SYNOPSIS OF THE THESIS

Assessment of Lean Manufacturing in Knitwear Apparel Industry of Okhla and Ludhiana

Submitted for the award of the degree of
Doctor of Philosophy

IN THE FACULTY OF ARTS & SOCIAL SCIENCES

THE IIS UNIVERSITY, JAIPUR

Submitted by

Prabhjot Kaur

Under the Supervision of

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INTRODUCTION

"The key to competing in the international market place is to simultaneously improve both quality and productivity on continual basis".

Mannan and Ferdousi , 2007

The Knitwear industry has been evolving over the years and is in a state of constant change, as different needs and technologies have arisen and responsiveness, quality and price are all major differentiating factors. The customer of the twenty-first century, demands comfortable, fashionable and innovative products in designs, colour and services, those are fast, right, cheap and easy and the buyer has many more options available in terms of quality, variety and source of the product. This puts pressure on knitwear manufacturers to develop or upgrade their current systems or look for new production techniques in order to keep pace with the rapid changes and speed up their production in a continuous manner in order to fulfill orders, while at the same time improving its quality and reducing all related costs. More flexibility in their production processes and fabrics handling is the urgent need of today can be attained through these new systems so as to not only satisfy fluctuating and unpredictable orders but also produce value-added knitted garments.

Even manufacturers facing intensive global competition are becoming increasingly aware of the importance of modern management philosophy in providing them with a competitive advantage in a free market system ***(Yeung and Chan, 1999).*** To reduce production costs, shorten lead-times, increased competitiveness, improved customer satisfaction, manufacturing efficiency and effectiveness, has forced a large number of manufacturing firms to embark on programmable automation technologies and lean production philosophy that will simultaneously improve both quality and productivity on continual basis. In the late 1980s the term "Lean Production" was introduced in a book titled "The Machine That Changed the World" written by ***Womack, Jones & Roos (1990).*** The Lean production thinking is a Japanese concept comprising complex cocktail of ideas including continuous improvement, flattened organization structure, team work, elimination of waste, efficient use of resources and cooperative supply chain management ***(Green,2000).*** The idea came to be adopted all over the world because the Japanese companies developed , produced and distributed products with half or less human effort ,capital investment, floor space, tools, material, time and overall expense. Hence the main aim of lean manufacturing is to eliminate waste and non-value-added activities at every production or service process in order to provide utmost satisfaction to the customer ***(Parthasarathi, 2009).***

Indian Knitting industry is dominated by small scale players which usually get orders in small quantities and complex designs; hence the units have to produce multiple styles even within a day. Moreover units are run as family business lacking skilled personnel as well as capital to implement new technologies for improving productivity and flexibility. Because of this, industries have been running in a traditional way for years and too are rigid to change. They are happy as long as they are sustaining their business. They don't have much confidence and will towards innovation over old processes ***(Gao, Norton, Zhang and Kin-man To, 2009)***. These units are family managed firms having age old management style where lack of trust rules. Neither management has trust on workers nor do the workers have trust in management. There exists a kind of compromise between them while none can survive without either. Management style is like this because the units are small and no specialist management practitioners are required to manage them. But, Indian hosiery Industry desperately needs to understand how to develop core competence and competitive advantage in them. This will help them bring out good product mix into the market and will increase their confidence in building their own brands in international markets. Also, they need to update their skills in CAD base garment designing, understanding lifetime value of customer and customer relationship management which is becoming the decisive factor in export marketing today.

Even though export of knitwear is increasing continuously, small and medium size export houses have been running at almost 40-50% capacity for the last two years as they have been subjected to global competition from countries like China, Bangladesh, Hong Kong, East Europe etc, after the successive lifting of quantitative restrictions and quotas under the WTO regime . These countries with latest production facilities have an advantage in terms of proximity and quicker delivery time. In such a present free market scenario and turbulent times, there is a need to match the product quality, technology, designing skills, productivity standards and cost of production with international players. Survival and success of any organization increasingly depends on competitiveness. To remain competitive, Knitwear industry must adopt strategic technologies, state-of–the-art textile practices and modernize the manufacturing processes alongwith innovative professional management practices to survive. The fierce competition in the market has changed the way organizations look at profit .They understood that there is no other option other than to reduce cost in order to make profit and survive in the global market and they have to be efficient in what they are doing by eliminating waste. This has led many manufacturers engaging lean production programs to achieve business excellence as both researchers and practitioners agreed that lean manufacturing if adopted and carefully implemented can undoubtly form the roadmap to global manufacturing excellence ***(Papadopoulou & Ozbayrak, 2005)***.Lean manufacturing will be the standard manufacturing mode in the 21st century and hence is considered a strategic weapon in competitive market. Even Indian government has realized the competitive pressure from low cost and foreign manufacturers and has launched Lean Manufacturing Competitive Scheme (LMCS) under National Manufacturing Competitive programme (NMCP) in 2010.But because of lack of awareness regarding this new production concept, not many Knitwear units are availing this available opportunity.

So this study proposes to not only to spread awareness, investigate the improvement performance through implementation of lean manufacturing and its tools and move a step further by engaging all the related personnel's in this effort.

REVIEW OF LITERATURE

Review of literature has been studied under following heads-

I. Evolution and status of knitwear industry

II. Lean manufacturing
III. Carbon footprint and Lean manufacturing
IV. Lean manufacturing with CAD/CAM technology

I. EVOLUTION AND STATUS OF KNITWEAR INDUSTRY

Knitwear is emerging as the fastest growing segment of Indian garment exports compared to all other segments, including woven garments and the mill-made garments. The knitwear industry has slowly, yet steadily, crept up to overtake the woven sector due to the preference of knitted garments over woven garments throughout the world. **Ajgaonkar in 2003** reported that comfort, free movement of air, maintenance of body temperature, fitting snugly to body contours, stretch ability, more air permeability, strength and easy breath ability built within the knitted fabric structure as few factors which had led to the increase in popularity of knitted garments. Also, for investment in modern technology. comparatively small capital investment requirement, less preparatory processes, less labour requirement, high adaptiveness of the machines, high productivity, more flexibility, variety of yarns, faster and simpler operation for setting up of knitting machines had further stimulated the growth of knitting industry**.**

The art of knitting has changed over the years. **Ahire** in 2008 reviewed the evolution of knitting industry and found that from hand knitting to hand operated machines to computerized machines; the journey was a long one. The ancient knitting by use of fingers was practiced around 1000 BC which gave way to the art of hand knitting in 256 AD. It took about 1500 years for the mankind to invent a machine which could replace the art of hand knitting. The first knitting machine was invented in the 16th century by William Lee from Nottinghamshire in England. Invention of latch needle led to simplification of the mechanism, increase in production speeds and reduction of costs. Warp knitting machines were invented in1775 some 200 years after the first weft knitting machines. Automatic or power operated flat bed knitting machines later came into existence in the 19th century. Gradually it was upgraded to power operated V-Bed and circular knitting machines .Subsequently, microprocessor controlled knitting machines also came into existence. 1970s saw the introduction of CAD/CAM systems in the field of textile and apparel industry which replaced the tedious, time consuming and laborious manual and mechanical shaping and patterning devices on machines with electronic controls, hence increasing the knitted garments production and it is considered one of the most revolutionary and landmark events in the history of knitting. Side by side with computerized knitting, another technology of producing complete garment in one process without the need for sewing was introduced by development of the slide needle. This '*Whole garment Technology'* was further developed in 1990 by Shima Seiki of Japan which was capable of producing complex designs.

