focus of quality improvement. The goal of eliminating waste is the removal of unneeded process steps, excessive movement of people or materials, and non-value added activities. The focus on the customer drives the determination of what is value or non-value added to a product (Womack & Jones, 1996; George, 2002).

In the articles and the goal of reducing lead times is shortening the time it takes to complete the tasks within a process (Womack & Jones, 1996; George, 2002; Ohno, 1988). These reductions enable the process to become more responsive and flexible to customers or other processes. Reduction of total cost is the expected result of reaching the preceding goals. Total cost consists has direct and indirect costs incurred in generating products or services.

These principles and goals originated from the original Lean principles set forth by Womack and Jones in “Lean Thinking”. There Lean principles are:

1. Specify value
2. Identify the value stream
3. Smooth process flow
4. Production based on pull
5. Perfection through elimination of *muda* or waste

Alex Miller said, “Lean is not a programme, it is a total strategy.”

Shigeo Shingo said “When you buy bananas all you want is the fruit not the skin, but you have to pay for the skin also. It is a waste and your customer should not have to pay for the waste.”

- ◆ **Improve quality:** Every organisation needs to adjust its production according to customer’s demands as well as to align itself to meet the customer requirements and expectations. Giving equal or better than expected is quality in intangible means. Almost all quality improvement comes via simplification of design, manufacturing, layout, processes, and procedures
- ◆ **Eliminate waste:** Waste defined as any activity that consumes time, resources but do not provide and value addition. There are following types of waste:
 1. Unnecessary movement of materials in transport
 2. Excess inventory
 3. Superfluous steps in production process because of inefficient layout
 4. Waiting time
 5. Overproduction
 6. Over Processing because of reworking, refurbishing and reprocessing
 7. Defects

By taking the first letter of each waste type, the acronym “TIM WOOD” is created. This is a common way to remember the wastes.

- ◆ **Reduce time:** Reducing the time cycle which is from start to finish and while doing it many wasteful activities will get eliminated as well as some new mythologies will be established to expedite the supply chain.

- ◆ **Reduce total costs:** To optimise the cost, a company should produce according to the customer demand. Excess production adds inventory cost because of storage needs.

Shigeo Shingo said, “The most dangerous kind of waste is the waste we do not recognise.”

Lean Manufacturing Technique

Lean is commonly understood in manufacturing to be the elimination of waste from a process in order to increase process speed and improve quality. Lean production methodology was referenced in Toyota Production System (TPS) created by Taiichi Ohno.

Ohno said, “Costs do not exist to be calculated. Costs exist to be reduced.”

Ohno considered the fundamental waste to be overproduction, since it causes most of the other wastes. Producing earlier or more than the customer wants by any operation in the manufacturing process necessarily leads to a buildup of inventory somewhere downstream. The material is just sitting around waiting to be processed in the next operation. We should note that the main reason the first seven wastes are so critical, according to Ohno, is because of their impact on what we are calling the eighth waste. Overproducing, inventory, etc., hide problems, and then team associates are not forced to think. Reducing waste exposes problems and forces team associates to use their creativity to solve problems.

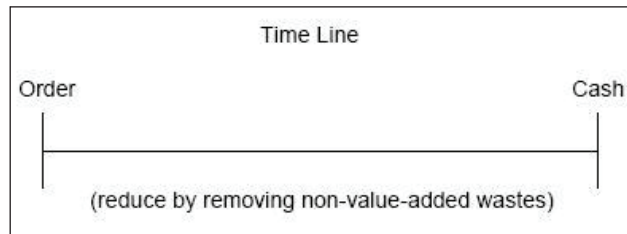
Ohno wrote “The key to the Toyota Way and what makes Toyota stand out is not any of the individual elements... But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner, not in spurts.”

He further emphasised the link between improved business results with removing waste by stating that “The objective of the Toyota system is to increase production efficiency through consistently and exhaustively eliminating the waste”. The reduction on the order-to-cash cycle is an important goal of production and supply chain management.

Lambert said “A streamlined process reduces the order-to-cash cycle which frees up capital, and reduces the delivery lead-time which allows for reduced inventory levels”.

Ohno used a simple graphical device, shown in Fig.11, to demonstrate the objective of shortening the order-to-cash timeline.

