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Assessment of Quality Management System and Intervention of Lean Six Sigma Tools in a Ready Made Garments (RMG) Factory

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CERTIFICATE OF RESEARCH

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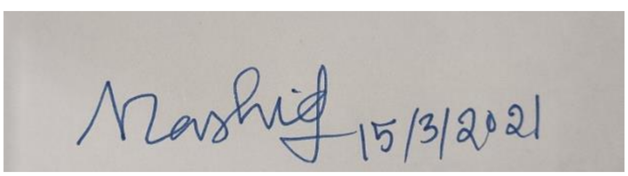

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DECLARATION

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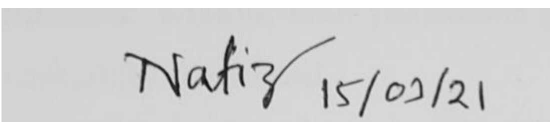

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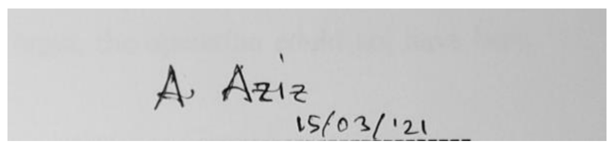

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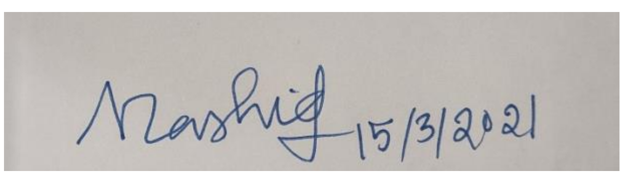

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ABSTRACT

Quality Management Systems have become an integral part of modern manufacturing processes. Lean Manufacturing approach, Six Sigma Methodologies and the various tools of Lean Six Sigma approaches are increasingly being applied to improve and sustain the production process. Pareto Charts, Cause and Effect Diagram, 5 Whys Analysis, Control Charts, etc. are some of the most popular tools that modern industries are implementing in order to maximize their production rate and minimize waste and non-value-added activities.

Implementation of Advanced Control Charts is one the innovative means of determining the status quo of the production line and to recognize the trends associated with a particular production line. But in the current perspective of the manufacturing industries of Bangladesh, this invaluable process control tool is not being used to full effect. Also, the root cause analysis tools like Cause-and-Effect Diagram, 5 Whys Analysis, etc. are scarcely used in the industries, leading to fewer effective measures being taken to mitigate major defects and problems.

In this study, initially we reviewed a number of advanced control chart, in order to find the most suitable one for implementation in the manufacturing industries of Bangladesh. Then a P-chart was implemented in the sewing department of a renowned RMG industry of Bangladesh to determine the defect rate and trend. After that various quality control tool like Pareto Chart, Cause and Effect Diagram and 5 Whys Analysis were implemented to find out the root causes of the defects and to provide some effective corrective action plan. Finally, a questionnaire survey was undertaken among the industry leaders to determine the best suitable lean six sigma tool for implementation in the RMG industries of Bangladesh.

INTRODUCTION

No one can deny the importance of quality in the modern world competitive market where only those survive, who can provide better quality products. Edward Deming explains “The Deming Chain Reaction” in his book “out of the crisis” in 1986 (Deming, 1982). According to him “when the quality is improved, the cost decrease (because of less rework, fewer mistakes, fewer delays and better use of machine, time and material), when cost decrease productivity improves, when productivity improves, they capture the market with better quality & low price and in this way, they stay in the business, enhance their business and provide more jobs”.

The rapidly changing business behaviors, such as global competition, declining profit margin, customer demand for high quality products, product variety, reduced lead-time etc. necessitate the manufacturing industries to adapt the changing business conditions. The demand for higher quality products with lower price is increasing. The competitiveness in markets and consumer pressure has forced many firms to rely on global sourcing for business advantages (Su, Gargeya, & Richter, 2005). As a result, manufacturers need to improve their process through producing right-first-time-quality and reduction of resources losses. Companies are concerned about continuous improvement of their productivity, product quality, working environment, operational performance etc. to meet internal and external consumers’ demand. In recent years, it has been intensified that implementation of world class strategies such as JIT (Just-In Time) (Lubben, 1988), TPM (Total Productive Maintenance) (Nakajima, 1988), Lean manufacturing (Reeb & Leavengood, 2010), Agile manufacturing (Yusuf, Sarhadi, & Gunasekaran, 1999), Supply chain management (Handfield & Nichols, 1999), TQM (Total Quality Management) (Dean & Evans, 1994), Six sigma (Evans & Lindsay, 2014), Time-based strategy of Quick Response (Kincade, Cassill, & Williamson, 1993) etc. lead the companies to achieve continuous improvement of productivity, high quality products, the shortest possible lead time, improved operational performance etc.