The first hosiery unit in India was set up at Kolkatta in a small shed in Khidderpu by Anand Prasad Mukherjee where a hand operated machine from England was imported in 1882 for the manufacturing of cotton hosiery goods, and, Ludhiana in Punjab followed by production of woollen knitwears . The knitwear and apparel industry of Ludhiana had its small beginning when Kashmir craftsmen came there to earn their livelihood by hand knitting coarse woollen yarns. The woollen hosiery industry was born in 1902-03 when a socks manufacturing unit was established in Ludhiana to cater to the need of soldiers especially during World War-1 and World War‖. Ludhiana experienced the real boom in its industry from 1950 to 1980 mainly as exporter of woollen garments to USSR. The disintegration of USSR in 1980 was a major setback for Ludhiana market. The entrepreneur spirit of Punjabis saw the real adjustments to the business ventures.

Tewari(1999***)***studied the adjustments made by the woollen knitwear industry of Ludhiana and found four factors responsible for this recovery. First, the best performing firms had a strong and simultaneous presence in dynamic segments of the domestic market alongside exports. This generated key organizational learning and helped in building up managerial and production capabilities that helped firms to quickly adopt more dominant markets. Second, an important feature of the learning relationship between first time exporters and their foreign buyers was the small scale nature of contracts and a 'customization of fit' between the producer and the feedback giving intermediaries. Third, the better performing firms paid more attention to make organizational changes in their work practices than to the purchases of new equipments. Fourth, the embedded nature of production networks and the best programmes of the government to assist local firms helped in creating a dynamic middle tier of local –routed exporters who appeared to be leading the transformation for modernization.

During the past few years there has been an expansion and diversification of Ludhiana hosiery industry. This change in the present industrial set up of the industry has been largely fashioned by modernization and computerization. In the beginning, V-bed hand flat knitting machines were installed, but, to increase the production, these were replaced by fully fashioned knitting machines, power flat and circular knitting machines. A large number of computerized knitting machines were installed for making woollen garments in 1980's and multi-head computerized machines were set up for embellishments. The focus of export shifted from USSR to European Union, USA and Latin America countries.

Kaur(1991) and Kaur (2002) explored the existing knitting, dyeing, printing and finishing technological processes and practices in knitwear industry of Ludhiana and found out that majority of units(96.1%) were fabricating and engaged in weft knitting while,the rest of units (3.9%)performed the integrated functions of knitting, dyeing, printing and finishing. Blends, acrylic and polyester were mainly used in fibres /yarns in knitwear units.63.9% of units had average technology. **Vohra (2011)** reported that Ludhiana is the prime centre that mostly makes knitwear straight from yarns and for the upliftment of the industry, there is need to bring quality awareness at all levels of operation in manufacturing, as many units resort to using inferior materials and non-standard methods due to the cost factor, thus compromising the quality aspects . Factors such as lack of unskilled workers and executives, lack of coordination between different segments of knitwear industries and educational institutions is an urgent need to bring quality awareness at all levels of operation. It is essential for units engaged in export business to sustain a high level of quality to build creditability and ensure better business globally.

Singh (1996) has discussed future potential of the woollen knitwear industry in his report and suggested that the industry needs to concentrate more on research and development to improve the services, information and technology available in Ludhiana alongwith the rural marketing.

Chari(2000) and Anonymous(2003) overviewed the success story of knit city Tripur, commonly known as Knitwear capital of India located in Tamil Nadu accounting for 56% of India's cotton knitwear exports valued at *Rs. 5000* crore per year. It reveals that majority of the owners of the agrarian Gounder caste were not only the owners but they were also predominantly ex-industrial workers who through their efforts made the Tirupur knitwear industrial cluster into a dynamic small-firm network. Major strengths of this industry was the local supply of cotton yarns from Coimbatore and Salem, dyes and chemicals from Gujarat and Maharashtra, ability to take up small orders at small notice, at low cost and reasonable good quality knitwear, and,the positive entrepreneurial attitude of people.

Udani(1993) and Kothari (2001) reported that Post Multi Fibre Agreement(MFA) era Indian hosiery industry was facing various issues regarding lack of modernization in all sectors ,environment issues involving child labour, reduction of import tariffs ,high cost of yarn, inadequate power supply, infrastructure, foreign competition , obsolete technology, credit facilities at high rate of interest, complex labour laws, lack of skilled labour, proper training facilities, availability of good quality raw materials and proper information. To improve competitiveness and ensure cost effectiveness ,measures suggested were technology upgradation, credit facilities on terms, adequate power supply, cost inefficient infrastructure facilities, simplification of labour laws, human resource development, marketing strategies, promotion of brand equity, need for continuation of excise duty exemption for knitted hosiery items and setting up of apparel park.

II. LEAN MANUFACTURING

The term 'leané' as Womack and his colleagues defines it as a system that utilizes less , in term of all inputs , to create the same outputs as those created by a traditional mass production systems, while contributing increased varieties for the end-customer. ***Saeng – xuto*** traced the history of lean to World War II,when Japanese manufacturing were faced with the dilemma of vast shortages of material, financial, and human resources. The problems that Japanese manufacturers were faced with, differed from those of their Western counterparts. These conditions resulted in the birth of the leané manufacturing concept. Toyota motor company, led by its president Toyota recognized that American automakers of that era were out-producing their Japanese counterpart, in the mid 1940's, American companies were outperforming their Japanese counterparts by a factor of ten. In order to make a move toward improvement early Japanese leaders such as Toyota Kiichiro, Shigeo Shingo and Taiichi Ohno devised a new, disciplined, process oriented system, which is known today as the "Toyota Production System" or "Lean Manufacturing" .Taiichi Ohno, who was given the task of developing a system that would enhance productivity at Toyota, is generally considered to be the primary force behind this system. Ohno drew upon some ideas from the West and particularly from Henry Ford's book "Today and Tomorrow". Ford's moving assembly line of continuously flowing material formed the basis of the Toyota Production System. After some experimentation, the Toyota Production System was developed and refined between 1945 and 1970 and is still growing today all over the world. The basic underlying idea of this system is to minimize the consumption of resources that add no value to a product.

Many Japanese companies gained strategic advantages over their American counterparts through the use of Lean manufacturing techniques. As U.S. companies benchmarked themselves against their Japanese competitors, they became aware of Lean manufacturing, more commonly known at that time as just-in-time (JIT) manufacturing. Initial efforts to implement JIT in the U.S. often resulted in only limited success due to the "me too" way in which it was often initially implemented. The limited success experienced by early United States adopters of Lean manufacturing was mainly due to the fact that the financial background of top management in many U.S. companies leads them to initially see JIT from an "accounting perspective". This perspective unfortunately ignores the primary benefits of implementing just-in-time or lean manufacturing, as for JIT to be successful it must be implemented as a continuous improvement tool, and not just as a method of freeing up cash by reducing inventory.

