CHAPTER 2
LITERATURE REVIEW

2.1 IMPLEMENTATION OF LEAN IN MANUFACTURING INDUSTRIES

Powell et al (2013) analysed typical lean and ERP implementations processes and examined concurrent implementation process in real-time and develop and proposed a process for ERP- based lean implementation. They combined the existing methodologies for lean production and ERP systems to obtain a single best practice approach which named as “ERP based lean implementation process”. The findings suggested that the implementation of a contemporary ERP system could act as a catalyst for the application of lean production practices. Future research need to be carried out on the ERP systems as one of the tools in the lean tool box.

Karvonen et al (2012), adapted the lean enterprise self assessment tool (LESAT) to guide the transformation of software development companies towards lean. A case study was done to analyse the concepts and expressions of LESAT and mapped to software development following the ISO/IEC/2207 standard. Using LESAT, seven assessment items concerning life cycle processes were modified. The modified LESAT was compared with lean assessment approach called “Lean Amplifier”. It is successfully practiced by Ericsson R&D in Finland. LESAT complement the lean assessment in the software domain at enterprise level, involving the entire value stream. The authors also emphasized the role of leadership in the transformation. LESAT
has needed more study to validate the tool and make a more comprehensive analysis of its utility. LESAT adapting life cycle processes is frequently intertwined with agile methods.

Salleh et al (2012) conducted a study on simulating, integrated TQM with Lean Manufacturing (LM) practices in forming process. A case study of the forming company in Selangor was conducted and simulation of the process is done by Delmia Quest software. The simulation study revealed that the company has been practicing TQM and LM separately.

Rahani & Mohammad (2012) demonstrated VSM techniques and discussed the application in an LP (Lean Production) initiative on a product (Front disc, D45T) case study. Before lean implementation, the assembly processes for the case product D45T was studied. The cycle time, change over time, transportation time, queuing, handling and machine time data were observed.

VSM tool was used in all the process steps of manufacturing the product and studied. A current state map was plotted and developed a future state map. The VSM is developed in three steps, first step is plotting current state map shows the present scenario of processes. The second step is identifying the root causes of waste and its process improvements by developing future state map to achieve a lean process flow. The third step is establishing improvements through implementation plan and gain project objectives by Kaizen activity.

The application of VSM tool in the production process resulted in savings on lower rejection rates; identify the substantial gaps between standardized work and real work, improvising the SOP for continuous
Sanjay Bhasin (2012) investigated to interpret whether larger organizations embrace lean as a philosophy was indeed more successful. They analyzed the primary data captured from 68 survey questionnaires undertaken in manufacturing organizations in Britain and extensive case studies were undertaken in seven companies as a comprehensive validating exercise. The results revealed that larger organizations performed better. Of the top 22%, whereas the large companies were comprised of the top 47%, large companies indeed were more successful.

Deifa (2012) assessed lean manufacturing based on variability. A case study was conducted in an industry using the variability assessment tool called variability source mapping (VSMII), focusing on capturing and reducing variability across the production system. The case study revealed that the new tool succeeded in capturing various variability sources in the production system and helped to reduce the variability level, reduce lead time and ensure sources in the production system were non-value added. It helped to reduce the variability level. Further research is required to face many improvement challenges and find answering questions such as reducing the inter-variability and calculating the co-efficient of variability for both cycle times and flow.
Vishnu et al (2012) focused on the implementation of lean philosophy in a refractory industry with an intense attention on the production line. The research methodology used in this research is a case study methodology.

A case study was performed in one of the refractory industry in Kerala. For lean implementation VSM tool was used. The making of refractory blocks consists of various processes such as design the product according to customer requirement, making of patterns for drawings, preparation of moulds for the patterns, making of flasks for the moulds with annealing media (grog), preparation of raw materials mixture and melt in furnace, pouring of oxidized molten materials in the flask and solidification, annealing of block, deflasking and removal of blocks, finishing of blocks with machining operations, assembly of blocks, and after inspection packing and shipping of blocks.

Accordingly current state map was plotted based on collected data directly from shop floor. The brainstorming session was organized with shop floor people to identify and analyze the wastes encountered along the value stream. The following discrepancies were found in manufacturing processes due to poor production balancing. In moulding section, instead of 72 blocks to make in a shift only 16 blocks is made due to want of patterns. In mould
bin picking from annealing area and cleaning of deflasking plat form. In machining section, noticed that at each station there is more inventory than the required due to unavailability of raw materials, machine shutdowns and unskilled labours.

The production techniques were analyzed for optimization to balance the production. The future state map was plotted by eliminating all wastes, setup times and proper process rearrangements to meet towards maximizing the production efficiency. The production is improved by eliminating various wastes by introducing lean principles. Furnace capacity is optimized for 17 blocks in a shift. FIFO system implemented in annealing section. In flasking section, Bin-mould assembly is done as a parallel operation. The proposed inventory level at machining section is 581 blocks. Mould shop function is reduced to two shifts. Total lead time is reduced to 13.26 days. Awareness of lean principle is created among workers. Kaizen was implemented. Continuous improvement at all stages of production is ensured.

The implementation of lean philosophy in a refractory industry enjoyed the improvement in production process by identifying and eliminating unwanted wastages.

Gotz et al (2012) showed how the concept of an engineering community provides basic tool support to realize ideas from modern production systems in the field of engineering projects. The methodology focused on a set of criteria comparing a modern production system with the engineering automation systems or other complex industrial systems by raising two main questions:
1) Are there any similarities between a modern production system and engineering?

2) Which methods and tools are suitable for applying them to engineering?

If the characteristics of industries are differ on one over the other in the case of implementing modern production system in engineering projects, the adoption of lean challenges will provide the solution. The future research required in the approach of the efficient networking of all people involved in engineering projects in order to attain the efficiency with lean concept.

Mohanram et al (2012) implemented lean principles in a printing equipment manufacturing company. A task team was formed choosing experts from different parts of the company with a motto to implement lean principles through VSM. As a case product, impression cylinder was considered. The sequences of activities involved in manufacturing the case product are:

- The production order for 75 numbers released from assembly section (Unit-A)
- Production control department of Unit-A issues the purchase order to supplier for supplying external castings after turning operation.
- At Unit-A, 100% inspection done for the supplied materials and sent to Unit-C
- Job order given to unit-C for machining the materials. After machining again sent to unit-C for inspection.

- To carryout for horizontal machining operation, materials sent to outside vendor and after inspection is done at Unit-A.

- Again materials sent for plating to outside vendor and back to unit-A and then delivered to assembly department of unit-A

Current state map was prepared based on the present scenario of manufacturing. CSM was studied and analyzed by brainstorming sessions. From the value stream map, various value-added activities, non-value added activities and bottle necks are identified and quantified in time. It is found that there is a mismatch of batch order timing and sizes of the batch order is the major issue and not cope with the current level of demand. It is noticed that about 55% value added activities compared to 45% non value added activities are present in the manufacturing system.

The future state map was plotted based on the analysis and implementation. The lean principles optimizing the production flow in manufacturing industry by minimizing several non-value added activities and non-value times improve the line efficiency through VSM and developed a more generic approach to design lean environment.

The corrective measures are taken to reduce time and cost. The following initiatives are taken to reduce NVA activities:

- Work sheet is standardized
• Improvement opportunities are noticed by introducing earnest monitoring.

• The unwanted and inefficient operations are removed if possible.

• Modification is done on process lay out.

Finally a drastic reduction in machining time is achieved. Improvement found that about 76% are value added activities compared to 24% non value added activities. Noticed that reduction in lead time, inventory, and transportation time and processing time.

Lombardi (2011) described how an application of a lean manufacturing principle prevented the risk of delays in new product introductions. The author studied and analyzed the lean manufacturing principle in training development and delivery methods and capacity requirements. The roadmap and FEMA are developed and focused on a rolling 6 quarter period with 5 year horizon. The road map is updated monthly with FEMA to find progress and review with equipment development groups to decide on future training needs.

The FMEA resulted in appreciable reduction in high risk training items and improves the training management. The application of FMEA with lean manufacturing principle increases the sustainability with year over year, supports the productivity improvements and reduces resource requirements.

Ma et al (2011) established a formal method of modeling and analysis of work flow systems of Lean Supply Chain (LSC). A case study was done by modeling and analysis for the cross organizational work flow systems
in the context of lean supply chain using petrinets. The modeling and analysis
for the cross organizational work flow systems in the context of lean supply
chain using petrinets, established a formal method and promoted operation
management of LSC in real world settings. Future research work is required
on schedulability analysis and lead time analysis of LSC with a perspective
using reduced CLTWN’s (Cross Organizational Labeled Time Work flow
Nets).

Muslimen et al (2011) implemented lean manufacturing in
Malaysian automotive component manufacturer. The case study company was
selected based on its achievements as a Toyota Production System. The model
company which was secured the award by Malaysian Japan Automotive
Industries co-operation (MAJAICO). The main function of MAJAICO is to
encourage and support companies to introduce continuous improvement in
manufacturing activities by total implementation of lean manufacturing. Two
lean experts have conducted interview with shop floor people as per their
prepared semi-structured and open ended questionnaires with the idea of
understanding LM and LM implementation. The interview was recorded and
findings of the interview were analyzed. The application of lean
manufacturing in Malaysian Automotive industry by project based approach
on the following characteristics; small area, bottleneck area and delivery area.
The benefit obtained by this lean implementation is reduction in level of
inventory. Consequently reduction in other wastes such as overproduction,
waiting times, excessive transportation, excessive processing, excessive
motion and defective parts. The production system continued the continuous
improvement effort until reaching the stable condition. The future research
work to be carried out on the next step of LM implementation in the company
to sustaining lean manufacturing.
Gustavsson & Axelsson (2010) improved the system architecting process through the use of lean tools. The architecting process is executed during the beginning phases of the development process where uncertainty is very high. The architecting process will not create immediate value to the end customer, but rather create the architecture to enable value creation, when working properly or prevent value creation.

The lean tool improve the value creation within a process is VSM. The VSM is adapted and evaluated to analyze and identify improvements of the architecting process within embedded systems developments. A case study was carried out using adapted VSM, conducting parallel interviews at two companies. The use of lean tools in automotive industry ensures the sustainability of industry in competition, even manufacturers were forced to release new models more often and satisfy individual customer demands. For future research work, the interviews should be with more explanations and case study to be conducted for more companies.

Dopp & Moran (2010) implemented lean manufacturing principles in a Ga As semiconductor factory. A case study was done by introducing a new production framework based on lean manufacturing principles and analyzed. Gallium Arsenide IC factory needs persistence, patience and strong change in leadership until to reach the sustainable change in industry, in the case of implementing lean manufacturing principles.

Deif (2010) studied the use of computer simulation to explore the impact of applying JIT, lean policy on a traditional inventory based production system. A system dynamic model is introduced to capture the different components of the production system. The inventory dynamics of the modeled system is examined against different production scenarios under
stochastic demand. The use of computer simulation in production system not able to fully transferred to lean and adapting lean principles are always not beneficial. It is required on dynamic analysis of lean policies to find more evident and calls to implement lean principles and tools among traditional manufacturers.

Wan & Chen (2009) developed an adaptive lean assessment approach using a web based decision support tool, and guided the lean implementation process. Using the web based program, an assessment tool is generated adaptively for each user to evaluate the current status of the system, pinpoint the urgent targets for improvements and identified the appropriate tools and techniques for developing action plans. This web based decision support tool simplifies the lean implementation process more systematically and efficiently. Future research is required to update the assessment models continuously with the advances and availability of technologies and managerial techniques.

Pattanaik & Sharma (2009) studied the implementation of lean manufacturing in cellular manufacturing system. To find a favorable lean line in manufacturing by identifying value adding activities through an optimum feasible takt time in a proper cell layout. Implementing various concepts of lean manufacturing within cellular layout is necessary to get an efficient cellular manufacturing unit.