According to Geoff Tennant, “A systematic continuous improvement process can largely minimize the defect percentage and increase the productivity” (Tennant, 2001). On the other hand, most of the garment factories in Bangladesh have not any particular quality management system. In order to minimize the defect rate, it is very important to follow a particular methodology in their quality management system.

Background of the Study

Readymade garment industry is highly dependent on several factors such as quality of the product, manufacturing lead time, production cost, quality of the available raw materials, workers efficiency, production managers' supervision etc. Various product defects hamper these factors. In garments factory, repairable defects lead to rework and non-repairable defects leads to rejection. To minimize the rework rate, factory personnel need to keep his eyes on defect rates from the beginning. When rework and rejection occur, a company loses profit margins, negative impact on production schedule, huge possibility to cancel the order from the buyer and increasing interest rate of bank loan. In short, rework rate creates a negative impact on production rate and rejection causes losses of huge profit margin for the company. To be powerful in defects and rejection reduction, it is essential to establish and keep clear, complete and modern-day written information of inspection and check processes for each operation. Those facts should identify standards for popularity/rejection. Inside the apparel production industry, main uncooked cloth is material; others are extraordinary kinds of trimming and add-ons. Operational wastages in the clothing production system are top surface transform, printed label remodel, sewing defects, pinhole rework, cloth defects, wrong fly shape, and different reworks. To gain the general goal in minimizing defects and rejection of completed merchandise its miles needed to set up document and keep a machine capable of ensuring that products conform in overall to requirements specifications. This will be required at each level of manufacture. Records have to be maintained to offer goal evidence that the required requirements have been met. Additionally, need to employ a control representative preferably unbiased of other functions to be accountable to oversee the overall manipulation gadget and inspection at every level of manufacture. The person appointed has to have the vital authority to execute any action associated with accomplishing the preferred popularity of the product. To be powerful the system requires planned periodic overview by means of senior management to ensure that its effectiveness is maintained.

Statement of the problem

In this thesis study, we tried to implement a number of quality control tools in an RMG industry of Bangladesh. We also tried to find the best lean six sigma tool for implementation using Analytical Hierarchy Process in the present circumstances of the RMG industries of Bangladesh.

Objectives of the study

Objectives of our study/thesis are:

1. Studying Advanced Control Charts
2. Studying Quality Control Tools
3. Implementing some Quality Control Tools to identify the defects and root causes of the defects
4. Using the acquired knowledge from the defect identification and the framework of the Quality Control Tools to provide feasible and effective remedy
5. Collecting statistical data from RMG industry leaders who have experience on Quality Control Tools (specially on Research & Development level)
6. Finally, finding the prominent Lean Six Sigma Tool for implementation in RMG industries of Bangladesh using AHP.

Significance of the study

Defect in the garments industry is a common phenomenon that hampers the smooth production rate and focuses on poor quality products having an impact on the overall factory economy. Minimization of defects is a must in quality and productivity improvement. Rework is a vital issue for poor quality product and low production rate (Islam, Khan and Khan, 2013). Reworks are the nonproductive activities focusing on any activity that customers are not willing to pay for. Nonproductive activities describe that the customers do not consider as adding value to his product. By reacting quicker in minimization of reworks to make a product as per customer demand with expected quality, the company can invest less money and more costs savings (Islam, Khan and Khan, 2013) (Comfit Composite Knit Ltd. – Youth BD, 2015).

Assumptions

The researcher assumes that the scope of the study remains within the present circumstances of Bangladesh for finding out the best-suited quality management system and tool for the production processes in the RMG industries of Bangladesh.

Limitation of the Study

There are a huge number of RMG industries in Bangladesh. Few engineers are working on the research and development side. The other engineers are serving there in the production process. And the experts who previously served in the production process are transferred or promoted to other functions or joined with some other organizations. Furthermore, industries usually do not allow experts to take part in such research studies due to their confidentiality policy. So, a few experts are available to carryout AHP related surveys.

LITERATURE REVIEW

Defective Items

Defective product is one of the common problems shared by all companies. Usually, a defective product contained in a product produces physical changes that are not in accordance with prescribed standards due to causes in the production process as well as other causes. Disability products may be due to the factors of machines, humans or the environment. Product defects can also cause loss of the company such as cost and production time. Moreover, if many defective products are produced, it will increase the cost for repairs and other expenses. Not only that, defective products also reduce the selling price. In order to cope with product defects each company must have a quality control department that is in charge of checking whether there is a defect of the product before it is marketed.