Research was done to determine the impact of world-class manufacturing practices on the operational performance of small manufacturers. Survey analysis as well as case studies methods was used and the results were very insightful and this lead to two major conclusions, that, world-class manufacturing practices have a positive impact on the operations of small manufacturers but, should be supported by the correct underlying philosophies and principles***(Johnson).***

Various Lean manufacturing tools & techniques involved are Quality Control Tools, 5S, Just in time, Single minute exchange of dies (SMED), point –of- use- storage(POUS), Kanban and Kaizen. Various approaches are used for effective utilization of above said lean tools. These are minimizing the required inventory level, development of the work cell, cultivation of team work, standardized and balanced work, zeroing down the defects, reduce the process lead time , one piece flow ,minimizing the production cost and continuous process improvement. (***Kumar &Sampath, 2011)***

Lean manufacturing is a proven approach for success in manufacturing industry. However, several organisations failed in their attempt to implement lean manufacturing. The transformation to lean manufacturing system requires radical change which involves total reshaping of purpose, system and culture of the organisation. An investigation on the influence of organisational change to the lean manufacturing transformation was carried by Nordin in 2010 in 60 firms in the Malaysian automotive industry. The respondents were chosen from those who were involved directly with lean manufacturing practices such as production and quality personnel. The survey findings show that organisational change factors such as change readiness, team development, leadership and management support, effective communication, employee training, employees' empowerment and review process have significant influence on lean manufacturing implementation. ***(Nordin et al, 2010a).***

An exploratory study of lean manufacturing implementation in sixty Malaysian automotive industries was conducted through a questionnaire survey to explore the extent of lean manufacturing implementation. Majority of the respondent firms were classified as in-transition towards lean. As the main barriers of these firms were the lack of real understanding of lean manufacturing concept and employees' attitude ***(Nordin et al , 2010b).***

Four industrial case-studies were conducted in different electrical and electronics companies in Malaysia to investigate the approach of adopting lean, the tools and techniques implemented, the changes in the organizations, the problems encountered as well as the lessons learnt. Interviews were conducted with the key personnel and were found that each of the organizations have developed its own unique technique and methodology to fit with its current production system. They have also integrated other approaches such as six sigma and Quality control practices to support their lean initiatives. Most vital part when implementing lean manufacturing lies on the people and everyone in the organization needs the right tools and support to make positive changes happen and should possess the thinking that is able to identify and eliminate waste because lean manufacturing requires systematic problem solving methods It was suggested that companies which want to implement lean manufacturing should continuously train their people to 'think lean' and 'act lean', and support them by giving them the right tools. ***(Wong,& Wong,2011a).***

Wong (2011) helped in developing a framework which serves as a guideline to implement lean manufacturing in this industry. The key intervention areas of lean manufacturing were identified as scheduling, inventory, material handling, equipment, work processes, quality, layout, employees, suppliers, customers, safety, ergonomics, management and culture, and product design depending on the nature of business.

Adoption of lean manufacturing in the electrical and electronics industry in Malaysia was explored in 14 key areas of lean manufacturing namely, scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture,tools and techniques. The respondents were asked to rate the extent of implementation for each of these areas and it was found that most of them were "moderate–to–extensive" implementers. ***(Wong et al, 2009).***

The use of lean manufacturing in the textile industry was examined in the research carried by Hodge et al in 2011. Interviews, plant tours and case-studies were used to collect data and results were compiled to create a textile specific lean implementation roadmap which consists of a list of barriers applying to textile companies implementing lean, a 5s system and Value Stream Mapping best practice checklists, and a recommendation model for implementing lean tools and principles in a textile environment. (***Hodge et al, 2011***).

A study to highlight the differences and similarities of performance between the companies of Bangladesh and other countries of the world using lean or other similar philosophies was conducted on nine garment firms with a semi- structured questionnaire to see the extent of lean implementation and the performance improvement. An interview was also conducted to gain a detail insight of the respondent. These results revealed that the organizations have several misconceptions about lean production techniques, their initiatives toward this technique brought several improvements for the companies, i.e. 10%-60% improvement in productivity, 10%-60% improvement in quality, 26.7% reduction in lead time, 26.1%reduction in manufacturing cycle time US $1.10 reduction in per unit cost and 30.1% reduction in inventory holding time. It was concluded that lean production can bring significant performance improvement for garment manufacturers ***(Farhana& Amir,2009a).***

An investigation of Manufacturing Performance Improvement through Lean Production in Bangladeshi garment firms indicated that the selected companies have adopted a wide variety of lean tools and techniques and gained many performance improvements. Companies that adopt lean manufacturing as a working philosophy within their organizations made significant improvement in terms of their operational performance even if it is in a modified format that best suits their particular business culture. Business challenge is the most important driving factor that led the companies to practice lean and different changes were experienced by the firms such as cultural change, education of workers and suppliers, empowerment of employees, commitment of top level managers, relationship with suppliers, rearranging the manufacturing process and awareness (***Farhana & Amir,2009b).***

The study on best Lean manufacturing practices in SMEs focused on feasible lean practices which are required to be implemented in order to be successful in lean implementation in small and medium units. Main barrier being financial and resources constraints,the authors have proposed the feasible lean practices which are generic to SMEs characteristics based on three categories; least investment feasible to apply in SME as recommended by researchers. Among the lean practices that require least financial investment are 5S, visual control & display, standardization of operation, Statistical Process Control (SPC) and quality circle. Therefore, SMEs should apply these practices first and then follow other practices such as kanban, small lot sizes. Kanban and small lot sizes practices can be implemented once the production flow is efficiently run, with minimum machine breakdown, quality problems and parts shortage. Even though piecemeal implementation of lean practices may not gain full benefits, but the steps taken could help SMEs to improve their performance gradually***(Rose et al,2011).***

Lean Six Sigma Methodologies was implemented in Sun garment industry located in Coimbatore for the assessment, improvement, and control of wastes. The garment industry in focus was exporting the final product to European countries. It was operating at a percentage defective of 4.42. After implemention of this methodology the percentage defective was reduced to 1.95. The same approach could be utilized to other products of the company which will reduce lots of defects. If the quantum of defectives are reduced and converted into cash flows, the company will benefit through increased revenues. As many medium scale garment industries in India are not aware of the lean six sigma concepts and this implementation tried to trigger a positive wave across the garment industries and become more competitive ***(Kumar et al,2011).***

Paneru conducted a study in the stitching section of a shirt manufacturing company which was facing problems like low productivity, longer production lead time, high rework and rejection, poor line balancing, low flexibility of style changeover etc. These problems were addressed by the implementation of lean tools like cellular manufacturing, single piece flow, work standardization, just in time production etc. Research tools used were time studies, the conversion of traditional batch production into single piece flow and long assembly line into small work cells. After implementation of lean tools, results observed were highly encouraging. Some of the key benefits were that production cycle time decreased by 8%, number of operators required to produce equal amount of garment was decreased by 14%, rework level reduced by 80%, production lead time comes down to one hour from two days, work in progress inventory stays at a maximum of 100 pieces from around 500 to 1500 pieces. Apart from these tangible benefits operator multi-skilling as well as the flexibility of style changeover also improved.

Nautiyal made a critical assessment of the profitability of the adoption of lean manufacturing practices by garment manufacturing units in Delhi-NCR region and also disseminated the compiled information to the non -lean compliant garment manufacturing units .Interviews, observation and time study method was used to collect data. The process of implementation and effectiveness of lean manufacturing was assessed through a comparative analysis of conditions existing before and after the implementation. Results revealed that different tools of lean manufacturing were used by different units on the basis of their requirement. Value stream mapping was prepared for the existing assembly line and for the projected assembly line after the implementation of lean manufacturing practices. Interventions were done keeping in mind the feasibility and elimination of waste. Reduction of wasteful activities in all individual departments led to successful lean implementation in the units.