A methodology for cellular layout is designed for implementing lean concepts to manufacture ammunition components for defense applications based on takt time for various parts. A case study was done in ALCAST Pvt. Ltd., supplying missile components and sub-assemblies to Government
Ordnance factories. A fuse DA5A assembly was chosen illustrating the methodology on shop floor to implement lean concepts.

Binary machine-part incidence matrix (MPIM) and jaccard coefficient were applied to workout machine cells for the parts of assembly. It is a familiar cell formation technique to identify machine cells. The original cell layout was analyzed for each parts operation sequence, processing material handling time, etc., and reducing several wastages. For achieving this, some operations are combined and machines are relocated according to implementation requirement within the cell.

The production flow among cells studied and optimized several non value added activities and times. The generic approach in designing cellular layout with lean environment based on Takt time for various parts and the optimized production flow among cells. The future research work to be carried out for the lean implementation on load balancing and maximum utilization of the cells in CMS.

Abdulmalek & Ragopal (2007) analyzed the benefits of lean manufacturing and VSM by simulation in a process sector. A case study was conducted at a large integrated steel mill in adapting the lean principles. VSM was used to identify the opportunities for lean techniques. A simulation model was developed using system modeling Corporation Arena 5 software and applied before and after the implementation of lean and thus the benefit of lean was illustrated. For various performance measures, comparison was done between actual and simulation.

Managers who are very earnest in implementing lean principles can do demo using simulation to know the uncertain about potential out comes.
Also the simulation can be used to evaluate basic performance measures and analyze system configurations. Further it can be used to validate the decision on implementation of lean manufacturing and can encourage the companies to implement lean with a view of desired results. Analyzing by simulation facilitates the managers who implementing the lean principles, to know about uncertain potential outcomes and validate the decision of implementing the lean manufacturing and motivates the organization during actual implementation in order to obtaining designed results.

Evans & Alexander (2007) used the multi-criteria modeling and simulation to achieve lean goals. The methodology based on the use of multi-criteria models in conjunction with optimization procedures and simulation in order to identify an ideal system state and associated policy. To achieve lean goals, the identification of current and ideal states and policy are necessary to attain an ideal state using optimization procedure and simulation model.

Houshmand & Jamshidnezhad, (2006) stated to introduce the process variables in production system design, while developing a product the set of PVs are interpreted as tools, methods and resources, required for implementing lean production system. They developed a hierarchical structure to model the design process of a Lean production system, composed of FRs, DPs and PVs. This axiomatic model provides an efficient guideline for design process and clarifying the required tools, methods and resources. This model is general to apply for different cases. The axiomatic model as the form of FR-DP-PV relationships provide a scientific model for concepts, principles and methodologies for lean manufacturing and thereby alleviating many existing implementation short comings. This model can be applied for different cases. Research work to be carried out in future to find the factors in the failure of lean implementation practices like lack of scientific
foundation for lean manufacturing and its associated transformation process, lack of precisely identified needs and reasons for change, resistance to change etc.

Melton (2005) mentioned that lean makes a revolution, just about using tools or changing a few steps in manufacturing processes. A case study was taken from the process industries, shows how the principles of lean can change business benefits and ongoing incremental benefits. The overall potential benefits obtained include decreased financial constraints, increased satisfaction, quality enhanced, people empowered with multi skills and increased knowledge in manufacturing processes and all other processes within value stream. A multi-product manufacturing process was considered for the study. Lean thinking is removal of wastes from many steps of manufacturing processes with robust supply chain and ensuring the flow of value. Lean thinking is a route to achieve real continuous improvement and a philosophy which has the potential to transform the business and this revolution should be welcomed with open arms. Lean thinking is very benefitable to all chemicals and pharmaceutical industries and all business processes within process industries.

Zee & Slomp (2005) illustrated how simulation and gaming can be used to support lean manufacturing systems. A study was done on a case example from industry – a manual assembly line for mail – inserting systems – for which a simulation game developed and analyzed. As a support tool simulation and gaming can be applied to demonstrate the application of a lean control concept at existing assembly line and helps train workers to take appropriate control decisions within this concept. It is also used in more industrial settings to take more appropriate control decisions in lean manufacturing system. Further research required on simulation modeling,
considering the workers without omitting relevant human factors that influence worker and system performance.

Willhite (2004) implemented the principles of lean manufacturing at Semicon Associates samarium cobalt magnet facility. Using VSM tool visualized both value added and non value added actions within the manufacturing process of case company. Analysis was done by using simulation tool. Lean Principles adopted at semiconductor associates, manufacturer of magnets, got benefits in reduction of wastes, ensured the stream lined flow of process, batch sizes were reduced, cycle time variability was eliminated with standardized work, non value added steps were improved with kaizen events and the execution of orders were improved to 100% on time.

Shah & Ward (2003) examined the effects of true contextual factors, plant size, plant age and unionization status on implementation of lean production systems in manufacturing practices and four bundles on interrelated and internally consistent practices. The study is carried out based on collected data from Industry week’s census of manufacturers. The research revealed two findings:

1. In organizational context, the implementation of lean practices influences the plant size strongly whereas the influence is less in plant age and unionization.

2. The application of lean bundles such as JIT, TQM, TPM and HRM on contextual factors of the plant improves its performance
The future research on lean manufacturing, context and the effects of environmental dynamism, complexity and munificence are to be considered.

Dankbaar (1997) compared the basic elements of lean production and socio-technical systems design (STSD) and again compare both with characteristics of the traditional Fordist system of mass production. A study is carried out in an automotive industry, car manufacturer and analyzed. Noticed that Lean production is very flexible than the traditional Fordist organization with a minimum quality work. In Fordist system, a worker knows when he will finish his job whereas in LP system a worker is not finished since he has to help others once he completed his own task. Lean production supports the industries to extend the life of mass production methods even in the situation of turbulent markets with large variety of products where as STSD not able to make a big impact on the mass production of Cars and STSD would be the succession of Fordism.

Brendon & Kenneth (1996) transformed the automotive component supplier to lean manufacturing. The production systems with global best practices implemented in a pilot manufacturing area. The concept of project management, process flow, layout, material flow, ergonomics, workplace organization, people-focused practices and supporting software development mere all integrated as a whole system using the specified monorail delivery system. The proposed modifications in the production systems transformed to lean manufacturing increases the production up to 50% to the current monorail systems.

Acaccia et al (1995) achieved a lean engineering organization with assured return on investment. A case study was done by introducing the
opportunities offered by the prototypical implementation on a simple pilot plant with computer simulator. To ensure a return on investment in intelligent manufacturing, the implementations of lean principles are essential to organization. It can be achieved by measuring the effects of flexibility and adaptability of combining control and management of the product and production process. Future research work is necessary on net production with complicated relationships among many process variables.

2.2 IMPLEMENTATION OF LEAN IN OTHER SECTORS

Gnoni et al (2013) designed a NMS (Near - miss Management System) based on the integration of principles of lean management in occupational safety for a worldwide automotive supplier firm. Application of NMS and lean thinking strategy principles forces firms, derive new approaches to design and manage the whole organization and safety management system. In chemical and petro chemical industries near-miss management systems are compulsory since these sectors are characterized by Major Accident Hazards (MAH). NMS is an effective tool to apply Learning from Experience (LFE) concepts in occupational safety management.

The system on lean occupational safety paradigm in the design process of a NMS has been developed for an automotive supplier firm which has its own reference model to apply lean strategies. Noted that the application found effective as the proposed structure of the NMS fully applied in all firm departments. Lean occupational safety is an innovational design of NMS which is based on integration of principles of lean management in occupational safety, encourages the firm in the direction of continuous improvement process.
Chen et al (2013) applied lean production and RFID technologies to improve the efficiency and effectiveness of supply chain management. A case study was done using VSM tool. VSM is used to analyze the various factors of insufficient supply chain operations. For improving the supply chain efficiency and effectiveness the implementation of lean production and RFID technology can be utilized. A current state map was drawn for a three-tier spare parts supply chain and future state map (with lean production and RFID) developed with material, information and time flows. Then, evaluation analysis was done.

The case study results shown that the total operation time from current state to future state with integration of lean and RFID saved by 81% if adopting cross docking the saving further increased to 89% (with 89% saving in waiting and transportation time and 70% saving in value-added time). Besides, one operator can be reduced in each warehouse while maintaining to current service capacity. The integration of lean production and radio frequency identification (RFID) improves the efficiency and effectiveness of supply chain management such as saving in total operation time, reduction in labors and good return on investment (ROI). Future study can be done with the spirit of lean production and RFID application in transport system to increase the traceability of deliveries.

Marhani et al (2012) enhanced sustainable construction in Malaysia by implementing Lean construction. Lean construction principles implemented in a malaysian construction company and studied its benefits. Lean construction principles implemented in construction industry benefited by maximizing its value and improved sustainability and ensured the continuous improvement. Future research should be on companies that have implemented LC concept by observing their practices on site.
Nee et al (2012) improved the manual assembly line by adopting lean tool for process improvement in electronic part supplier company – SME. The process improvement were divided into several phases and carried out each, phase by phase in order to ensure the impact of improvement. The Kernel concept of lean production played an important role to maximize the effectiveness of lean production than using several lean production techniques. The lean implementation in assembly line improved its efficiency by reduction of production time and idle time of operator with less number of operators. It was observed that lean production method increases the improvement in management and enhances the ability of competitiveness of company at international level. The result of case study proved that 40% reduction in man power, 7.13% reduction in cycle time and 81.64% reduction in idle time. The implementation of lean production concept at different phases in manual assembly line of an electronic company enjoyed the impact of implementation as increase in profitability, reduction in idle time and save in operators.

Panizzolo et al (2012) investigated the adoption of lean production in India and examine the lean practices implemented by the SME’s. A case study methodology was utilized and presented the findings. The Indian small and Medium Enterprises faces the problems of hesitate to change over from a traditional to a lean manufacturing environment. But industries which have implemented the lean naturally attained significant improvement in manufacturing performance.

Foung et al (2011) adjusted the lean practices so as to implement on small and medium enterprises (SME). A study was done Simulation based optimization model, developed to optimize a set of parameters of lean SME against three performance measures- cycle time, WIP and work force
utilization. In order to implement lean manufacturing in small scale industries and small and medium scale enterprises, the use of simulation helps to predict the impact of proposed changes ahead of implementation and to drive away the mitigate risks through the factor analysis phase (cycle time, WIP and staff utilization). Future research efforts are required to develop decision making models that can optimize the contradicted response functions simultaneously.

Staats et al (2011) investigated the implementation of a lean production system in Indian software services firm, to examine the application of lean production to knowledge work-task uncertainty, process invisibility and architectural ambiguity. The target organization for case study is Wipro Technologies, a global software services industry. It provides services on software development projects as fit to individual customer’s specific needs. A productivity office was formed to train, educate and monitor the lean implementation activities, found that lean initiative changed Wipro’s internal operations comparison on performance of lean projects with non-lean projects was done.

They documented the influence of lean principles on internal processes and examined the techniques which affected both problem identification and problem resolution. The implementation of lean initiatives in software services firm proved that lean software projects perform better than non-lean software projects, ensured the lean production system in knowledge work is possible and resulted in improved operational performance. The limitation being investigation on implementation of lean production in knowledge work, experiences that generalization is not possible to fit all software industries.
The role of IT in achieving lean, three important topics are Riezebos & Klingenberg (2009) investigated that the application of IT and Lean Principles are claimed to be interdependent and complementary by some whilst others have seen as the approaches as being mutually exclusive. reviewed, the use of IT in production logistics, computer-aided production management systems and advanced plant maintenance. Kanban and similar logistic systems are simple, robust and very successful but they are much more successful if they are connected with automation and computerized planning and control.