Fig. 11: Objectives of Toyota Production System



Elimination of waste from the system is achieved with lean manufacturing using following techniques.

- ◆ Total Quality Management (TQM),
- ◆ Total Productive Maintenance (TPM)
- ◆ Just In Time (JIT) techniques
- ◆ Flow charts
- ◆ Workplace Redesigning techniques

Ernie Smith said “Many people think that Lean is about cutting heads, reducing the work force or cutting inventory. Lean is really a growth strategy. It is about gaining market share and being prepared to enter in or create new markets.”

Steps in Lean Manufacturing Technique

While adopting Lean manufacturing regime for a production line, it is needed that some broad outlines or steps should be followed. Some of these are as follows

◆ First Step

Ohno said, “The more inventories a company has, the less likely they will have what they need.”

In this step requirements are created to establish lean manufacturing movement in organisation. It has to be realised that there is presence of waste in the system and it needs to be cleaned off. Many organisations often are unaware of hidden wastes in their system hence they don’t realise the importance nor any requirement of removing waste from their system. Hence first step has to be a realisation that organisation wants to remove something which they don’t want and management has to agree and give its full commitment to it.

◆ Second step

Organisation will identify waste, its cause and locations in this is very important step of the process. Lean manufacturing never talks about handling symptoms but it handles treating the causes and providing permanent solutions. Ishikawa diagrams or cause and effect diagrams are used during the step.

◆ Third step

In this step solution are found to handle the identified root causes. The complete picture of the system has to be taken while providing the solutions and care has to be taken to ensure that no localised solutions are provided until their effect globally has not been determined. As an example while trying to reduce the downtime in line, it is important to ensure that the solution is increasing the lot sizes too much resulting in negative effect on the organisation.

◆ Fourth and the final step

In this step there is implementation process and check are being done to ensure that manufacturing is going as desired. At this point solutions will be finally commissioned but may be tweaked to correct practical issues occurred in implementation. User training and regular follow-ups are important features of this step.

There are many tools which are used in all the above four steps to achieve the intermediate and final goals of Six Sigma steps. The implementers have to ensure that they look problems and solutions in totality and also study the effects of them in previous and lean system.

J. Temple Black and Steve L. Hunter proposed a ten step process to achieve lean production. These ten steps have been taken from hundreds of successful functional manufacturing systems conversions to lean manufacturing. The 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/reorganise 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 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%.
- ◆ **Step 4: Integrate Preventive Maintenance into Manufacturing**
There should be no equipment failure and the workers should be trained to perform routine low level process maintenance.
- ◆ **Step 5: Level, Balance, Sequence and Synchronise**
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 for final assembly.
- ◆ **Step 6: Integrate Production Control into Manufacturing**
Cells respond to demand by delivering parts and products only as they are needed, or just in time.
- ◆ **Step 7: Reduce Work-In-Process (WIP)**
Minimise the necessary WIP between cells, and parts are handled one at a time within cells.
- ◆ **Step 8: Integrate Suppliers**
Reduce the number of suppliers and cultivate a single source for each purchased component or subassembly.
- ◆ **Step 9: Automation**
Inspection should become part of the production process (100% inspection) and there should be no overproduction.
- ◆ **Step 10: Computer-Integrated Manufacturing**
Production system has to be as free of waste as the manufacturing system.

Lean Manufacturing Tools

Following are the main “Lean Manufacturing Tools.” There may be many others, but these serve as the primary ones and solve most of the issues.

- ◆ 5S Visual Workplace
- ◆ Standardised Work Instructions
- ◆ Value Stream Mapping
- ◆ Total Productive Maintenance
- ◆ Kaizen Blitz Events
- ◆ Error & Mistake-Proofing
- ◆ Self-Directed Work Teams
- ◆ Mixed/Level-Loaded Production
- ◆ SMED Setup Reduction
- ◆ Inventory & Lead Time Reduction
- ◆ Lean Visioning
- ◆ TOC Constraint Management
- ◆ 2-Bin Auto-Replenishment System
- ◆ Quality System Certification
- ◆ Kanban Implementation
- ◆ Lean Six Sigma

Robert E. Spector said that Lean and Six Sigma are two of the most effective business improvement techniques available today.