III. CARBON FOOTPRINT AND LEAN MANUFACTURING

Adoption of Lean production is said to directly improve the public good by improving the environmental performance of the adopting firms. The good housekeeping practices associated with Lean production have the subsidiary benefit of reducing spills and other forms of waste. Hence, it is believed that Lean is green.(***Florida 1996;Hart 1997).***

Textile industry is the producer of greenhouses and one of the largest sources of greenhouse gases on earth due to its huge size. Carbon dioxide, the most important greenhouse gas produced by combustion of fuels, has become a cause of global panic as its concentration in the earth's atmosphere has been rising alarmingly. The gas is released from burning of fossil fuels i.e. oil, petrol and natural gas ***(Sivaramakrishnan,2011).***

Lean not only shortens the lead time between a customer order and the shipment of the products by elimination of all forms of waste in the production processes. Also, lean principles and methods focus on creating a continual improvement of culture that engages employees in reducing the intensity of time, materials and capital necessary for meeting customer's need. But, the process ends only when receipt of payment is realized since hoarding of money at any stage is considered as a negative syndrome. Therefore, the end user plays a vital role in lean manufacturing. Its implementation also enhances green or environmental performance; hence environmental savings becomes a part even when it is not part of the financial justification for lean improvement activities ***(Naikwade, 2010).***

Relation between lean production and environmental performance was explored by ***King and Lenox*** in 2001.The authors was of the view that 'Lean is green' As 'zero waste' is the mantra of lean production, the adoption of lean practices led inadvertently to pollution reduction as proven by empirical analysis of 17,499 U.S. manufacturing establishments. Units that were engaged in lean production adopted formal environmental management system i.e. quality standards (ISO9000 AND ISO14000) and led to reduction in inventory and hence released less toxic chemicals and wastes. It also facilitated reduction in emissions through pollution prevention rather than end-of-pipe treatment.

'Carbon footprint' has become a widely used term and concept in the public debate on responsibility and abatement action against the threat of global climate change. "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product." The task of calculating carbon footprints can be approached methodologically from two different directions: bottom-up, based on Process Analysis (PA) or top-down, based on Environmental Input- Output (EIO) analysis. Both methodologies need to deal with the challenges outlined above and strive to capture the full life cycle impacts, i.e. inform a full Life Cycle Analysis/Assessment (LCA).

Meena reported various constituents of Carbon Footprints in percentages i.e. financial sevices (3%),recreation and leisure(14%),household(9%),carbon in car manufacture(7%),food and drink(5%),holiday flights(6%),electricity(12%),coal, oil gas(15%),private transport(10%),clothes and personal effects(1%) and share of public services(12%).Green house gases emissions were also categorized into direct emissions resulting from activities of organization controls, indirect emissions from use of electricity and products and services.

Chaudhary in her research "carbon footprint in a garment manufacturing unit" identified different waste generated in ISO certified, government recognized export house, and manufacturing garments located in Faridabad and provided the suggestions to reduce its generation. Various departments like administrative, Design and line development, Production contributed to some amount of carbon footprint. Their work consumed electricity in running of machines like electric cutters, sewing machines, fusing machines and steam iron sets and generated garbage like fabric scarps, papers pattern, cardboard boxes, labels, and tapes, thread cones, fusing rolls, fabric scraps and stickers. Main two sources of carbon footprint were transport which was used by the personnel working in the unit for traveling, and ,electricity which was consumed by all the departments. The data collected for the consumption of fuel used in transport and machinery, chemicals, water and electricity was considered. The calculations of the components of Carbon Footprints were natural gas - 2, 81,820 kg of CO_2 eq per year, diesel - 4, 45,000 Kg of CO_2 eq per year, petrol - 1, 75,915 Kg of CO_2 eq per year, mobil oil - 3,000 Kg of CO_2 eq per year and LPG - 295.36 Kg of CO_2 eq per year. A sum total of the above values was taken and was divided by the production per year to arrive at a value of carbon footprint generated per garment and it was found to be ranging between 1.0 kg-1.5kg of CO_2 eq. Different suggested ways to reduce carbon footprint were- recycling of small pieces of waste fabrics into shoddy items, avoid usage of fusible interfacings, use of CAD and CAM systems , efficient stitching methods, use of motorized 'Energy star mark' sewing machines, regular maintenance, lubrication and upkeep of the machine, use of large baler bags for storage, use of local raw materials etc.

Khurana in her research assessed Carbon foot printing in a home furnishings knitting unit in Ludhiana. Various factors contributing to carbon foot printing were listed as ,usage of fossil fuel, water, chemicals and wastes generated during various processes. Value of carbon footprint generated per product varies from 1.75 kg-2.1kg of CO_2 eq in the unit. Awareness about the carbon footprint reduction among different officials of the unit was provided by conducting workshop.

Varshney conducted a study in Elegant Spinners (unit of Bhiwani Grasim Suitings) for assessment of Carbon Footprint. Interview was used to gain information regarding the wastes generated in the unit and carbon footprint value was found out to be 0.7 kg of CO_2 eq in the unit.

IV. LEAN MANUFACTURING WITH CAD/CAM TECHNOLOGY

Indian Knitwear industry's manual planning and production suffers from a complete lack of standardization hence JIDOKA (autonomation) which is important lean tool meaning "intelligent automation" or 'automation with human touch', can be applied to production machines. It means that when a problem occurs, the equipment stops immediately preventing defective products from being produced. It prevents the production of defective products, eliminates overproduction and focuses attention on understanding the problem and ensuring that it never recurs. For instance rather than waiting until the end of a production line to inspect a finished product, autonomation may be employed at early steps in the process to reduce the amount of work that is added to a defective product. To complete Jidoka, not only is the defect corrected in the product where discovered, but the process is evaluated and changed to remove the possibility of making the same mistake again.

Conventional automation and other types of manufacturing technologies have traditionally positively affected the production. Automation can be divided into three general categories: 1) computer-aided design; 2) computer-aided manufacturing (e.g., robots, computerized machine tools, flexible manufacturing systems); and 3) computer-aided techniques for management (e.g., management information systems and computer-aided planning).

CAD/CAM has been evolved as an integral and essential part of automation leading to the speedy development of the product with less wastage and optimum usage of resources hence an aiding in Lean manufacturing. Most efforts to reduce fabric waste have centered on marker-making CAD software that prepares the most efficient marker and places the garment pieces on a length of fabric as closely together as possible. It also locks the grain orientation of each piece unless an override function is used to adjust them and can detect errors and stop automatically and also root cause can be found quicker.It acts as poka-yoke device or mechanism that either prevents a mistake from being made or makes the mistake obvious at a glance.

Hands et al (1997) reviewed the evolution of CAD/CAM technology and reported that in the 1960s, several brands of computers were introduced onto the market, and textile engineers started to think about CAD. These machines, called mainframes, were gigantic devices. Punch-cards were prepared and then processed in the computer using the technology of the time. The result of the work that was ordered could only be obtained the next day or sometimes the following week. These methods, such as transforming the work of the designer into the punches on the cards and arranging their positions in jacquard weaves and knits, required long and arduous efforts during routine textile processes. This process was first put into practice at MIT in the years 1963-64. In the beginning, the data was loaded onto central computers simultaneously. After some time, graphic terminals were developed, which proved to be a great help. The real development, on the other hand, which paved the way for creative designing, started with the introduction of interactive computers. Mini-computers started to be used by small groups of people, and our modern-day PCs formed strong networks with one another. It became possible to see on the screen what the designer had in mind at a period no later than the time he would have spent if he had drawn the whole design himself.

By the end of 1993, many CAD/CAM vendors had automatic marker-making capability which enables an automatic marker-making system to compact patterns (by placing the pattern pieces as closely together as possible) in only 30-45 seconds has been developed almost as efficiently as an operator does. However, it needed some corrections by the operator so as to improve cutting quality and fabric usage productivity.