Now-a-days companies are possible to take advantages of both push and pull systems by building hybrid environments. It is observed that the roots of different ways of working were similar whereas its subsequent developments were in opposite directions. The acceptance of lean production became more pervasive, converged the practices into hybrid production systems and consistent companies having limited choices to change over to lean, would have missed important opportunities to improve competitiveness.

Riezebos et al (2009) discussed the changing role of Information Technology in advancing lean production. Lean principles and techniques were applied in a wide variety of organizations and service sectors. The variants were developed for various areas where the lean principles applied. IT is used to develop such variants. Over the years, the role of IT has been changed. IT systems helps to apply lean production concepts - pull control and serve in non-traditional application areas, speed up the process of adapting automatic production systems, increase the effectiveness and acceptability of employee training programmes, improve productivity through computerized progress control and support practitioners in deciding on the next step in a change process towards lean production.
The simulation of research efforts, advancing the lean production in manufacturing and service industries. Since many of traditional techniques cannot be applied directly in their processes, the application of lean production principles in industries and services seems to be still lagging behind. It provides ample opportunity for new developments and innovative applications of IT in these areas.

Wei (2009) addressed the question, if banishing waste is the core value and mission of lean, what would be the opportunity cost of delayed diffusion of lean from manufacturing to services? By proposing ten lean principles of service process design.

The ten principles to be followed to extend lean into service operations are:

1. Document the value stream with visual tools.
2. Identify wastes and ask, 5 why?
3. Be proactive via ‘five S’ and service inventory,
4. Error proof the process.
5. Manage ‘loop-back’.
6. Enable 1- price flow.
7. Standardize.
8. Buffer the bottle necks.
9. Ensure segment complexity
The First two principles laying the foundation to process improvement; Principles 3 to 6 are primary represents the beginning of change; Principles 7 to 9 are build upon the previous principles; At last, 10\textsuperscript{th} principle standing above the remaining nine principles, helping in aligning all the principles towards the goal and objectives of the organization. Any organization can get benefit by applying these ten principles since these principles are tested in a wide variety of real-world scenarios.

Identified some common design problems by adopting existing service theories or some lean principles from the experience of evaluating more from 150 lean process design projects. The adaptation of lean principles in service industries not required more investment to start and enable people to tackle bad service processes with a macro level game plan so that they can rapidly solve the problems in the current system.

Ray et al (2006) implemented the lean manufacturing in pre cast concrete plants reduce wastes and improve their production operations. The lean manufacturing applied in the pre-cast industries and studied eight types of wastes are identified in process and eliminated. A lean principle introduced in the production system substantially enhances the performance. The application of lean techniques in PCI substantially reduces the production cost, minimizes the reworks overall production capacity increases and profit enhances.

Til et al (2005) taught students about lean manufacturing as an interdisciplinary approach by faculty of Oakland University and Oakland’s Pawley Institute. The faculty members of Oakland University developed an interdisciplinary course entitled “Lean principles and application and taught the students of various disciplines as a semester long project work with
company personnel. Students were taught on lean manufacturing principles and trained them that how to solve real world problems and focuses on continuous improvement. It helps these future employees to add immediate value while hiring them in the companies.

Cagliano et al (2004) explored the supply strategies of European manufacturing firms. Based on the supplier selection criteria and the integration mechanisms adopted, four clusters were identified. The two clusters were agile and lean strategies and other two were traditional supply strategies. The strategies are analyzed in terms of contingent and structural factors and manufacturing performance. The analysis on supply strategies of lean, agile and traditional on manufacturing performance, revealed that those lean and agile strategies outperform the other clusters on many dimensions whereas no significant difference among them in terms of performance. Future research work needed on the possible dominance of leanness and agility after considering the associated costs and risks.

Ranky et al (2003) focused the challenges of dynamically scheduling and balancing lean, reconfigurable disassembly cells and lines. Since the processing times are less accurate and in consistent, production scheduling and balancing disassembly cells and lines are challenging than assembly. Create a set of methods, software tools and industry validated cases that enable the managers to execute different computer controlled and management programmes, helps to run their real world disassembly lines and factories. The created algorithms (Dynamic Disassembly line Scheduling & Line Balancing) and code written are generic and very efficient; they could be employed to production schedule and balance small and large systems with hundreds of files without any difficulty. The achievement attained deploying
own code and system architecture in to real time, wireless controlled and communicated embedded systems.

Arbos (2002) proposed a methodology to implement lean management in the services of telecommunication system. While services were subject to more degree of variability of features, analysis was done on that variability and a proposal fraction to be to be taken when it was excessive. The implementation of lean production principles on management of telecommunication services caused the elimination of wastes, increased the productivity and greatly reduced the service time using same no. of operatives and resolved excess variabilities in service times. Future research required on the development of innovative relations with relations, by increasing the care on customer service with seems to be conditioned variables.

McIvor (2001) determined whether the principles of the lean supply model are currently present between an OEM and its key suppliers in the electronic industry. The research focused on two key dimensions of lean supply:

1) Supplier involvement in customer design activities and joint buyer

2) Supplier cost reduction and analysed.

The introduction of lean supply model for key suppliers in the electronics industry not attained total leanness along the key dimensions. Future research is required on implementation of lean supply principles in area such as greater supplier integration in the new product development activities of OEM’s.
2.3 IMPLEMENTATION OF LEAN IN ENVIRONMENTAL MANAGEMENT

Diaz-Elsayed et al (2013) identified a technique to incorporate both lean and green strategies into a manufacturing system. A case study was conducted in an automotive sector on past production, in which combination of lean and green strategies were implemented with simulation model. The implementation of lean and green strategies in production system reduces the production cost. Future research efforts required on broader variety of quantifiable green strategies within the factory.

Jabbour et al (2013) verified the influence of environmental management (EM) on operational performance (OP) in automotive companies, analyzing whether Lean Manufacturing (LM) and Human Resources (HR) interfere in the greening of these companies. A questionnaire was prepared, based on the theory of conceptual framework and hypothesis and sent to the respondents of automotive companies. The collected data were analyzed using structural equation modeling.

While analyzing the influences on one and over other among EM, OP, LM and HR in Brazilian automotive companies, LM influences EM positively and statically valid but weak to moderate manner. EM influence over OP is positive and statistically valid but with a weak explanatory power. HR influences EM in a positive manner but does not like LM over EM. It revealed that the poor integration between human resource management practices and environmental management practices in the companies. Future studies to be carried out to find out the better understand reasons for poor integration between human resource and environmental management practices. The research sample size was considered only based on the
participating companies and restriction of analyzing a single industrial sector. Another limitation concerned was the existence of overlaps among HR, EM, and LM variables.

Azadegan et al (2013) investigated the effects of environmental complexity and dynamism on lean operations and lean purchasing practices. Empirically examined the relationships using archival and survey data from 126 manufacturers. The higher levels of unpredictability and instability in dynamic environments are very difficult for lean operations to synchronize production process and reduce inventory which weakens the effectiveness of lean operations. The environmental dynamism reduces the benefits of lean operations on performance enhances the benefits of lean purchasing on performance. The future studies required on assessing specific impact of industrial settings on lean operations and lean purchasing.

Vinodh et al (2011) emphasized the need for environmental consciousness and importance of environmental waste as ninth presented some of the strategies/techniques that would enable the achievement of sustainability objectives using lean initiatives.

Puvaneswaran et al (2011) analyzed lean and environmental management systems (EMS) and provide an understanding of how these processes are contributed to improve business efficiency. Study and understand the individual systems and explore the possibilities of integrating the two models to provide an effective approach to achieve organizational efficiency. The integrative approach business model based on lean and environmental management system (EMS) in organization improves business efficiency and productivity and helps to attain ISO standards and creates sustainability. The future research studies can be carried out on evolving
technology implementation to provide improved models that can simplify work processes and explore the managerial mechanisms.

Yang et al (2011) explored the relationships between lean manufacturing practices, environmental management and business performance outcomes. The hypothesized relationships of this model are tested with data collected from 309 international manufacturing firms (IMSSIV) by using AMOS. Analysing the relationships among lean manufacturing practices, environmental management and business performance outcomes, found that prior lean manufacturing experiences were negatively related to market and financial performance. However the improved environmental performance reduces the negative impact. Future research is required to develop multi dimensional environment performance measures which predict the market and financial performance better.

Miller et al (2010) integrated lean tools and sustainability concepts with discrete event simulation modeling and analysis as well as mathematical optimization to make a positive impact on the environment, society and its own financial success in a small furniture production company. Lean and green manufacturing have a more significant, positive impact on multiple measures of operational performance when implemented concurrently rather than separately and demonstrated the idea of optimization using discrete simulation with the three applications.

Fliedner (2008) identified some of the sustainable benefits from lean principles including reduction in material usage, energy consumption, hazardous waste, water usage, etc. Lean principles are aimed at waste reduction hence results in capital gain. The author concluded that sustainable benefits are also achieved through various lean tools.
Dennis & Clare (2005) applied the concepts of lean and sustainability in higher education. The authors developed the questionnaire and collected in 18 public and private universities and found that the focus in higher education is now on cost reduction or budget containment initiatives. The participating universities in this study shared their beliefs about how "lean" thinking can contribute to the sustainability of higher education. Other universities can "learn from their lessons".

2.4 IMPLEMENTATION OF LEAN IN MANAGEMENT

Herron & Hicks (2008) investigated the objective of NEPA (North East Productivity Alliance) to help companies improve productivity through applying lean manufacturing management practices and knowledge in the north east of England. The industry forum’s master’s class technology used to transfer technology into local companies. For the Technology transfer process Lill rank model was chosen. It has three stages in implementation. In the first stage, the abstraction of lean expertise from Japan, followed by its application at the Nissan (UK) surrender land plant and its dissemination to IF engineers. In the second stage, the abstraction from IF and Nissan (UK) engineers transfer it to NEPA engineers. The third stage involved in training of change agents to complete the final dissemination of lean methods into the companies.

However, NEPA helps the companies to improve productivity by applying lean practices and knowledge, the commitment of management and ability of change agents one key determinants of success. The outcome of each company was evaluated and summarized as follows:
Eight Companies were successfully achieved the technology transfer and attained continuous improvement.

Seven companies were unsuccessful in technology transfer because of management interventions and change in senior level staff.

The companies adopted NEPA programme significantly shows better performance and success in competitiveness.

Seddon & Caulkin (2007) contributed the systems thinking supports lean management though action learning. Two case studies are carried out illustrating the application of ideas behind the Toyota System for the service organization. In each case manager trained to learn how to take opportunity provided by a systems approach to design and management of work. The systems thinking claimed that lean management is a technique to understand by action learning as the ideas are counter-intuitive.

Panizzolo (1998) addressed the challenges posed by lean production principles for operations management. Challenges in operations management to implement lean production principles. An empirical case study was done on 27 excellent firms operating in international markets, exploring the difficulties and major problems incurred while implementing the lean production model. While implementing the lean principles, the most critical factor noted is the management of external relationships rather than internal operations. A research model based on empirical study has been developed to operationalize the lean concept. The lean production model was applied in 27 excellent firms operating in international markets.
The research methodology derived based on data collection on lean production from high-level managers of various firms through face to face structured interviews. The interview was structured covering the areas of process and equipment manufacturing planning and control, Human resources, product design, supplier relationships, customer relationships. The interviews were conducted to measure the degree of diffusion of the best practices by means of both objective and perspective measurements with the aim of understanding the various improvement programmes.

The empirical findings are obtained by analyzing the collected data. The firms are grouped into three groups based on characterization on a logistic relation and a partnership relation. The first group consists of 12 organizations named as flexible enterprises. These are lean enterprises has high level operational integration with suppliers and customers. The relationship with suppliers on the quality, reliability of the service, regularity and timeliness of deliveries are found honest.

The relationships with suppliers on product mix are flexibility and on the time required to customer orders from the buyer partners are clear. These group firms are has regular and fast flow of materials and reduction in total lead time.