In current times, many companies struggle to use one or both disciplines to reach the desired results. Solution lies in the combination of lean/Six Sigma and constraints management. As by adopting constraints management, companies can test waters and identify where to put focus on the lean and Six Sigma efforts for maximum success.

George Michael L. said that one of the main aims of Lean is to reduce or eliminate waste in every area of the business like customer relationship, design of product, vendor’s networks and management of factory.

Breyfogle F. W. said, “In a system that combines the two philosophies, Lean creates the standard and Six Sigma investigates and resolves any variation from the standard”.

George Michael L. states that the purpose of Lean Six Sigma is twofold.

1. “To transform the CEO’s overall business strategy from vision to reality by the execution of appropriate projects”

2. “To create new operational capabilities that will expand the CEO’s range of strategy choices going forward”.

Ohno said, “Lean Six Sigma has been defined as a defined approach that synthesizes the use of established tools and methods”. The tools and methods of the Lean Six Sigma practitioner encompass the tool sets of both Lean production and Six Sigma.

Dr. Jiju Antony concludes, “the disciplined and systematic methodology of Six Sigma combined with the speed and agility of Lean (methodology) will produce greater solutions in the search for business and operations excellence.”

Process of lean manufacturing is destined to reduce labour, inventory and time to produce quality products in economic and efficient way simultaneously responding to demands from customer with much trouble.

Lean counters traditional manufacturing process which takes economic order quantities with high-capacity utilisation and high inventories. In the case of lean high inventories are avoided as it destroys company’s competitive advantage and it says produce only what one can sell.

MERGER OF LEAN, LOGISTICS AND SIX SIGMA

1. Definition of value according to the end customer’s perspective. They are determined by understanding the needs and expectations of customer.
2. Entire value stream for each product is identified with its product family, use to eliminate waste. Value stream covers complete action set which is needed to pass a product across manufacturing assembly. Value stream mapping is used to find which activities are not value adding and may be eliminated.
3. Creating value-creating steps flow with focus on optimising value by manufacturing only required amount in the shortest time using least resources.
4. Pull according to customer demand. Production is in direct correlation with the rate of customer demand only.
5. Maintain and seek perfection and precision. Empower and teach employees tools of waste re-

duction as well as creating a continuous improvement environment.

According to Devane T., the key concepts of Lean Six Sigma are the following:

- ◆ Voice of the customer (VOC)
- ◆ Critical to quality (CTQ)
- ◆ The Six Sigma metric
- ◆ Elimination of non-value added activities and waste
- ◆ Process
- ◆ Unintended variation is the enemy
- ◆ Value Streams
- ◆ The “DMAIC” improvement process

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 corporate improvement is not slow in Six Sigma not because of lack of knowledge in this field but because of unavailability of transition methodology from paper to practice. Practitioners and implementers need clear cut unambiguous step by step guidelines which will arrive at predictable results. These guidelines provide the basic strategy which enhances confidence, curiosity and their answers in most acceptable form.

The Six Sigma regime is for reduction in defects, improvement of process, and customer satisfaction. It is based on the belief that everything can be treated as process and all of them will have inherent variability or noise. Data is processed to increase the understanding about the variability and navigate through process-improvement decisions.

The Emergence of Lean Six Sigma

Individually lean or Six Sigma exclusively has some limitations. Six Sigma will help in eliminating defects which increase the reliability of processes. It doesn’t address the problems of optimisation of process flow and competitive element of speed. Lean reduces complexity, but it does not track reliability as Six Sigma does.

Through mutual combination of these approaches is called as Lean Six Sigma. It can handle key requirements i.e. speed and quality. For example, in a typical BPO call centre, Six Sigma may help in identifying a requirement to answer calls within 10 seconds and then system

enablement to answer 95 percent of the calls in no less than 6 seconds and no more than 15 seconds.

Lean would help trim the length and volume of the calls which in turn lead to less full-time staff and facilities for them. In a supply chain, Six Sigma can identify variation in schedule and production processes and their root causes while lean will complement by establishing lower manufacturing cycle times and less inventory as per market scenario.