Gupta (2001) pointed out that to meet the rapid changes in market forces, increased competitiveness, productivity, enhanced creativity, product flexibility, higher quality, economical in terms of time, cost, fabric and resources has led to the slow but steady proliferation of CAD in India. Hosiery manufacturers needed to invest in new CAD and CAM technology. ***Kansal et al(1994) and Stephens (1999)*** revealed in their article that computers had changed the production time and cost of knitting .CAD systems permit designers to see a pattern or garment design without having actually knitted a sample. Knitting machines tied into the computerized design accept patterns and stitch changes in minutes rather than hours allowing greater freedom for experimentation. ***Arun(2000)*** was of the view that CAD facilitates number of freedoms to the textile designer namely freedoms of chores, freedoms of geography, freedoms of visualization, freedoms of additional sources , freedoms of ease and speed in sampling and freedoms of information flow to and from the organization. Prices of CAD systems are decreasing and user base is broadening. CAD systems should be considered an instrument of assistance rather than replacement techniques.

Groover et al.1984 believes that now CAD is no longer considered as just a tool for design department but as an integral part of the entire business process as new softwares are developed keeping in mind the needs of designers for design creation and visualization of the designs. It also allows the designers to use, recombine or change elements, applying colors and prints to garment designs onscreen either by scanning a fabric swatch or the whole garment. Experimentation with the size, shape, orientation, hue and intensity is possible which further can be communicated to other locations via fax or the on line computer system. As it provides digital images for advertisement and catalog, buyer's approval from around the world for manufacturers without even leaving their offices becomes possible. Even for making first pattern CAD system speeds the process of making a production pattern and can improve accuracy. It also automatically grades the pattern to all the sizes using CAM and further gets linked to marker allowing markers to visualize a greater variety of possible arrangements of the pattern pieces keeping track of the percent of material utilization ,matching stripes and plaids, automatically overlapping and tilting it improves material utilization. The computer generally helps the marker maker achieve 1 to 4% higher fabric efficiency and also transmits markers electronically to remote factory locations. This technology is moving in the direction of greater integration of design and manufacturing -two activities which have traditionally been treated as distinct and separate functions in a production firm. Ultimately, CAD/CAM will provide the technology base for the computer integrated factories of the future.

Dehia(2005) gave an insight of technologies in garment manufacturing. She reported that CAD/CAM in fabric and garment design holds extreme importance in cutting room for pattern making, grading and marker making, spreading, cutting and fusing and in the sewing room for line and assembly system of manufacture, sewing machines, irons and presses and material handling. Various CAD systems like textile design, pad, embroidery, digitizing, grading, marker systems together have helped to produce apparel anywhere in the world keeping information in electronic form so that it could be sent quickly and efficiently anywhere. A web based automatic *marker planning* service offered by Assyst Bullmer has become a rage as it doesn't involve any overhead or hardware and software costs and only by sending the width of fabric and patterns to their website, the resulting marker is delivered back within 10 minutes. *Latest plotters* systems connected to PC can plot files received via internet. While *spreading machines* are interconnected with with CAD stations creating different types of spread i.e. face up, tubular, traditional face to face or face to face without end catcher for knitted fabric leading to significant time and material savings and eliminating the risk of error.

The *cradle feed system* provides fast loading of rolls for high flexibility and ensures tension free lays and perfect fabric alignment. Spreading CAM machine such as Shelton, Assyst Bullmer helps accurate, tension free spreading, leading to high quality spreads, reduced handling and increased productivity. Pin table technology for spreading on which there are several pins are operated with the help of air pressure and the fabric is spread on it. The next layer is spread on it and fixed with pins, so mismatching with checks does not occur. In Automatic Spreading Machines, the fabric is laid on the table automatically and it auto stops, returns to starting place and when in emergency it stops and the laid cloth won't get pulled. Automatic Defect Detector, reduced noise, electronically controlled feed cradle, twin opposite feeding preventing delicate fabrics being caught under tapes and development of new on line relaxation system for elastone, delicate, thick and heavy fabrics were some of the added advantages.

Cutting technologies provided by Lectra, Tukatech, Tesan, Autex, Turbocot, Gerber, Eastman and Ramsons increases accuracy and precision in built inkjet part identification that automatically prints barcodes on the material leading to quality cut blade deflexion controller automatically and optimizes cutting pitch so that all the plies are cut identical .Special cutting solutions are there for elastomeric ,delicate denims introducing dual beam cutter having two heads for maximized productivity. Time management software analyses production time helps edit reports and flexible cutting parameters which allows possibility of alteration and shade mixing machine ensures no mixing of different shades of the same colour of fabric during assembly were the added features.

Srivastava et al(2004) and Kaur et .al. (2009b) reviewed various CAD softwares, Computer aided Designing included Textile designing ,garment pattern designing,3D scan & drape software packages which help the designers to experiment with textures, colors and patterns for producing the perfect designs along with the availability of sketch backgrounds ,tools for repeating patterns, texture mapping and product renderings and are integrated with looms, dobbies and jacquards.e.g.Corel Draw,Vision 3D,Karat CAD,Adobe Illustrator, Adobe Photoshop,TEX Illustrator, TEX Edit , TEX Develop, TEX Trace, TEX 3D,Fashion CAD,Investronica,3D Studio Max,Designer,Tuka studio modules(colour separation, weaves, knits,story boards, Repeats, colourways) Tuka Design,Tuka Mark, Accu Mark, Auto CAD,Lectra are effectively used for pattern designing, grading and marker layout. Computer aided manufacturing have entered in many departments like plotting, spreading, cutting, sewing assembling, surface ornamentation i.e printing and embroidery. Lectra, Gerber, Zuki are the few companies catering to the demand.

Arun (2001) , Somasundaram (2004) and Parthasarathi (2010) compared existing manual modes for a complex design complexity with CAD facility and reported that manual designing requires one week to four weeks time depending on design complexity But with CAD integration, this process duration can be shortened to a few hours. They conducted an experimental procedure to assess the improvement in productivity and quality by comparing various work processes involved in manufacturing men's full sleeve casual shirt through CAD/CAM and manual manufacturing. The authors found out that the use of CAD leads to reduction in pattern designing, grading, and pattern alteration time by around 90% (time required by CAD unit was 36.81 min while that of manual unit was 350 minutes), greater flexibility in pattern designing, grading and marking ,reduction in waste up to 10%,increasing quality of cutting room by around 50%and reduction in sample making time by 60%(5 days by CAD unit and 10 days by manual unit),increase monthly productivity by 75%(productivity /day in CAD unit was 15,856while productivity /day in manual unit was 4,013) and reduction in lead time up to 45 days(CAD unit 39 days& manual unit 55days). It was proved that CAD/CAM increased the production with excellent quality of the material in the apparels. So, it was advisable for all the suppliers, who have running orders throughout the year to implement the same to enhance their highest profit and to maintain their delivery in advance.

Another experimental comparison was conducted by ***Ondogan and Erdogan (2006)*** in pattern and marker making using CAD and manual methods with regards individual course steps and total time taken to design pattern to marker layout of 4 different model shirts each having different set of pieces. The steps followed were main size pattern preparation, main size pattern checking and correction, putting necessary allowances on patterns, main size pattern size setting, size set patterns check and correction, Arrangements prior to marker making, Marker making and correction and Marker plotting. In the preparation of main size patterns, the manual system found to be superior due to the fact that the main size patterns are prepared in advance manually and then digitized. These methods were preferred since the system operators do not have sufficient qualifications in steps such as checking, correcting and putting necessary allowances on main size patterns, no significant difference was found between the two methods, due to effects of personal skills and productivity in particular. CAD systems were found to be advantageous in this step of grading main size patterns, checking graded patterns and making arrangements prior to marker making procedures. During marker-making preparation, checking, correcting and plotting procedures, neither method was found to be superior to the other. In assessing the total times for all stages, CAD was found to be favorable. Marker length prepared by CAD was shorter in model, which had less number of pattern pieces and that the difference between the marker lengths prepared manually and by CAD increased in favour of CAD as the number of patterns increased and the size of patterns decreased.CAD investments was considerable with respect to savings, not only in labour costs but also in fabric usage, which amounts to 60% of total garment costs.