The second group of Companies called network enterprises has eight Companies. These Companies has a high level of logistic relationship with customers and suppliers in addition, these firms developed a partnership relation with suppliers. It ensures the coherence of suppliers in all activities of firm towards excellence. This partnership relation keeps up the consistency with aims and skills of the supplier.
The third group of firms named as customer driven enterprises consists of seven Enterprises. These groups of organizations have partnership relation not only with suppliers and with customers also. They responded to the expectations and demands. They provide services to meet the needs and expectations of the customers and resolve their problems.

The challenges faced are how to integrate different organizations into value stream in order to ensure excellence into final products and services, and then how to integrate customers into organization. The future research to be carried out based on the empirical findings.

2.5 REVIEWS ON LEAN SIX SIGMA

Snee (2010) carried out a review on the evolution of lean six sigma to assess advancement over the last ten to fifteen years and the need for integration so as to carry out improvement. The origin of the two methodologies and the benefit of integrating the two approaches with a view on things that have gone right and things that have gone wrong so as to develop a framework for future. The holistic approach needs to be considered for incorporating improvements throughout the organization with emphasis on leadership to bring about the improvement in the business.

Zhang et al (2012) carried out a review on the literature work on lean six sigma from different perspectives. The literature was reviewed in context of lean six sigma and 116 papers were reviewed in this context. The analysis was carried out regarding the implementation of lean six sigma, area of application, industry wise, year wise focus areas and industries. The review revealed that lean six sigma is mostly implemented in health industry and the
future need for lean six sigma implementation in SME (Small and Medium Enterprise).

Hoerl & Gardner (2010) carried out a research work on relationship of lean six sigma with creativity and innovation. The review of literature on creativity and innovation revealed that these terms are not well defined and are generally used as "Buzzwords". The literature revealed that Lean six sigma drives creativity, but innovation can be incorporated by combining other approaches with Lean six sigma. Disruptive innovation aspect is considered as an approach along with Lean six sigma application with a healthcare case study.

Ray & John (2011) presented an application of lean tools for cycle time reduction six sigma projects in BPO (Business Process Outsourced) sector. The case study is considered for an Indian BPO working for a European financial services client in which the company was not able to meet the SLA (Service Level Agreement) due to variation in cycle times. The current problem was measured and analyzed by carrying out normality test of cycle time and then identifying improvement opportunities using a value stream mapping along with why-why analysis approach. Finally standard operating procedures along with regular audits were carried out to sustain the improvements.

Pamfilie et al (2012) proposed that leadership adopted by an organization may have a significant impact on the employees by validating the survey data. The data was collected for 120 service organizations via E-mails with a 23% response rate. Regression analysis was carried out for collected data for testing the hypothesis that there is a synergy between organization goal and lean six sigma, leader is an efficient communicator for
employee support and motivation and employee motivation increases during implementation of lean six sigma. The results suggested that leadership adopted by the organization will have impact on the employees.

Salah et al (2010) carried out a literature review on lean and six sigma, integrating lean and six sigma which complements each other, benefit of integrating the two approaches with emphasis on similarities and differences of the two approaches. It was concluded that all projects follow DMAIC (Design Measure Analyze Improve Control) and to apply proper lean tools as applicable to the problem. The author also emphasized on future research on validating the results using data and analysis.

Habidin & Yusof (2013) identified CSFs (Critical Success Factors) for LSS (Lean SIX Sigma) in the Malaysian automotive industry. SEM (Structural Equation Modeling) was carried out for testing the model for a sample of 252 Malaysian automotive organizations. Exploratory Factor Analyses (EFA), Confirmatory Factor Analysis (CFA), and reliability analysis showed that leadership and customer focus are the two most important factors for LSS implementation. The research work can be further extended for identifying other factors for automotive industry while generalizing structural relationship between LSS and organizational performance and for generalizing it to other industries.

Gibbons et al (2012) proposed VIM (Value Improvement Model) by applying holistic lean and six sigma approach for aligning the resource bundles for value enhancement of repetitive process with a case study of inter terminal shuttle transportation system. SIPOC (Supplier Input Process Output Customer) cycle and shuttle value analysis was carried out for current process and a future state VIM map was formulated. Hypothesis testing was carried
out to analyze whether the number of alarm events are dependent on period of analysis for individual cars and system.

Hardeman & Goethals (2011) used DMAIC process to improve the efficiency of a shimming process for airfoil extrusion process by conducting stakeholder analysis, and applying lean tools like cause and effect diagram and integrating with six sigma tools like FMEA (Failure mode and Effect Analysis) and CTQ (Critical-to-Quality) scorecard. The improvement resulted in product defect rating to be reduced by 94% and improvement in six sigma rating from 0.868 to 3.207.

Duarte et al (2012) developed a structured approach for lean six sigma project identification. The approach applies clustering approach to group similar process based on seven process characteristics. The clustering is then evaluated for its application. The future research can be carried out by incorporating current process performance and use of the model in conjunction with balanced scorecard model can be explored.

Bailey et al (2012) demonstrated how lean and six sigma were integrated for a US aerospace company by initiating strategic intent, improving learning capacity, cultural change, information technology and knowledge sharing, co-operation through network relationships, change management and process management practices. The lessons learned during the implementation can be further used by other companies for implementing LSS in their companies.

Gibbons et al (2010) proposed a methodology which uses a new method along with OEE (Original Equipment Efficiency) for measuring lean six sigma capability at plant and process levels by employing an action
research approach. The OEE approach incorporates process capability, asset management effectiveness and gross process throughput so as to develop a modified framework. The proposed framework was applied to an aerosol and valve manufacturing company for an injection molding process in which an OEE improvement from 40% to 85% was achieved in three months time period.

Cheng et al (2012) applied lean six sigma approach to a NPO (Non-Profit Organization) so as to enable self-support to these organizations. A case study was used to demonstrate the applicability of the study by use of Lean Six Sigma tools and principles to increase the efficiency of managing resources for an enterprise manufacturing devices for physically disabled. A small machining shop that repairs, produces and customizes devices for the physically disabled was selected as the NPO. The goal was to make its production process more efficient by use of DMAIC approach along with lean tools, which decreased the non-value-added process by 70%. The lessons learnt from implementing the lean six sigma is also focused in context of NPOs.

Karthi et al (2012) used an integrated model of Lean Six Sigma and ISO 9001:2008 standard based QMS, L6QMS-2008 for a textile mill. The ISO 9001 has been implemented in textile industry as a part of QMS (Quality Management System). The textile industry has also started implementing other lean tools in a sequential manner. Although, an integration of lean six sigma and ISO standards were proposed, but case studies are not available in this context. The study was carried out for a textile mill and it resulted in an annual savings of 2 million INR.
Shah et al (2008) used implementation and performance data from 2511 plants and analyzed associative and predictive patterns for 15 lean practices and six sigma programs. The results indicated that implementation of lean subsequently results in implementation of six sigma and plants which incorporate quality management can be used to differentiate between plants that implement six sigma from those which does not implement.

Kumar et al (2006) proposed a Lean Sigma framework to reduce the defect occurring in the final product for an automobile accessories manufactured by a die-casting process. The proposed framework integrates Lean tools such as current state map, 5S work place organization, and Total Productive Maintenance (TPM)) along with Six Sigma DMAIC approach to attain operational objectives and in turn also satisfying the customer. The framework was implemented and resulted in drastic improvement in performance measures such as defect per unit (DPU), process capability index, mean and standard deviation of casting density, yield, and overall equipment effectiveness (OEE). The organization also benefited by generating substantial financial gains as a result of implementing the integrated framework.

Vinodh et al (2012) developed an integrated lean sigma framework to reduce the defects occurring in the final product, thereby resulting in savings to the organisation. The proposed framework integrates lean tools within six sigma methodology to improve the operational measures and to satisfy the customer needs. The implementation of the proposed framework shows dramatic improvement in performance measures and also resulted in generating substantial financial gain.
Hu et al (2008) proposed a unique decision support system that utilizes a multi-objective formulation for project portfolio selection problem in manufacturing companies. The formulated model integrates Lean and Six Sigma concepts for effective implementation. The suitability of the integrated model is demonstrated with an industrial case study that applied the model for implementing the Lean and Six Sigma approach.

Vinodh et al (2011) developed a refined concurrent approach by integrating lean manufacturing to eliminate the wastes and six sigma methodology for reducing the defects. Direct Lean sigma framework is not effective as there is a lack of systematic and scientific management and weak integration of lean with six sigma. The approach was applied and implemented in an Indian valve manufacturing organization and substantial benefits were obtained as a result.

Gnanaraj et al (2012) developed a model based on Lean Six Sigma for successfully implementing it in small and medium engineering enterprises (SMEs). The model known as Deficiency Overcoming Lean Anchorage Define Measure Analyse Improve Control Stabilise (DOLADMAICS). The designed DOLADMAICS model was proposed to lift up an SME through the implementation of Lean Six Sigma in five levels. The implementation study of first level of DOLADMAICS model was conducted in an Indian SME, manufacturing cylinder frames component. After the successful implementation of the study, it was found that the first level of DOLADMAICS model would act as a driving enabler and render the management of SMEs to successfully implement Lean Six Sigma proposed model.
Wang et al (2012) applied Lean Six Sigma (LSS) approach along with Soft systems methodology (SSM) as a tool during the improvement phase to enable accurate forecasting the manufacturing costs for a flat panel display equipment manufacturer. SSM was selected on account of its problem-solving methodology and suitability for complex problems with due importance given for a participative process where knowledge and outcome can only be gained through discussions. The purpose of the discussion is to reach a consensus which will be accepted by everyone. The outcome demonstrated that the application of integrated LSS approach with SSM resulted in improving effectiveness of both the direct manufacturing as well as support activities.

Al-Aomar (2012) developed a practical framework of lean construction by complying along the guidelines of project lean delivery system developed by the Lean Construction Institute (LCI). The approach integrated lean techniques and Six Sigma rating into the developed framework. The approach was applied by defining performance measures by setting benchmark values and then suggesting the improvement actions. Wastes identification a case industry in Abu Dhabi revealed that there are 27 wastes, out of which defects i.e. errors and corrections are found to be the most common type of construction waste. Lean project management has been developed with a set of key performance indicators (KPIs), which were assessed at the end of each period for future. Lean tools were used initially and then Sigma Rating is assessed at the end of the period along with other KPIs. The proposed LSS-KPIs along with sigma ratings resulted in measuring the outcome and suggesting future improvements.

Sarkar et al (2013) presented an application of Lean Six Sigma approach for claim settlement cycle time reduction in the insurance sector.
The approach integrated statistical aspect of six sigma with the analytical approach of lean methodology. The study identified the sub processes for improvements by use of SIPOC for claim settlement process and then conducting performance analysis of process times. The improvement actions were suggested by using lean tools like pareto chart for identifying the reasons and Process FMEA (Failure Mode and Effect Analysis) for suggesting solutions for improvement. The implementation of suggestions resulted in increase from 3 to 95 per cent for compliance with respect to the deadline of 30 days for claim settlement.

Gremyr et al (2012) integrated DFSS (Design for Six Sigma) and LPD (Lean Product Development) to attain improvements in quality by reducing unwanted variation, while at the same time being able to increase flow and speed in the development processes. The study involved conducting interviews at seven companies that either use DFSS or LPD. The interviewees were selected in such a manner that they were a part of the company’s internal expertise in the use of these methods, such as Master Black Belts in DFSS and project leaders for LPD implementation. The study showed the potential of merging the two approaches could prove important in guiding the structure as well as content of improvement for both incremental and radical efforts, by giving due importance to the prevalent industrial practices.