Table 5: Difference between Lean and Six Sigma

Issues/Problems/Objectives	Six Sigma	Lean
Focuses on customer value stream	N	Y
Focuses on creating a visual workplace	N	Y
Creates standard work sheets	N	Y
Attacks work-in-progress inventory	N	Y
Focuses on good house keeping	N	Y
Process control planning and monitoring	Y	N
Focuses on reducing variation and achieve uniform process outputs	Y	N
Focuses heavily on the application of statistical tools and techniques	Y	N
Employs a structured, rigorous and well planned problem-solving methodology	Y	N
Attacks waste due to waiting, over processing, motion over production. etc.	N	Y

Dr. Jiju Antony said, “While the fundamental principle of Six Sigma is to take an organisation to an improved level of Sigma capability through the rigorous application of statistical tools and techniques, Lean production has a role in eliminating waste and non-valued added activities across the entire supply chain”.

A further understanding of how Six Sigma and Lean complement each other’s approach to continuous improvement can be seen in a more detailed comparison in Table 5 as defined by J. Antony, J. L. Escalilla and P. Caine.

While writing “The Perfect Engine,” Patricia E. Moody and Anand Sharma describe “Use of Six Sigma tools once the Lean methodology has reaped all of the low-hanging and intuitive improvements become difficult.” This approach describes a concurrent method that blankets the organisation or process with Lean to be followed by Six Sigma once improvement productivity slows. Although this limited approach would be defined as continuous improvement, it fails to capitalise on the complementary nature of Lean and Six Sigma methodology.

Definition of Logistics

It is controlling the movement and management of goods right from procurement to end customer.

Lean and the Logician

The combination of Lean on the logistician is important as Lean eliminates waste (inventory) which reduces WIP (work in process) inventories which in result decreases process time leading to increases in supply chain velocity and flow.

The Lean practitioner does not envision on cost factors such as transportation or warehousing separately, but rather sees “total cost of ownership”. Normally inventory carrying costs is around 15-40% of total logistics costs so for industries total cost oriented decisions have dramatic impact. Many organisations still have view on visible cost point like transportation, warehousing and sourcing practices.

Lean Logistics Understanding

Supply chain management is meant to take waste i.e. excess inventory, time and cost out of supply chains. Supply chains management techniques make moves to pull instead of pushing inventory across itself. Lean logistics handles waste removal and variation in supply chains or the Kanban, Pull.

Cost, time, and inventory are three factors on which all parties like wholesalers, manufacturers, retailers, distributors, suppliers feel the need to reduce or to remain lean. In the case of with global supply chains this feeling becomes more and more prominent.

Lean logistics faces many intermediate challenges. One of them is the add-on time required for shipments to travel door-to-door over the long distance having many parties involved. It has been suggested that up to seventeen parties may be involved with one shipment like the raw material suppliers, loading labour, truckers, freight forwarders, insurance providers, terminals, customs and excise brokers, freight carriers and many more depending on the process. Implementing of lean process across multifold transactional supply chain is very difficult.

To face the competitive environment companies are embracing Lean and Six Sigma processes to achieve cost reductions and quality improvements. Initially Lean and Six Sigma programmes use to be separate programmes

in most organisations but now Lean and Six Sigma complement each other and provide for continuous improvement activities.

Logistics, Lean and Six Sigma converge to form a natural combination. This combination uses the positive and negatives of each discipline to achieve an operational model that will help the logistics manager to improve operations at all levels.

Six Sigma and the Logistics

Even the thought of variation reduction will please the logistics manager. Logistics is managing inventory and its movement which in turn leads to managing the variations which is between the inventory piling to out of stock situations as boundary conditions. Variation should be low to make sure the extra cost of carrying is less as well as upward supplies are not affected.

Buffer stock is hedging against the unknown variables which are not foreseen during the planning. Safety stocks are always kept because there are chances of variation in quality from supplier, transportation, internal operations, manufacturing process and customer demands. Controlled and supervised variation from supplier to customer will lead to reduce dependency on safety and buffer stocks.