Kaur et al (2009a) conducted a study on automation and CAD/CAM adoption in designing by knitwear industry of Ludhiana. Data were collected from 110 knitwear units of Ludhiana consisting 56 small, 29 medium and 25 large scale knitwear units by using interview schedule. The sample was selected according to the probability proportional to size by following stratified sampling technique. The results revealed that for fabric designing, automatic machines, computer aided designing systems and manual sketching were used whereas in garment designing, manual sketching and CAD system were used. For the designing of knitwears, various softwares like Corel Draw, Adobe Illustrator, Adobe Photoshop, Fukuhara, Universal, Stoll, Gerber, Autocad and Shima Seiki were used. Rapid generation of new styles, value addition, cost reduction, fast modification of design etc. were the main reasons given for using automation and CAD/CAM systems in knitwear designing.

RESEARCH GAPS:

1. Number of studies has been conducted on Lean manufacturing implementation in automobile and electrical and electronic industry but only few efforts have been made to study its implementation in knitwear industry.

2. There is a lack of research evidence regarding the impact of lean practices on production improvement performance, carbon foot printing reduction in Knitwear industry.

3. Researchers are mostly silent on this very important area of production philosophy. This lean concept remains unexplored and new to the Knitwear sector.

4. Only few studies concentrated on the issue of lack of awareness of lean manufacturing, non compliant firm owners regarding new production concepts and latest technologies and their unwillingness to upgrade to modern and new technologies.

This research will attempt to bridge this gap. The present study will carefully and systematically investigate the lean practices in the Knitwear firms and give an assessment of their performance improvement.

Keeping in view the importance of lean manufacturing and not so much work has been done or documented earlier in Northern India, the present study has been designed to determine the existing lean manufacturing implementation status in the knitwear apparel industry in Okhla and Ludhiana as well as how it can be used to its full potential, further leading to making the knitwear industry more globally conscious and competitive. Thus this study is proposed to identify the following objectives.

OBJECTIVES:-

1. To systematically study the principles, tools and techniques for implementation of lean manufacturing.

2. To comparatively analyze assembly line production in the lean manufacturing compliant and non- compliant knitwear units in Okhla and Ludhiana with special reference to CAD/CAM technology.

3. To assess the driving factors and key constraints which motivate and inhibit the implementation of lean manufacturing in knitwear apparel manufacturing units.

4. To identify the processes contributing to Carbon footprint generation and calculate it in compliant and non- compliant knitwear units in Okhla and Ludhiana.

5. To comparatively assess the performance improvement after Lean manufacturing implementation among compliant knitwear units of Okhla and Ludhiana.

6. To disseminate the compiled information regarding lean manufacturing, carbon footprint and CAD/CAM technology through workshop in selected non –lean compliant knitwear units in Ludhiana and assesses the gains in knowledge through Questionnaire cum Interview schedule post workshop.

HYPOTHESIS:

1. Lean manufacturing implementation will lead to a significant difference in the production level, production cost, quality, Carbon footprint generation and lead time required in garment production processes.
2. Participation in workshop will lead to increase in knowledge of the participant.

LIMITATIONS:

1. The study will be confined only to knitwear units of Okhla(Delhi) and Ludhiana (Punjab).
2. To obtain in-depth information for assessment, number of units will be limited to five each (compliant and non- compliant knitwear units of Okhla and Ludhiana).
3. Information regarding the lean manufacturing implementation will be collected from Managing Directors and Production Managers and Executives of various units.
4. Awareness workshop will be held in selected non-Lean manufacturing compliant units only in Ludhiana.
5. Only units manufacturing T-shirt will be included in this study.

6. Compliant units using CAD technology and Non –Compliant using manual methods for pattern development, grading and layout will be taken.

METHODOLOGY

The study will use both ***primary and secondary data*** but it will be mainly conducted with the help of primary data collected by conducting personal interviews through a semi- structured interview schedule using field study, observation and time study method. However, the study will also be encircled with the help of secondary data wherever needed**.** The sources of secondary data will be - the District Industries Centre, Ludhiana and Delhi, Ludhiana knitwear associations, Small Industries Development Bank of India (SIDBI) and Apex cluster development Services Pvt Ltd.

Keeping the objectives in mind, the study will be carried in following phases-

Phase-1 Exploratory phase

Phase-2 Collection of data and its analysis

Phase-3 Dissemination of information

RESEARCH PROCESS FLOW CHART

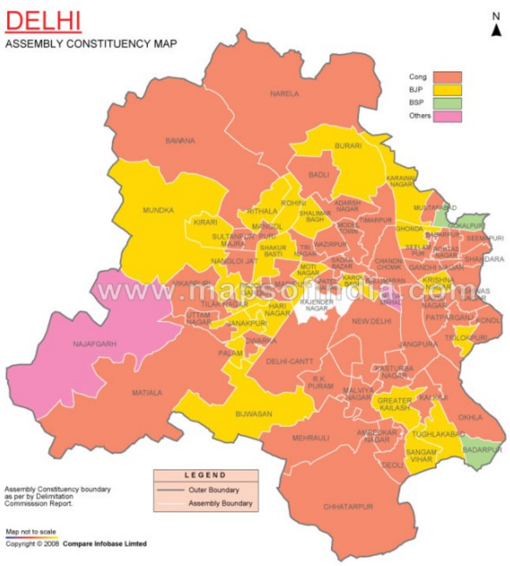
PHASE 1:

In the first phase of the study, the following methodology will be undertaken for the collection of data with the objective of the study:

1. Locale of the study
2. Sampling Design
   a) Sample size
   b) Sampling procedure
3. Selection of the research method
4. Development of research tool

1. **LOCALE OF THE STUDY**

The locale of the present study will be confined to the Knitwear Apparel cluster of ***Okhla(Delhi)*** and ***Ludhiana(Punjab)***. **Okhla in Delhi** is the oldest synthetic knitwear cluster and is home to more than 3,000 industrial units, the Okhla Industrial Area Phase I and II, together form one of the largest industrial areas in the country. And along with Phase III, separately referred to as Okhla Industrial Estate -- Okhla Industrial Area is located in the centre of the National Capital Territory. Whereas Ludhiana is not only Punjab's industrial capital but an important upcoming Knitwear and Apparel cluster. It is famous for woollen and synthetic knitwear manufacturing. It is known as Manchester of India contributing to almost 80% of the total woollen /acrylic output of the economy.



okhla

MAP OF DELHI **MAP OF PUNJAB**

Plate No.-1 **Plate No.-2**

2. SAMPLING DESIGN

Five lean manufacturing compliant of **Okhla** and **Ludhiana** each will be purposively selected from units registered under Lean manufacturing competitive scheme(LMCS) under National manufacturing competitive programe (NMCP) for micro small medium enterprises(MSME) and number is considered adequate and manageable to obtain the required data. Five non-compliant knitwear units will be randomnly selected on the basis of investment in plant and machinery ranging from Rupees five crores to ten crores.. According to Small-Medium Enterprises (SMEs) Development Act, 2006, medium scale unit have the investment in plant and machinery between Rupees 5 crores to 10 crores,small scale unit have it from Rupees 25 lakhs to 5 crores while micro units's investment is below 25 lakhs (Gill,2010).This selection has been done intentionally keeping in mind the cost of the new production techniques involved.