2.6 INTEGRATION OF LEAN AND AGILE MANUFACTURING

Plonka (1997) examined the contribution that human factors practitioners can make to improve work force capabilities in the lean and agile manufacturing environments. The author addressed the demands that lean and agile manufacturing initiatives will place on the current and emerging work force to achieve increasing levels of quality and flexibility with lower costs
and shorter product life cycles. The issues of worker selection, continuous skill development, work place design, equipment maintenance, process improvement, mistake proofing, and process reconfiguration for new products are discussed from a human factors perspective.

Prince & Kay (2003) described the need for combining agile and lean characteristics in manufacturing organizations. They also described the development of the virtual group (VG) concept, which is the application of virtual cells to functional layouts. VGs enable the appropriate application of lean and agile concepts to different stages of production within a factory. The identification of VGs is achieved through the use of a methodology called enhanced production flow analysis (EPFA), which is described together with how it differs from Burbidge’s PFA. Finally the results of two case studies are presented which tested the ability of EFPA to identify VGs, and assess its usability.

Elmoselhy (2013) hydrided the lean and agile systems together are technically valid and can be implemented in an industrial setting. Lean strategies could increase competitiveness and profitability by reducing manufacturing costs. Concurrently, agile strategies could enable enterprises to cope with fluctuations. A hybrid lean–agile approach can be an optimal strategic blend for a manufacturing enterprise to meet this challenge. This study showed how strategically a hybrid lean–agile system can be implemented. It also shows that about one third of the variation in successfully dealing with the sources of competitive advantage in automotive industry can be explained by adopting the technical facet of the hybrid lean–agile manufacturing system.
Towill & Christopher (2002) described lean and agile principles are contrast according to the requisite business strategy via a time-space matrix. Still they tried to reunite the two paradigms through a case study. Also they highlighted the fundamental requirements of a supply chain for combining lean and agile manufacturing.

Naylor et al (1999) showed the possibility of combining the lean and agile manufacturing principles. The use of either paradigm had to be combined with a total supply chain strategy particularly considering market knowledge and positioning of the decoupling point as agile manufacturing is best suited to satisfying a fluctuating demand and lean manufacturing requires a level schedule. This view is supported by consideration of a PC supply chain case study.

Riezebos & Klingenberg (2009) discussed the various role of information technology in advancing lean production. Lean principles and techniques have been applied in a wide variety of organizations, from make-to-stock to engineer-to-order industries, and even in typical service sectors, such as healthcare. In order to apply lean principles in various areas, variants were developed of well known techniques, such as Kanban, Kaizen, SMED, and 5S. IT is used to develop such variants. Over the years, the role and use of IT in the application of the lean principles has changed.

### 2.7 INTEGRATION OF LEAN AND EMS

Salleh et al (2012) proposed Green LTQM IM framework established in this study based on the result obtained is believed to offer preliminary insight on the status of level in IM. Green Lean Total Quality (GLTQ) Information Management System is a system comprised of
Information Management (IM) in Environmental Management System (EMS) practices which is integrated to TQM with Lean Manufacturing (LM) principles. IM is essential especially in dealing with communication breakdown problems and ineffective communication system. The ultimate goal of this system is to focus on achieving total communication efficiency that uses Green and Lean TQM System. Knowing their level, the companies can embark on new journey to enhance their IM. The proposed framework is a synergy of 4 awards practices and 5 systems which were integrated in the questionnaires. Future study can be conducted to access the status of IM in other companies and extended to other industry.

Lean production and environmental management systems (EMSs) are fundamentally different business initiatives. Yet recent research suggests that the two approaches can be both compatible and synergistic (Jennifer Tice et al 2005). Organizations have much to gain from properly aligning and integrating their lean and environmental management practices. Jennifer Tice, Lori Ahouse, and Tim Larson, 2005 discussed various aspects namely overview of lean production and how it relates to environmental performance, along with a brief discussion on the benefits of EMS adoption. Then summarizes key conceptual similarities and differences between lean and EMSs. Then findings on lean production and EMSs were discussed, including how lean and EMS efforts can complement and add value to each other. Finally, they suggested the strategies to improve environmental performance through lean and EMS integration.

Yang et al (2010) explored relationships between lean manufacturing practices and environmental management. The hypothesized relationships of this model are tested with data collected from 309 international manufacturing firms (IMSS IV) by using AMOS. The findings
suggest that prior lean manufacturing experiences are positively related to environmental management practices. Environmental management practices alone are negatively related to market and financial performance. However, improved environmental performance substantially reduces the negative impact of environmental management practices on market and financial performance. The empirical evidences with large sample size that environmental management practices become an important mediating variable to resolve the conflicts between lean manufacturing and environmental performance.

Jabbour et al (2013) studied the influence of Environmental Management (EM) on Operational Performance (OP) in Brazilian automotive companies, analyzing whether Lean Manufacturing (LM) and Human Resources (HR) interfere in the greening of these companies. For this, three hypotheses were presented. The data, collected from 75 companies based on questionnaire prepared, were analyzed using structural equation modeling. The main results are as follows: (a) the model tested revealed an adequate goodness of fit, showing that overall, the relations proposed between EM and OP and between HR, LM and EM tend to be statistically valid; (b) EM tends to influence OP in a positive and statistically weak manner; (c) LM has a greater influence on EM when compared to the influence HR has over EM; (d) HR has a positive relationship over EM, but the statistical significance of this relationship is less than that of the other evaluated relationships.

2.8 INTEGRATION OF LEAN AND SUSTAINABILITY

Pham et al (2009) defined manufacturing fitness as the combination of lean and agile in consideration with sustainability. In order to compete in this environment, there should be a clear integrated strategy that removes the
competing issues of lean agility. That strategy should combine these concepts into one business approach. Companies should now look at becoming fit.

Hajmohammad et al (2013) developed a conceptual model proposes that the magnitude of environmental practices mediates the relationship between lean and supply management with environmental performance. Prior research suggests that lean management and supply management are potentially important determinants of environmental performance and can be seen as capabilities that ease the adoption of environmental practices. To test the model, plant-level survey data from a sample of Canadian manufacturing plants is used. The results indicate that supply management and lean activities provide means by which resources are invested in environmental practices. The empirical analysis also confirms that the impact of lean management, and to a lesser extent supply management, on environmental performance is mediated by environmental practices.

Pampanelli et al (2013) presented an integrated lean and green approach that results in (i) a reduction in production waste and (ii) a reduction in environmental impact. The purpose of lean thinking is to promote continuous improvement culture within a business. Lean thinking considers the expenditure of resources, for any goal other than the creation of value for the end customer to be wasteful. There has been much anecdotal evidence suggesting that a lean approach can help make the case for environmental impact reduction to businesses. In this model, we integrate environmental sustainability into pure lean thinking. The model presented in this paper adopts a Kaizen approach to improve mass and energy flows in manufacturing environments that already possess the necessary deployment level to apply lean thinking. The findings confirm that the Lean & Green Model can reduce resource use from 30 to 50% on average and has the
potential to reduce the total cost of mass and energy flows in a cell by 5 to 10%.

Miller et al (2010) integrated lean tools and sustainability concepts with discrete event simulation modeling and analysis as well as mathematical optimization to make a positive impact on the environment, society and its own financial success. The implementation of lean and sustainable manufacturing was aided by the use of discrete event simulation and optimization to overcome deficits in lean’s traditional implementation strategies. Lean and green manufacturing can have a more significant, positive impact on multiple measures of operational performance when implemented concurrently rather than separately. These ideas are demonstrated by three applications.

Aguado et al (2013) proposed a general approach, based on environmental innovation, to help firms harmonize efficiency and sustainability. Globalization has changed the world as well as how a customer judges the value of a product, which has created a new business focus. Different approaches have been oriented on this direction, such as the lean manufacturing system and the concept of sustainability. The goal of this study is to add extra value to the product, which provides the potential to enhance competitiveness in the 21st century globalized market. A case study demonstrates that the costs, the incomes, the social responsibility and the sustainability can be improved when environmental innovation is applied, transforming the traditional production system into a lean system.

Bergmiller & McCright (2009) tested the results of combining lean practices and green principles. Companies have implemented Lean Manufacturing Programs which yield increased efficiency, reduced costs,
improved customer response time, and more. Others have adopted “Green” Programs resulting in reduced energy consumption, waste generation, and hazardous materials usage. Models for both Lean and Green systems all include management systems, waste identification, and implementation of waste reducing techniques (WRT) to achieve desired business results. This has been conducted in company which correlated lean practices and green principles this study confirms that result, Lean and Green Programs lead to improved business results.

2.9 INTEGRATION OF LEAN AND ISO STANDARD

Russell V. Thornton described the relationship between lean manufacturing and ISO 14001 principles. The main focus is to describe how things will play out as organizations use ISO 14001, lean manufacturing, and new transportation methodology to meet their goals and remain competitive. The article covers various aspects of lean manufacturing, transportation issues and finally the role of ISO 14001 in a manufacturing firm. ISO 14001 can help ensure that “better” includes a better environment with fewer negative impacts

Chiarini (2011) defined a guideline for integrating ISO 9001 and lean thinking. It seeks to cross-reference the guideline presented with ISO 9001 requirements and to integrate parts of the standard text with lean principles and tools. Over the past nine years, a group of consultants has been collecting data and information from 107 manufacturing companies around Europe. The companies have been chosen from different European countries and they are of different sizes. All the companies are ISO 9001 certified and at a “mature” stage of lean implementation. It is found that in general, lean thinking implementation affects documentation such as quality manual,
procedures and work instructions. Furthermore, tools and principles such as value stream mapping, lean metrics, 5S and takt time are the most used inside the 107 companies. Jidoka and total productive maintenance are those that have been more formalized into ISO 9001 documents.

Granly & Welo (2013) presented a study to extend current knowledge on manufacturing small and medium sized enterprises’ (SMEs) experiences with the implementation of the alternative environmental management system (EMS) Eco-Lighthouse, and to compare this with that of ISO 14001 adoption. The study seeks a deeper understanding of the drivers, challenges and outcomes that are related to the implementation of EMS models through semi-structured, in-depth interviews with nine Norwegian manufacturing SMEs that are ISO 14001 or Eco-Lighthouse certified. The findings indicate that market benefits and cost reduction are the key drivers for the Eco-lighthouse, while customer pressure and improved environmental routines pull ISO 14001 certification.

A higher level of customer pressure for EMS favours ISO 14001 adoption over Eco-Lighthouse adoption. While Eco-Lighthouse certification is challenged by a low realisation of market benefits, the challenges that relate to employee buy-in, competence and time are more prominent for ISO 14001 adoption. While similar sustainability practices were identified within all of the studied companies, the ISO 14001 certified companies were more systematic and formal in their identification and management of environmental improvements.
2.10 REVIEWS ON LEAN SUPPLY CHAIN

The fundamental principle of lean supply is that the effects of costs associated with less than perfect execution of a sub-process are not limited to the location of the execution. This is a fundamental point, since lean supply does not recognize the traditional positions of customer and supplier, which tend to obscure the central quest for the removal of waste. In this way, the lean suppliers will ensure that their value is transferred to the end consumer in the most efficient way, thus ensuring their survival.

Lamming (1996) in lean supply, the entire flow from raw materials to consumer is considered as an integrated whole. Interfaces between stages (i.e. between companies – suppliers and customers) are thus seen as artificial – created not as natural transformation stages in the development (or addition) of value, but as a result of the economic arrangement of assets (boundaries of firms) governed by many other factors (e.g. labour skills, convenient configurations of technology, geographical location of raw materials, etc.).

Goldsby & Griffis (2006) tried to further the understanding of lean, agile, and hybrid (or so called “leagile”) supply chain strategies, with particular interest directed toward the dynamics and trade-offs associated with each of the strategies. This objective is achieved by operationalizing the three strategies in a real-world case setting. Simulation research is used to examine the operationalization of the different strategies and to measure the respective performance associated with each, identifying the similarities and differences among strategic inputs and outcomes.