Lean Six Sigma Logistics

We are now going to merge the three elements i.e. lean, Six Sigma and logistics with their individual concepts explained before, summary of which is as follows

1. Lean is elimination of waste as well as manage speed and flow
2. Six Sigma is enhancing reliability and variation reduction
3. Logistics managing inventory

Lean Six Sigma Logistics is jointly merged as: Reducing of unwanted inventory following disciplined approach to reduce variation and enhancing reliability simultaneously enhancing the speed and flow of supply chain.

Ohno said “All we are doing is looking at the time line, from the moment the customer gives us an order to the point when we collect the cash. And we are reducing the time line by reducing the non-value adding wastes.”

In the global supply chain the above merger will have significant impact on all participants in supply chain as

they also have to align themselves with parent on waste reduction and variation control.

George Michael L. explained the impact on company’s performance in each, by combining the strength of today’s two most important initiatives i.e. Lean Production and Six Sigma into one integrated programme. He developed a roadmap for milking the best elements in Lean and Six Sigma, showed how to achieve major cost and lead time reductions; compress order-to-delivery cycle times; and handles variation in process and delete waste from organisation.

Kenneth E. Kirby said “Implementing Lean concepts and principles is not a technological issue, it is primarily a management and human resource issue.”

Both Lean and Six Sigma principles are tools for logistics. Using these principles and tools will ensure that an organisation is able to unearth and deal with idle and waste inventory and inefficiencies of the system.

In order to make Lean and Six Sigma work in field of logistics a totally devoted management is needed and their mindset has to be shifted and tangible benefits should be shown to them.

This requires two commitments

- ◆ “Total Logistics Cost” is used in decision making
- ◆ Courage to reduce or eliminate unwanted inventory

These are not simple in practical aspects as good they sound in theory. The prime reason for it being

- ◆ Organisational norms and financial accounting traditions
- ◆ Practice and wrong addiction to inventory

EXAMPLES OF LEAN SIX SIGMA IMPLEMENTATION

Lockheed Martin

Lockheed Martin is rooted in the production of aeronautical and space systems, their integration and technology services. The company put Lean Six Sigma into practice in the year 1998 under the name “LM21 Best Practices”. This included thorough and careful study of the processes, proper differentiation of value added and non-value added processes, waste elimination and improvement measures.

As a top down approach, the programme started with the training of the top management and went down in the organisation structure. The company has made it mandatory that anyone with incentive compensation has to undergo the training. This includes people holding a position of director and above. As per the Lean concepts, the initial step in the process enhancement plan was to develop a value stream mapping. It provided information about whether customer expectations are met, presence of any gaps in meeting customer requirements and availability of possible solutions to bridge the gaps.

The entire organisation was involved in all the process improvement projects. Improvement methods were a combination of tools from both lean and Six Sigma. Lockheed Martin was losing a huge sum of money just on inspection. They worked with critical suppliers to integrate Lean and 5s into their plants. By implementing Lean Six Sigma Lockheed Martin encompassed about 5000 projects, out of which a majority were improvement projects. All started with the aim of reducing the cost of \$3.7 billion over a four year period, which resulted in close of \$4 billion of reduction in cost.

Bank One

Lewis Fischer, the division executive of the National Enterprise Operation (NEO) encouraged the implementation Lean Six Sigma. Being one of among top 10 banks back in the 1990s, they were struggling hard for basic continued existence.

As a part of the improvement process, focus was laid on performance measurement and opportunity identification. Their problem solving approach was divided into different stages. The first stage was to address all possible gaps in their network.

The second stage focused more on lean goals such as eliminating complexity and increase process velocity. It was based on kaizen, a series of continuous improvement events. The objective was to first identify the value stream, spot the problems and resolve them by providing solutions. One of the main and initial hurdles they had was to gain trust of their employees. But eventually by empowering the people to facilitate the processes, the organisation managed to gain their trust.

This paved the way for providing training for all employees and creation of project oriented teams. The second stage started with the top management being introduced to key concepts on Lean and Six Sigma. They listed opportunities and prioritised projects. Other than forming cross functional teams, employees who were directly responsible for selected processes were involved in the improvement cycle. Within a span of two years, there was a whole lot of change in the work culture. Also there was considerable reduction in the overall cycle time. Cycle time improvements ranged from 30 percent to 75 percent, one administrative process went from 20 minutes to 12 minutes, a complaint resolution process dropped from 30 days to mere 8 days.

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