3. SELECTION OF METHOD

A pilot study will be done in Okhla and Ludhiana to identify lean manufacturing compliant knitwear units as this is a relatively new development in the apparel sector. Observations and field study are considered most suitable research method in order to meet the specific objectives of the study.

4. DEVELOPMENT OF RESEARCH TOOL

An interview schedule will be prepared to collect data regarding the concept of lean manufacturing practices from the various Lean consultants registered with union ministry of micro, small and medium enterprises(MSME). To ensure the positive response, the objectives of the study will be explained to the respondents and they will be assured that the information provided by them would be kept confidential and would be used for the purpose of this investigation only with a view to draw general conclusions. They will further be assured that specific information pertaining to their particular units will not be disclosed to anybody. Objectives of the study will be explained to the management in the selected Lean manufacturing compliant knitwear units. The data will be collected personally by the researcher through personal interview by administering the ***Interview schedule*** to the senior officers of Industrial engineering, production managers, supervisors, administrative heads, and marketing heads after taking telephonic appointment. Their co-operation will be vital to the collection of the data. Before designing schedule for this study, an interview with President of Ludhiana's knitwear associations (Knitwear Club, Apparel Exporters Association of Ludhiana (APPEAL), Readymade Hosiery Manufacturers Association (REHMA), Bhadur Ke Textile and Knitwear Association & Knitwear Development Group (KNIDGRO) will be arranged. A discussion will be carried out upon the Indian knitwear (hosiery) manufacturing processes, machinery, management practices, environmental wastes generated, use of technology, electricity and fuel consumption so that its content could be validated and no gaps are left while collecting information. **Observation technique** will be used to study the assembly line, Implementation of lean manufacturing tools and principles and general working environment in terms of the provision and use of natural light, ventilation in the selected five compliant and non-compliant Knitwear units in Okhla and Ludhiana each. **Field study** and interview will be used to get detailed know-how of processes being carried out at various levels in various departments which act as sources of carbon dioxide production.

PHASE-2

In the second phase of the study,

a) *Comparative analysis of performance improvement after lean implementation with CAD/CAM:*

The tools used will be interview schedule, time study and observation .
The interview schedule will focus on the lean journey of the units and and time study will be used to comparatively analyze and assess the effectiveness of the lean manufacturing, pre and post implementation in individual departments of all Knitwear units.

i. ***Productivity level***:
Production of finished pieces per day (for 7 days continuously).
will be taken into account and recorded when the units are running to its fullest capacity.

ii. For finding ***the time required*** in designing patterns, digitizing, grading, marker making, spreading and cutting:
Particular time required for each operation will be observed –

- Sketch preparation(for spec sheet)
- Designing patterns/ digitizing
- Grading
- Marker making
- Spreading/Layering
- Cutting

By using a stopwatch and 5 sets of readings will be taken. Average time taken then will be calculated.

iii. For finding ***Waste percentage*** in marker layout and spreading: The fabric consumption for 500 T-shirts will be calculated. Set of readings will be taken per day (for 7 days continuously). Average waste taken then will be calculated.
Percentage realization will be calculated and compared.

iv. For finding the effect on ***quality*** of the garment : Inspection sheets will be used for in process marker, spreading & cutting garment inspection to check the defects in one week (for 7 days continuously) of 10% of the the garment parts in the marker on the basis of following quality particulars alongwith review of quality specification sheet from time to time:

- Correct grain lines
- Pattern parts missing
- Mixed parts
- Pile direction of the fabric.
- Dimensionally accurate garment that do not exceed specified tolerance.
- Spread at correct tension /creasing
- Consistent and accurate marking-Skimpy markings/generous markings
- Not correct direction
- Splicing & Misscuts
- Matching of pattern, stripes, and checks.
- Notch placement & size
- Drill hole size
- Cutting edges-Fuzzy, ragged, serrated, fused, frayed cuts.

b) ***Carbon footprint generation after lean manufacturing implementation :***

Life cycle assessment (LCA) method will be used to calculate the carbon footprint generation by usage of fossil fuels, water, chemicals and waste generated through processes in various departments after lean manufacturing implementation.

PHASE 3

1. Information regarding lean manufacturing, carbon footprint and CAD/CAM technology will be compiled from the analysis of data in the earlier phase. Dissemination of the information will be done through workshop, organized in five selected non compliant knitwear units. Units will be selected randomly from the list of non compliant knitwear units in Ludhiana. The workshops will be conducted through Power Point presentation attended by General Managers, in charges of production, sampling. Merchandising departments and supervisors of various departments of the company.

2. Assessment in the gains of knowledge through interview questionnaire schedule, where participants will be personally interviewed and questionnaire will be filled after attending workshop.

3. Assess the practicality of knowledge gained by personally visiting the units and interviewing the owners, two month after holding the workshop.

ANALYSIS OF DATA

The data collected will be edited and analyzed carefully. Simple average and percentage techniques will be used to summarize the data as follows:-

a) ***Processing of data*:** The obtained data will be summarized by
- Coding
- Tabulating

b) ***Presentation of data***: The coded and tabulated data will be presented in following manner:
- Percentage
- Frequency
- Tables
- Charts
- Flow charts
- Graphical presentation
- Descriptive analysis

Mean and standard deviation will be calculated and checked from T-statistic value whether it is lying in acceptable region or not. The data gathered will then be analyzed by using appropriate univariate and multivariate statistical tools.

Formula of Mean: It is used to find out the average value of the observations

Sample Mean	Population Mean
$\bar{x} = \frac{\Sigma x}{n}$	$\mu = \frac{\Sigma x}{N}$

where Σx is sum of all data values

N is number of data items in population

n is number of data items in sample

Formula of Standard deviation: It is used to find out the deviations of the items from their mean.

$$\sigma = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n}}$$

σ = standard deviation

Σ = sum of

x = each value in the data set

$\bar{x}$ = mean of all values in the data set

n = number of value in the data set

Formula of Chi square test: It is used to find out the association between 2 or more attributes

Observed individuals with a given phenotype

Expected individuals with a given phenotype

Greek letter "chi"

$$X^2 = \sum \frac{(o-e)^2}{e}$$

Summation => add together a term for each condition

Formula of T-test: It is used to compare the mean difference of output of two sample units

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S}\sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

$$S = \sqrt{\frac{\Sigma(x_1 - \bar{X})^2 + \Sigma(X_2 - \bar{X}_2)^2}{n_1 - n_2 - 2}}$$

where

$\bar{X}_1$ = Mean value of the first sample

$\bar{X}_2$ = Mean value of the second sample

n_1 = Size of first sample

n_2 = Size of second sample

S = Combined standard deviation of two samples

The degree of freedom is equal to $n_1 - n_2 - 2$.

JUSTIFICATION OF THE RESEARCH:

1. This research will help in understanding the lean manufacturing concept and tools and their practical application in apparel sector.
2. As shortage of labor is the major concern for Ludhiana knitwear industry as it is dependent on the migrant labour which due to various national employment schemes like the National Rural Employment Guarantee Act (MNREGA), 2005, have reduced. This study aims at showcasing the advantages of the lean manufacturing which can ultimately eradicate the problem of labour shortage.
3. This research will not only explore the new problems faced while introducing new production philosophy into the organization but it will also factors influencing its successes and failures within knitwear units.
4. This research will explore how well-driving and inhibiting factors that have been documented in the literature actually work in Ludhiana and Okhla knitwear cluster and also discover factors that are unique to these cities.
5. The research will bring awareness regarding impact of new production techniques on production, lead time and efficiency. It will also help the business leaders to take a stand on climate change which will produce benefits in the form of customer loyalty and it may help capture new markets.
6. It will facilitate to interpret space, light and other requirements of employees thus leading to improvement in their working conditions and health by providing better options with reduction in carbon footprint.
7. This research will also be helpful to government in development of production strategy for organizational effectiveness through application of various lean manufacturing tools.
8. This research aims to present guidance to Knitwear manufacturing units in implementation of lean manufacturing tools according to their unit requirement.
9. This research will also be an effort in the direction of sensitization to change the mind of firm owners and making them sensitive towards both the visible and invisible factors that contribute to carbon footprint during manufacturing process. It will bring awareness among people especially manufacturers regarding global warming.