Agarwal et al (1999) defined best supply chain is one which adapts the changes if it is flexible and agile in nature. For this, the authors developed a framework, which encapsulates the market sensitiveness, process
integration, information driver and flexibility measures of supply chain performance. The author also explores the relationship among lead-time, cost, quality, and service level and the leanness and agility of a case supply chain in fast moving consumer goods business. The paper concludes with the justification of the framework, which analyses the effect of market winning criteria and market qualifying criteria on the three types of supply chains: lean, agile and leagile.

Bruce & Daly (2004) discussed characteristics of the textiles and apparel industry and identifies the perspectives of lean, agile and leagility (a combination of these) within existing supply chain literature, which have been proffered as solutions to achieving quick response and reduced lead times. The textiles and apparel industry has been neglected in terms of supply chain management research. Recently, the industry has undergone a great deal of change, particularly with global sourcing and high levels of price competition. In addition, textiles and clothing has market characteristics, such as short product lifecycle, high volatility, low predictability, and a high level of impulse purchase, making such issues as quick response of paramount importance. Through case studies of textile and apparel companies, importance and different approaches to supply chain management are illustrated.

Cagliano et al (2004) empirically explored the supply strategies of European manufacturing firms within the third edition of the International Manufacturing Strategy Survey. Four clusters are identified on the basis of the supplier selection criteria and the integration mechanisms adopted. Two clusters are similar to the Lean and the Agile models, while the other two are more traditional supply strategies, even if they present some advancement compared to the arm’s-length supply model. The strategies are then described
in terms of contingent and structural factors and manufacturing performance. Lean and Agile strategies outperform the other clusters on many dimensions, while no significant difference emerges between the two in terms of performance.

Stratton & Warburton (2003) explored the role of inventory and capacity in accommodating such variation and identifies how TRIZ separation principles and TOC tools may be combined in the integrated development of responsive and efficient supply chains. Lean operations depend on level scheduling and the growing need to accommodate variety and demand uncertainty has resulted in the emergence of the concept of agility. A detailed apparel industry case study is used to illustrate the application of these concepts and tools.

Naylor et al (1999) showed the possibility of combining the lean and agile manufacturing principles. The use of either paradigm has to be combined with a total supply chain strategy particularly considering market knowledge and positioning of the decoupling point as agile manufacturing is best suited to satisfying a fluctuating demand and lean manufacturing requires a level schedule. This view is supported by consideration of a PC supply chain case study.

This article reports a study conducted in Livonia Modular Strut Department for the implementation of Delphi Chassis Systems established a Manufacturing Systems Core Team to develop a production system for automotive component applications. The production system will provide the foundation required for manufacturing to exceed any customer requirement. In order to accomplish the development of a production system, global best practices had to be benchmarked and implemented in a pilot manufacturing
area. The production system concepts of Project Management, Process Flow, Layout, Material Flow, Ergonomics, Workplace Organization, People-focused Practices, and Supporting Software. The new production system was 25% more productive than the original build cell production method. The proposed modifications will allow a 50% production improvement to the current monorail system (Mabry & Morrison 1996).

Shah & Ward (2003) examined the effects of three contextual factors, plant size, plant age and unionization status, on the likelihood of implementing 22 manufacturing practices that are key facets of lean production systems. Further, we postulate four “bundles” of inter-related and internally consistent practices; these are just-in-time (JIT), total quality management (TQM), total preventive maintenance (TPM), and human resource management (HRM). We empirically validate our bundles and investigate their effects on operational performance. The study sample uses data from Industry Week’s Census of Manufacturers. The evidence provides strong support for the influence of plant size on lean implementation, whereas the influence of unionization and plant age is less pervasive than conventional wisdom suggests. The results also indicate that lean bundles contribute substantially to the operating performance of plants, and explain about 23% of the variation in operational performance after accounting for the effects of industry and contextual factors.

Abdulmalek & Rajgopal (2006) described a case where lean principles were adapted for the process sector for application at a large integrated steel mill. Value stream mapping was the main tool used to identify the opportunities for various lean techniques. We also describe a simulation model that was developed to contrast the “before” and “after” scenarios in
detail, in order to illustrate to managers potential benefits such as reduced production lead-time and lower work-in-process inventory.

2.11 LEAN ASSESSMENT IN INDUSTRIES

Amaia Sopelana et al (2012) investigated the following objectives:

1) Provide first insights of the successful validation of the SMART assessment tool in companies.

2) Summarize the results of study which evidences difficulties and best practices in regards to the implementation of lean practices in product development.

Developed a novel maturity, model and assessment tool called SMART as a part of lean transformation kit (Lean ‘12) and applied in companies and studied. SMART helps to give insights and how to get over difficulties raised during the implementation of lean product development in the companies. It enables the companies to understand and identify the main lean practices to adapt and achieve a lean product development process. A larger study is needed for a lean PD implementation with too many constraints.

Vinodh & Chintha (2011) assessed the leanness of an organization using multigrade fuzzy approach. A leanness measurement model with multigrade fuzzy approach was designed. The substitution data were collected from a case industry. After the computation of leanness index, the areas for leanness improvement are identified. The leanness measurement model incorporated with multigrade fuzzy approach can be used as a kit for periodically evaluating the organizations leanness. More case studies should
be carried out for different organizations to improve the practical validity of the model.

Niu et al (2010) considered the Lean production as third production paradigm. Forward a reasonable improved definition to lean production base on related references and apply set pair analysis to assess leanness degree. A case study was done to show this model’s feasibility. LP has been proved as scientific production paradigm but its application in china is less due to lack of universal definition and proper assessment tool. This paper provides one improved definition with LP’s main traits and introduced SPA to measure leanness. Future research is required to assess leanness, flexible to different industries.

Allen & Laure (2006) overviewed the concepts and tools of process improvement of six-sigma and lean manufacturing. Lean sigma is a new methodology which combines the disciplines of lean manufacturing process improvement and six sigma process improvement to get the benefits of each discipline. Both stresses for meeting customers’ needs and delivering products without defects. Lean manufacturing principles by eliminating the wastes, reduce lead time and lower total costs whereas six sigma techniques focuses on reducing variation in processes and product and eliminating rework and ensures the faster delivery time and reduction in total costs. The activities that fall in domain of test, modeled as processes. Process improvement is a process that helps organizations deliver better product at an economic price and quickly, using the concepts and tools of process improvements of six-sigma and lean manufacturing. The combining of lean and six-sigma provides a complete tool set for process improvement. The Training-Within-Industry (TWI) training program provides a model for training people in industry with lean manufacturing and Kaizen and lean six-sigma.
Doolen & Hacker (2005) described the development of survey instrument to assess the implementation of lean practices in an electronic manufacturer industry. The exploratory study was conducted by mailing pre letters to companies engaged in electronics part manufacturing. The letter containing the detailed questionnaire of survey, the obtained replies were analysed. The exploratory study established that implementation of lean practices subject to certain significant factors are organizational size and the type of manufacturing. Future research is required to study significant differences between all sub categories of organizations on implementation of lean practices.

2.12 IMPLEMENTATION OF LEAN IN DECISION AND ANALYSIS PROBLEMS

Rivera & Chen (2007) discussed the expected impact of lean implementation on CTP and CTI. A CTP is a graph shows the accumulated costs that have been expended during the manufacturing of a product at every time unit during the process. The area under CTP is the cost-time investment (CTI), denotes how much money tied up in manufacturing process and for how long before being recovered through sales. In the manufacturing process of a product the reduction of CTI is considered as desirable improvement. It can be achieved through reducing the cost of materials, releasing materials just in time for manufacturing process, reducing the waiting time or idle time and reducing the cost of activities. A case study was carried out in implementation of lean tools and techniques on the CTP (Cost-Time-Profiles) and on the CTI (Cost-Time-Investment) and evaluated and justified. The impact of lean implementation noticed on CTP and CTI are as follows:
The first wave of lean implementation is focused on reduction of waiting time by coupling of dedicating equipments towards production of specific families. Group technology, cellular manufacturing etc. are utilized to attain this.

The second wave of lean implementation is focused on improvement and standardization of internal processes, Standard Work, SMED, Jidoka and TPM are used to improve the processing times and practices and resulted in reduction in processing times and production costs.

The third wave of lean implementation insisted to implement pull systems in manufacturing to attain further reduction in waiting time. It improves the reduction in inventory between operations and WIP inventory at minimum level.

The fourth wave of lean implementation, ensures the evenly distribution of materials among machines by introducing JIT practices in manufacturing processes.

The achievements on these improvements using CTP and CTI resulted in highlighting the economic consideration. The VSM access to visible the time products spent on the production systems and helps to identify and eliminate idle time and non-value added time because the time dimension in manufacturing is prime factor in determination of costs.

Sullivan et al (2002) illustrated an equipment replacement decision problem within the context of lean manufacturing implementation. The industries which are maintaining high volume batch and queue manufacturing
process with help of large machines. These machines are difficult to align with lean Work Cells and not able to devote to the production of a family of products. By eliminating monuments and investing new smaller machines would be an issue to the managers. So it is necessary to abandon high-volume monolithic machines for the sake of implementing lean principles and inducting cellular manufacturing systems.

The analysis was carried out in two aspects, quantifying the economic benefits associated with lean manufacturing and economic trade-offs arise from a decision replacing a high-volume transfer line by Work Cells.

VSM used to map the current state of a production line and design a desired future state. It provides necessary information for analysis of equipment replacement decision problems. VSM helps managers to visualize to source of wastes in LSM and potential benefits that can be achieved in implementing a future state for a product value stream and more easily conduct equipment replacement analysis in adoption of lean manufacturing. As looking into the sources of waste in current state and potential benefits realized in implementing a future state for a product value stream helped to take a decision on disposing of transfer machines and introduce cellular manufacturing for the cause of implementing lean manufacturing. This research can be extended on other types of capital investments, beyond traditional processing equipment.

2.13 IMPLEMENTATION OF LEAN TOOLS/TECHNIQUES

Michalska & Szewieczek (2007) illustrated the way of implementation of 5S methodology in a company. The implementation was
carried out in a Polish company. The study was conducted in a production process, where the workers were introduced with 5S and control questions were asked. An inspection was conducted using a checklist. The outcome of the study was that the implementation of 5S methodology is beneficial in following ways: costs reduce and thereby improvement in process can be brought, effectiveness and efficiency of the processes can be increased, machines’ efficiency can be improved, increased safety, reduced pollution and proceedings can be done according to decisions. Essentiality on training the employees and also continuous improvement of the 5S methodology were to be addressed.

Khamis et al (2009) aimed at assessment of 5S implementation also the development of 5S activity checklist in manufacturing companies. The study was conducted using a systematic approach with specific software to get the accurate results. 5S checklist was prepared and audits were conducted in two organisations based the level of information that can be obtained by the organisation. Their level of quality system is evaluated. The study showed that the effectiveness of 5S activity in an organisation depends on the level of commitment from the top management, employee involvement, business background, importance given for the implementation of 5S and the training given for 5S implementation in the organisation. The obstacles for the implementation of 5S, such as communication gap between the top management and shop floor employees, lack of consciousness have to be fully understood and addressed.

Ananthanarayanan (2006) addressed the necessity of establishment of quality management system for the improvement of layout planning for NDT laboratory. The study discussed the implementation process which involved the steps as follows: visual inspection followed by formation of a
task team, plan implementation, announcement of the program and finally evaluation of results. The study discussed the benefits as to be wastage reduction, laboratory being organised in a customer friendly manner, improvement of health and safety and ease of data management.

Naufal et al (2012) showed that the implementation of Kanban system improves the manufacturing system and also helps in practice of just in time. They gathered production parameter and forecast demand based on the condition of manufacturing process line. Takt time of process line was defined using the data. Kanban was calculated with all the relevant data and finally the pull mechanism and rule were established. The implementation of Kanban system at a manufacturing firm in Malaysia synchronised the manufacturing pace with the market demand. Smooth flow of the part throughout manufacturing system was created. The process showed reduced lead time, reduced in process and finished goods inventory. The study suggested Kanban to be part of the core task of JIT practitioner.

Lambert et al (1998) focused on overcoming the problems in implementation of JIT by small sized manufacturing firms. The main obstacles were scarcity of material and human resources, high employee turnover, lack of influence over suppliers etc. The study proposed two strategies. A new structure of the enterprise was given for its products to be simple and flexible to work with. The second one was a project management approach for production planning which kept the number of projects at manageable level. The study discussed the benefits to be the increase in productivity and quality and the reduction in lead time from six months to less than two months. The study suggested the usage of step by step midterm improvement strategy. It also suggested the training of foremen and new employees to bring about improvement in the performance of the company.
Tardif & Maaseidvaag (2001) developed an adaptive system of Kanban which was easy to be implemented and also outperformed traditional Kanban pull control mechanism. The performance evaluation of a single-stage, single product Kanban system was conducted where the arrival of demands were poison distributed and processing times were exponential random variables. The proposed system of Kanban pull mechanism was ahead of the traditional one even with the simple set of releases and capture rules. The study conducted was to be extended to assess the impact on adaptive systems on multi stage, multiproduct systems and capacitated systems with varied capacities and also machine failures and repairs.

Arbulu et al (2003) proposed the strategy for effective material management functions with least waste. Unnecessary inventories and processing time, waiting time and physical waste were the identified wastes. The strategy involved the use of supplier Kanbans to signal the need for replenishment of selected products from preferred suppliers to the site. A combination of lean and material management techniques together to create value to the final customer was illustrated. The study stated the need to rationalise the stock profiles during the implementation phase of the strategy. The study suggested the individual companies and their supply chain partners to adapt the Kanban strategy to their scenario and using their specific processes and project data.

Farris et al (2008) found from the literature of organisational learning, that the understanding of less successful Kaizen events is necessary for organisational learning. They demonstrated how less successful Kaizen events contribute to organisational learning. The organisations were interviewed on its Kaizen event program. Four instruments were used to collect data for the study; two were completed by team members, one by log
of team activities and one by the facilitator of the event. In addition to these instruments organisational documents were collected. Further qualitative data were used to explain conclusions drawn from quantitative data. Interpretation of team success and identification of obstacles to team’s success were done. The study showed that identification of the key variables that influence event success helped organisation to develop mechanisms that can take control over the variables that influence Kaizen event. The scope of the study was limited to description of interpretation of team’s success and identifying obstacles to team’s success, but the above mentioned instruments were not presented.

Teplicka & Culkova (2011) focused on decreasing of cost during the process of maintenance in concrete firm by Kaizen method. Inefficiencies of processes resulting in high cost for maintenance were identified. Goal values were set and were compared with the present values which were achieved after implementation of Kaizen. Corrective measures were suggested. The study showed that using of Kaizen brings improvement in firms mainly by increasing quality, improving productivity, decreasing stock, shortening production line, shortening loss time and shortening production period.

Lyu (1996) proposed a framework for integrating Kaizen and automation to reengineer a manufacturing process. The framework included eight stages and a PDCA cycle for continuous improvement efforts. The sequence of activities involved in process reengineering were – envision the future of the company, organise team and set goal, examine existing process, identify process reengineering opportunities and current capability, design new process, implement the new process and modify infrastructure, measure the performance, standardise the new process. A visual interactive simulation model was created for the case study. The study concluded that an animated simulation model was an important step during process redesign. The study
also showed that labour productivity can be doubled with a streamlined manufacturing process. The study suggested having decision support for simulation modelling since managers and engineers of the pipe shop where the case study was conducted feel it difficult to design and implement simulation model.

Scyoc (2008) adapted quality management tools for process safety improvement. It also explored how tools intended for product quality applies to continual improvement of process safety. Instead of applying tools concerned to the relative field, tools from different arena were chosen. Kaizen, Poka Yoke and TRIZ (theory of inventive problem solving) were adapted and process safety improvements achieved due to them were addressed. The study concluded that product quality improvement tools have significant effect on the improvement of process safety. The study discussed the effect of quality improvement tools over the process safety improvement while there is no tool developed for process safety alone. Process safety improvement tools can be developed or the quality tools used have to be assessed and modified for getting benefits.

Radharamanan (1996) applied Kaizen in a small-sized custom-made furniture industry to achieve higher quality, lower cost, higher productivity were achieved while meeting the customer requirements. The comparison between the Kaizen and innovation characteristics with respect to various factors that affect firm’s performance was carried out. Thus the Kaizen implementation was justified over innovation. A cause and effect diagram was used to find the root causes for problem by which the causes for problem of enterprise were listed. A brainstorming session was conducted with the employees. Suggestions for improvement were given at the end. The study
discussed the benefits of implementing Kaizen to be achieving of better position in competitive market, generating profits and minimising costs.

Chan et al. (2005) aimed at evaluating the effectiveness and implementation of TPM in an electronic manufacturing company. The study began with a case study where the company background details were collected. The stages of TPM implementation were as follows: Establishment of TPM organisation, organisation of TPM office, introductory education and campaign, setting the policies for TQM, creating the master plan for TPM development, TPM kick off, establishment of system for production efficiency improvement. The study revealed the following changes observed after TPM implementation:

1. Effective equipment management: equipment productivity rate was improved, equipment stoppage rate was reduced. Effectiveness and quality in production was observed.

2. Empowerment of employees: The work environment became more creative, bright and relaxed. Promotion of cross functional team created enthusiastic workforce helping the company to be more competitive.

The study suggested the adaptation TPM technique to the whole production area as it was limited to only model equipment in the study. It also suggested including factors such as training with tangible TPM achievement result, resources management, reliability central maintenance (RCM) in preventive maintenance system.
Chand & Shirvani (2000) proposed in their study that total productive maintenance is linked to total quality management and continuous flow manufacturing or cellular manufacturing. They demonstrated how OEE is achieved with establishment of TPM. They recommended a pilot project where a TPM program can be conducted in a cell and further it can be extended to all factory cells.

Sun et al (2003) recorded the primitive implementation and evaluation of TPM in the advanced manufacturing environment of a Hong-Kong manufacturing company. The implementation process started with selection of a model machine. Members were chosen for TPM teams. Policies and targets were set for the model machine as well as the team activities. Finally, how the goals were achieved through implementation TPM was described. The implementation of TPM was found to be successful for the Honk-Kong based company. The aspects which contributed to the success were: Management commitment, employee commitment, and training of employees, selection of the right team members, proper training materials and human resources. The study was restricted to one company which was Hong-Kong based and it was suggested for other companies to consider their own special situations.

Singh et al (2013) discussed the implementation of total productive maintenance and benefits of implementing TPM in an automotive industry. Several pillars of TPM such as 5S, planned maintenance, quality maintenance, Kaizen, office TPM and Safety, Health and Environment were identified. TPM was implemented in a phased manner. One pillar was implemented at each phase. Overall Equipment Effectiveness was taken as a measure of evaluating the success of TPM implementation.
The study concluded that:

Success of TPM would be dependent on other pillars like 5S, planned maintenance, quality maintenance, Kaizen, office TPM and Safety, Health and Environment.

OEE improved indicating the improvement in productivity as well as quality of the product

Efforts made to improve the preceding processes since defects from previous stage affects productivity

Continual support from top management and employee involvement makes TPM to succeed.

Eti et al (2004) discussed the ways in which industries in Nigeria were able to implement TPM as a strategy and culture for its performance improvement. The study proposed that TPM is linked to Just-In-Time (JIT) manufacturing and Total Quality Management. The study TPM to be sustainable and expected the management to be fully committed for the programme. TPM improves OEE while reducing all the big six losses.

Burlikowska & Szewieczek (2009) presented a new approach for implementation of quality philosophy Zero Quality Defects by using Poka-Yoke method. The purpose of this usage of mistake proofing devices was connected with control and improvement of operations in the process. A practical case of usage of Poka-Yoke method in automotive companies has been addressed. The company monitored and prevented defects at each stage of its production. The three levels of Poka-Yoke: alert, control and prevention in the automotive company were discussed. The study concluded that in the
present scenario organisations must go for quality tools that support prevention strategy and each element and operation of the process must be supported.

Nahmens et al (2012) explored the impact on level of job satisfaction as a result of Kaizen implementation in an industrialized homebuilder plant. Questionnaires were used company-wide to characterize the current level of job satisfaction at the plant. The case study revealed the increase in job satisfaction level as a result of Kaizen event implementation. Workers with more experience had lower job satisfaction while there was no difference in job satisfaction levels among different age groups. The study was limited to industrialized homebuilder. The impact of Kaizen on the job satisfaction levels has only been addressed.

McKone et al (2001) wanted to show that Total Productive Maintenance (TPM) relates to high quality, low cost and on-time deliveries. They used structural equation modeling to investigate the relationship between TPM and Manufacturing performance (MP). They found that relationships between TPM and MP could be expressed with both direct and indirect relationships. The study showed that in particular there is a significant and positive indirect relationship between TPM and MP through Just-In-Time practices.

Juhari et al (2011) attempted to examine the relationship between different 5S system variables and employees’ motivation in implementing 5S system. The study was conducted in paper mills. The study showed positive relation of the communication of 5S system and training of 5S system with employees’ motivation in implementing 5S system while not for the other variables such as reward and recognition for 5S system and top management
role in 5S system. The employees’ motivation must also be increased with respect to these variables and has to be addressed.

Shangyou & Yaqing (2011) proposed measures to improve 5S implementation which could be used as onsite management reference in the make to order (MTO) electronic assembly industry and other similar industries in China. The main defects in implementation of 5S were first identified. Suggestions were discussed based on 5S principles for onsite management. The authors suggest setting the rules that fit the company’s circumstances for the implementation.

Seikola et al (2011) presented lean product maintenance through Kanban at two Ericsson R&D centers which included the identification of key success factors that were generalized to some extent. Kanban was implemented at Customer Support Request (CSR) handling and fault handlings. Teams were formed, backlogs were found, Kanban board was created, work in progress was defined by each team, meetings were held and the status of implementation was monitored. The successful transition of Kanban has been described in the product maintenance organization.

Moradi et al (2011) explained the relation between 5S and pillars of TPM. They studied the status of 5S implementation in a foodstuff production factory in Iran through a checklist. Then the effect of implementation of 5S on TPM was studied. The study revealed that implementation of 5S is prerequisite for TPM implementation. It was also found by the study that 5S can improve OEE and provides better conditions for implementation of TPM.
2.14 LITERATURE REVIEW ON VSM

VSM is a pencil and paper tool, which is created using a predefined set of standardized icons. The three important steps in VSM are to choose the product family, draw the current state map and create the future state mapping, which is the picture of how the system should look (Abdulmalek & Rajgopal 2007; Teichgrsber & Bucourt 2011) used VSM to categorize VA and NVA activities. VSM was applied as an approach to the industry to identify and remove NVA activities and various NVA activities present in the stream were identified (Seth et al 2008; Hines et al 1999) have described the application of a new variant of process benchmarking called VSM to the development of a supplier network.

The steps in the VSM include identification of product family, mapping the current state and providing the future state map by incorporating the proposals (Lasa et al 2008; Hines & Rich 1997) presented the various types of wastes in the value chain and seven VSM tools. With an example, they explained the tools appropriate for the particular waste. The activity categorization in the supply chain was explained. VSM has been used for streamlining the process sequence and also to solve other manufacturing issues. (Lummus et al 2006) have reported a VSM project in medical field. Many case studies have been recorded in VSM and some of them were discussed here. (Abdulmalek & Rajgopal 2007) have presented the case study in which lean principle is applied in a continuous manufacturing sector and the scope for applying various lean techniques using VSM tool was tested. A simulation model was developed to compare before and after scenarios in order to signify the potential of lean manufacturing to the managers. (Seth et al 2008) have understood that the processes involved in the value chain of the cottonseed oil industry, using techniques like Critical observations and further interviews; VSM was applied as an approach to the industry to identify and
remove NVA activities and various NVA activities present in the stream were identified. They discussed about the various obstacles for productivity improvement. (McDonald et al 2002) described an application of VSM, enhanced by simulation, to a dedicated product line in an engineer-to-order motion control products manufacturing plant. They described the application of both current state and the future state for the product line, as well as the analysis and results obtained from simulation.