10. Calculating Carbon footprint generation will be valuable initiative towards reducing climate change impact. Hence, this study will help to develop pathway by shifting to carbon neutral technologies and promotion of energy efficient method.

11. It hopes to bring behavioral changes in buyers leading to change in choices by moving towards carbon neutral suppliers.

GLOSSARY

1. **BALANCED FLOW:** It is the most effective and efficient way to deliver goods and services for customer. The focus is on removing process waste through operator and machine balancing as per calculated takt time and layout design.

   Operator required=Time required for operator/takt time.

2. **CAD:** Computer aided design. It is also called Computer aided drafting or Computer aided drawing. It includes industry specific design systems or devices performing high-tech services such as garment design, pattern preparation, pattern grading and marker making.

3. **CAM:** Computer aided manufacturing. It includes Computer hardware & software systems that grade and make markers electronically and has a capacity to do computer controlled cutting and use lasers for specialized cutting.CAM systems include **i**ndustry specific manufacturing systems or devices performing high-tech services using computerized sewing machines, fabric spreading & cutting systems, and mover systems used during the sewing process of apparel production.

4. **CARBON FOOTPRINT:** It is the total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a process or product. Carbon footprints are typically calculated to include all green house gases and are expressed as CO_2 equivalent measured in kilograms or tones.

5. **CELLS:** Proper placements of machines.

6. **HOISERY:** In the generic sense, all types of knitted fabrics and goods. In restricted sense, it is knitted coverings for the feet and legs.

7. **KAIZEN:** Japanese word for continuous improvement.

8. **KANBAN:** An information system that controls (pulls) required parts in required quantities in required time.

9. **KNITTING:** Knitting is second most common technique of constructing textile structures by forming a continuous length of yarn into columns of vertically intermeshed loops .Types of knitting are warp and weft knitting which is explained as follows:-

a) Warp knitting: It is considered as a combination of weaving and formed by interlacing loops of yarn vertically down the length of the fabric. Tricot and Rachel warp knitting machines produces single and double knits like dress materials, lingerie, laces and nets.

b) Weft knitting: It is formed when yarn is interlooped course-wise or across the fabric i.e. one yarn forms successive loops on the same course. Flat bed, fully fashioned and circular weft knitting machines produces plain, rib and tubular or circular knits like outer wear under garments, home textiles and functional textiles.

10. **KNITWEAR**: A term is applied in generic sense to all knitted outer garment except stockings and socks.

    a) **Knitted fabric**: It is manufactured by weft or warp knitting machines.
    b) **Knitted garment**: It is manufactured by panel knitting, cutting & assembling or fully cut garments made from knitted fabrics.
    c) **Complete knitted garments:** It includes sweaters, hosiery and underwear.

11. **LEAN:** The term leané denotes a system that utilizes less, in term of all inputs , to create the same outputs as those created by a traditional mass production systems, while contributing increased varieties for the end customer. It refers to systematically identifying and eliminating waste through continuous improvement using the full production with a view to get perfection.

12. **LEAN MANUFACTURING:** It is a systematic approach for eliminating the process waste through continuous improvement. The basic idea behind the lean manufacturing system, which have been practiced for many years in Japan, are waste elimination, cost reduction, and employee empowerment.

13. **ONE PIECE FLOW:** To minimize work in progress, operators focus on completing one part through the operation before starting the next part.

14. **POINT –OF- USE- STORAGE (POUS):** Locate all parts, raw material and understandable at a glance.

15. **QUALITY AT SOURCE:** Error proofing devices are used.

16. **SINGLE MINUTE EXCHANGE OF DIES (SMED):** A system that allows the mixing of production without slowing output of creating higher costs from waste setup.

17. **STANDARDIZED WORK:** Jobs are broken down into elements and examined to determine best and safest method for each.

18. **TAKT TIME:** It is the rate at which the customer requires the product or a process needs to produce to achieve customer demand. If products are made faster than takt time then it leads to overproduction and if slow then outcome is mean downstream shortages or the need for overtime. Pace is set as per takt time to ensure timely delivery.

Takt time=Available work time/Amount of product required (customer demand)per day.

19. **TEAMS**: Departmental barriers are eliminated and replaced with cross –functional teams.

20. **TECHNOLOGY**: It is the usage and knowledge of tools, techniques, crafts, systems or methods of organization in order to solve a problem or serve some

purpose.It is derived from Greek word τεχνολογία (technología),τέχνη (téchnē) meaning "art, skill, craft“ and -λογία (-logía) meaning "study of-"

21. **TOTAL PRODUCTIVE MAINTENANCE /(TPM)**: Consist of a companywide equipment maintenance program that the equipment life cycle and require participation by every employee.

22. **VALUE STREAM MAPPING (VSM):** It is a method of visually mapping a product production path, including materials and information flow, from dock to stock. It takes a holistic look at the activity required (both value added and non –value added) to move a product from raw material to customer.

23. **WASTE:** From the customers' point of view process waste is anything which does not contribute the product transformation that is all the non value added activities in the process line is known as waste.

24. **WORK PLACE ORGANIZATION (5S):** Sort(seri), set-in-order(seiton), shine(seisco), standardize (shitsuke) and sustain(seiketsu).

25. **WTO:** General Agreement on Tariffs and Trade (GATT-1994) of the World Trade Organization (WTO) disciplines was embodied in the Agreement on Textiles and Clothing (ATC) which was negotiated during the Uruguay Round of talks and was being implemented in stages over a period of 10 years. Abolition of quotas on specified products to be 16 per cent of the total volume of imports into the quota countries in1990 on the date of commencement of the agreement on 1st January, 1995; 17 per cent on 1st January, 1998; 18 per cent on 1st January, 2002; and the remaining 49 per cent on the final day of the transition period i.e. 1st January, 2005.

LIST OF PUBLICATIONS

1. Kaur, Prabhjot and Joseph, Ruby.(2010). A Study of the Liturgical and Non Liturgical Vestments worn by Catholic Christian Priests. *Research Journal of Humanities and Social Science.* Jan-March,(1), 30-36.

2. Kaur, Prabhjot and Joseph,Ruby.(2010). Study on Liberlisation and Incluturation in Vestments worn by Catholic Christian Priests. *Diviner* . Jan-June, (7) , 61-72.

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4. Kaur, Prabhjot and Joseph,Ruby.(2010).Dying art of Punjabi Jutti in Patiala. Asian Journal of Home Science .5(2), 226-227.

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6. Kaur, Prabhjot (2011).CAD/CAM technology: A boon to Apparel industry. *Gyan Management* .5(1),157-168.

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8. Joseph,Ruby, Kaur,Prabhjot and Mehtab,Shazia (2011). Lattice smocking techniques: An innovative approach to smocking. *Asian Journal of Home Science.* 6(1), 5-11.

9. Joseph,Ruby, Kaur,Prabhjot and Verma, Anubha .(2011).Designing of shrugs using decorative knot craft Macramé. *Textile Trends* .24(5), 35-39.

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