They have concluded with a discussion of future research and applications in this area. (Sullivan et al 2002) discussed the VSM used for solving equipment replacement decision problem. In particular, they demonstrated that VSM suite of tools can be used to map the current state of a production line and designed a desired future state and illustrated how VSM can provide necessary information for the analysis of equipment replacement decision problems encountered in lean manufacturing implementation. (Hines et al 1999) have described the application of a new variant of process benchmarking called VSM to the development of a supplier network. This involved mapping the activities of the firm, identifying opportunities for improvement and then undertaking improvement programs. The resulting supplier association program involved around 50 key suppliers across eight product category areas.

They concluded with the evidence of early results of the program as well as a number of key learning points for other organizations wishing to follow a similar path. (Hines & Rich 1997) have applied the seven VSM tools for waste elimination in Toyota Production System (TPS). They have also used Value Stream Analysis Tool (VALSAT) for enabling the selection of effective VSM tools. (Hines et al 1999) have applied VSM for the development of a supplier network around a prominent distributor of
electronic, electrical and mechanical components. (Sullivan et. al. 2002) have provided a roadmap as to how VSM can provide necessary information for the analysis of equipment replacement decision problems encountered in lean manufacturing implementation. (McDonald et al 2002) have presented an application of VSM enhanced by simulation to a dedicated production line of a manufacturing industry. (Huang & Liu 2005) have presented a novel approach using VSM to lean control for Taiwan-funded enterprise in mainland China. (Kocakulah & Upson 2005) have presented the implementation aspects of a computerized physician order entry system of a healthcare industry which has been evaluated using VSM techniques. (Lummus et al 2006) have reported a VSM project in a small medical clinic that has resulted in lower patient wait time and increased patient throughput thereby improving quality.

(Abdulmalek & Rajagopal 2007) have described a case where VSM and other lean principles are adopted for the process sector for application at a large integrated steel mill. (Esain 2000) has used VSM benchmarking technique across a supply chain in the automotive sector. (Bandarian 2008) has described about exploiting value chain process concepts in research organizations to present a framework for the sequence of work in a chain manner at research organizations. This new approach is an idea-to-market process, which is considered more in strategic literature when studying research organizations. The work clarified the goals of the value chain and identifies the managerial actions that improve the value chain performance in terms of the desired goals.

(Lasa et al 2008) have proved that VSM is a suitable tool for redesigning the production system based on the conduct of the case study. Gibbons, 2008 has presented the introduction of a lean resource mapping
framework. The work details the extant lean theoretical framework can be further developed, overcoming the flexibility, responsiveness, dehumanizing and contingency criticisms by operationalising a more holistic and dynamic triangulated framework inclusive of qualitative waste analysis, complementary to the extant quantitative data from VSM.

(Sawhney et al 2009) have developed a value stream map to evaluate breakdown maintenance operations. This work on maintenance management has found new vigor and purpose to increase equipment capacity and capability due to increasing focus on lean manufacturing. The case study has been focused on the improvement of production systems for the manufacture of plastic casing on mobile phones. They have derived the various proposals for the improvement of the manufacturing system of the case company. They have developed the seven VSM tools for specific applications in a Distribution Industry.

(Hines & Rich 1997) have applied seven VSM tools for waste elimination in Toyota Production System. Value Stream Analysis Tool was used for enabling the selection of effective VSM tools. (Hines et al 1999) developed the supplier network around a prominent distributor of electronic, electrical and mechanical components using VSM. (McDonald et al 2002) presented an application of VSM along with simulation to a dedicated production line of a manufacturing industry. (Seth & Gupta 2005) developed VSM for lean operation and cycle time reduction in an Indian manufacturing industrial scenario. (Kocakulah & Upson 2005) evaluated the aspects of a computerized physician order entry system of a healthcare industry, using VSM techniques. (Lasa et al 2008) proved that VSM is a suitable tool for redesigning the production system based on the conduct of the case study. (Sawhney et al 2009) developed a value stream map to evaluate breakdown
maintenance operations for the manufacture of plastic casing on mobile phones. This work on maintenance management has found new vigor and purpose to increase equipment capacity and capability due to increasing focus on lean manufacturing. (Mohanraj et al 2011) developed the QFD integrated VSM for the enablers of lean manufacturing. QFD technique is used for prioritization of wastes and techniques for waste elimination. The application of the methodology was explained with a case study conducted in an Indian pump manufacturing organization.

2.15 LITERATURE REVIEW ON QFD APPLICATIONS

Dr. Yoji Akao is regarded as the father of QFD who has contributed a widely used definition of QFD. QFD provides the means for translating the consumer needs to appropriate technical requirements for each stage of a product / process development cycle (Akao & Mazur 2003). It helps in the development of customer friendly and high quality products. QFD is an excellent management tool that enables the teams to focus on the needs of the customers for enabling product design. QFD has been used in the industry for the past two decades. QFD emphasizes quality in design process to prevent the defects at early stages thereby reducing cost and improving productivity. Other benefits of QFD include reduced design changes, increased market share and improved product quality (Akao & Mazur 2003; Chan & Wu 2002). Researchers have reported the limitations of QFD, some of them are narrated as follows: QFD is a complicated process, which requires the expertise of qualified professionals to develop a House of Quality (HOQ) (Olhager & West 2002). In QFD process there is no provision to incorporate the opinions and preferences of all levels of employees (Dijkstra & van der Bij 2002). There also exist problem in the decomposition of tables separately from HOQ. (Sharma et al 2010) have analyzed programming tools for the development of
QFD software. This work attempted to explore the various available programming languages, analyze them and pick a suitable one for the QFD software automation. Along with an insight into traditional QFD, this work also explores QFD from the software automation perspective. (Nikhil et al 2010) have reported the modeling customer satisfaction using QFD which details customer satisfaction is of paramount importance in research due to rapidly increasing customer demands and the usage of internet and the computerised models. (Oke et al 2009) presented the application of QFD and Value analysis tools in design of an automobile which reported significant improvement in manufacturing cost. (Waterworth et al 2010) reported an investigation into the application of QFD in e-commerce.

This study had developed ultimately demonstrating how organizations can adapt traditional quality management tools to measure quality and guide improvement efforts in an e-commerce environment. (Kabeil 2010) has described an analytical hierarchy process (AHP)-QFD approach to developing DSS (Decision support system) for crisis management which includes a framework based on the AHP and QFD technique; QFD is used for defining and assigning relative weights for design components that support the defined requirements. (Xu et al 2010) have made a comprehensive review on recent developments in QFD. This work aims to provide a more balanced review of QFD that exhibits enough depth to be useful to researchers as well as enough breadth to cater for amateur readers. This paper reviewed methodologies that include fuzzy set theory, multi-criteria decision analysis model, artificial neural network and hybrid approaches. Resource allocation, Kano's model, failure mode and effects analysis, robust design and an assortment of other recently developed tools are reviewed.
The prioritization of improvement proposals need to be scientifically ranked (Vinodh et al 2011b). QFD is a technique extensively used for the purpose, when voice of the customer needs to be accurately translated into technical languages. They demonstrated the scope of integrating fuzzy logic in QFD when vagueness is associated with relationships and correlations (Vinodh & Chintha 2011a). (Vinodh et al 2007a) reported the research work, where agile innovative total quality function deployment (Agile ITQFD) was designed and used to tap the synergic powers of these strategies. The case study was conducted in Indian electronics switches manufacturing company.

This company has successfully applied many world class manufacturing strategies. Hence, the inferences drawn from this study indicated the feasibility of the application of agile ITQFD. (Vinodh et al 2011a) explained the application QFD in the supply chain domain to select the supplier by considering various supplier demands. The results showed the practical feasibility of application of QFD. (Vinodh et al 2011b) presented the case study where QFD was used to scientifically prioritize wastes and techniques for waste elimination. Using VSM, wastes were identified and proper proposals were derived to eliminate those wastes. Then using QFD, prioritization was done. (Vinodh et al 2007b) proposed ITQFD, which facilitates the spontaneous involvement of team members for bringing innovation out of customers’ voices. The implementation study conducted in electronics switches manufacturing company was explained. From the results, they indicated that ITQFD can be implemented in real time manufacturing scenario.

QFD is used as a powerful tool for improving product design and quality, and enabling a customer-driven quality system (Kahraman et al 2006;
Prasad 1996) reviewed some historical developments in QFD and extended HOQ. Since the inception of QFD in Japan in early 1970s, it has met with varying degrees of success. (Chen & ko 2010) used QFD to maximize customer satisfaction in New Product Development. They Defined design requirements, part characteristics, process parameters and production requirements, as the important decision problem during four phase QFD activity. They build a set of fuzzy linear programming models to determine the contribution levels of each “how” for customer satisfaction. QFD is a technique extensively used for the purpose, when voice of the customer needs to be accurately translated into technical languages.

They demonstrated the scope of integrating fuzzy logic in QFD when vagueness is associated with relationships and correlations (Vinodh & Chintha 2011a). (Vinodh et al 2011a) illustrated the application of QFD in the supply chain domain to select the best supplier by considering various supplier demands. The results showed the practical feasibility of application of QFD. (Mohanraj et al 2011b) presented the case study where QFD was used to scientifically prioritize wastes and techniques for waste elimination. Using VSM, wastes were identified and appropriate proposals were derived to eliminate those wastes.

Then using QFD, prioritization was done. (Vinodh et al 2007b) proposed ITQFD, which facilitates the spontaneous involvement of team members for delivering innovation out of customers’ voices. The implementation study conducted in electronics switches manufacturing company was explained. From the results, they indicated that ITQFD can be implemented in a real time manufacturing scenario. (Almannai et al 2008) developed an integrated approach using Failure Mode Effects Analysis (FMEA) and QFD. By combining the principles of both, they formed a
decision making tool. QFD was used to select the manufacturing process and FMEA was used to check the associated risks. Due to ill-defined and vague indicators which exist in human judgment on advanced manufacturing systems, most measures need to be described subjectively by linguistic terms which are characterized by ambiguity and multi-possibility. However, fuzzy logic provides a useful tool for dealing with decisions in which the phenomena are imprecise and vague (Lin et al 2006). (Jia & Bai 2011) proposed an approach for manufacturing strategy development based on fuzzy QFD.

A methodology related to manufacturing strategy development based on QFD is developed. They proposed a methodology which integrates fuzzy set theory and QFD to mitigate the inherent impreciseness and vagueness of decision-relevant inputs. Supplier selection is a highly important multi-criteria group decision making problem, which requires trade-off between multiple criteria exhibiting vagueness and impreciseness with the involvement of a group of experts. A fuzzy multi-criteria group decision making approach that makes use of QFD concept is used for supplier selection process. Finally, a fuzzy number ranking method have been be used for final ranking of suppliers (Dursun & Karsak 2013).

2.16 RESEARCH GAP

Based on the literature review, it has been found that there has been no concrete research reported on the integration of QFD with VSM framework for enabling leanness.

Based on the literature review, the application of fuzzy QFD for identifying the improvement proposals in VSM framework towards enabling
leaness forms the scope of this research study. Based on the literature review, it has been found that lean manufacturing principles provide scope for ensuring sustainable benefits. Though researchers have contributed certain theoretical concepts behind this extension, concrete studies to illustrate the scope of lean principles for ensuring sustainable performance is not justified. This aspect forms the scope of this study.