Waste Minimization

In the contemporary world of manufacturing due to the highly competitive nature of the market, different companies have started to look for different approaches and practices to reduce the wastage of raw materials. Waste minimization plays a very important role in manufacturing industries. Wastage of raw materials affects the price of the product and decreases the profit level of the company or industry. Therefore, industries are continuously trying to reduce operational wastages. Pareto analysis helps to identify different defects and classify them according to their significance. These defects often lead to the rejection of raw materials. To determine possible root causes of rejection, Cause-and-Effect Diagram (CED) is also a very useful tool. It helps to identify, sort, and display causes of a specific problem or quality characteristic. It graphically illustrates the relationship between a given outcome and all the factors that influence the outcome and hence to identify the possible root causes i.e., basic reasons for a specific effect, problem, or condition. The reduction of raw material consumption in manufacturing processes will increase the efficiency as less material will be exhausted, transported, transformed, and disposed. Increasing the raw material efficiency will increase both resource efficiency (to use less material for producing one product) and energy efficiency (to supply, transport and process fewer raw materials per finished product). Developing countries' hunger for raw materials is increasing rapidly. Manufacturing industries have to tackle the challenge of rising raw material prices. "Zero-waste" and "zero defect" approach may result in a 35% cut in raw material consumption in highly automated production lines [IMS, 2020, Roadmap on sustainable manufacturing, Energy efficient manufacturing and key technologies, 15 February 2010].

Control Chart as SPC tool

As quality has become the key issue in sustaining in the modern competitive business market, the manufacturers are more and more conscious about the quality of their products. This has been accompanied by a significant increase in the industrial applications of statistical methods.

Statistical Process Control is a collection of powerful techniques for achieving process stability and improving capability of operating around the target with little variability. Control charts are efficient Statistical Process Control (SPC) techniques to carry out online process monitoring on an important quality characteristic when 100% sampling is not possible. Today, the implementation of control charts in long run processes with large populations is a well-established practice and there is a wide availability of tools to perform SPC.

SPC was pioneered by W. A. Shewhart in the early 1920s. The concept of control charts was first introduced by Walter Shewhart in 1931. In 1939, he created the basis for the control chart and the concept of a state of statistical control, through carefully designed experiments (Shewhart and Deming, 1986). He discovered that some process variation in manufacturing data is natural to the process, while others display uncontrolled variation that is not present in the process causal system. W. E. Deming later applied SPC methods in the US during the World War II, thereby, successfully improving the quality in the manufacturing of munitions and other strategically important products. Deming also introduced SPC methods to Japanese industries after the war. The methods were practiced by many manufacturing and service organizations.

In various studies, implementation of the control chart as a SPC tool is carried out successfully. Sultana, Razive and Azeem (2009) tried to show machine breakdown frequencies and time duration of making cigarettes, as well as the major causes of those breakdowns by using control chart as a part of SPC tools. Semel, Kasputis and Gummeson (1988) indicated implications, not only to manufacturing and quality but also to research programs and product development.

Fouad and Mukattash (2010) focused on monitoring real life data in a Jordanian manufacturing company that specialized in producing steel to identify the key ingredients for successful quality management in any organization. The research attempted to show the intergradations between SPC tools and effective implementation of SPC. Another investigation was by Rahman et al., (2008) that studied eight companies, only four of them fully implemented the SPC system. Their study compared the companies' level of SPC adoption, types of SPC software used, problems encountered and advantages of its application. Ab Rahman et al. (2009) carried out a case study on the implementation of SPC in eight Malaysian manufacturing companies using different methodologies. Finison, Finison and Bliersbach (1993) discussed the fundamental control chart theory in the context of implementing SPC charts in healthcare applications, while Bakker et al. (2008) explained that statistical analysis is necessary when variation exists. Reed and Reed (1997) demonstrated that SPC charts are very useful in monitoring survey data quality.

Chen, Boning and Welsch (2001) noted their introduction of a new eigen space detection strategy, to detect subtle covariance structure change. According to Hanna (2003) SPC is routinely used to monitor different accelerator manufacturing processes, in which, the resulting data is used to initiate actions to preserve consistent and high-quality performance. Rai (2008) reported their work on the characterization of statistical inference at work, to compare SPC as a commonly used technique for process improvement in industries with hypothesis testing. Smith and Chaudhry (2005) noted on their study, the application SPC tools in public transportation services in the Philadelphia area, in the operation and maintenance of a large number of transit vehicles for daily use. Rungasamy, Antony and Ghosh (2002) reported their work on the examination and analysis of implementation of SPC by conducting a survey of 33 manufacturing small and medium enterprises (SMEs). According to their research results, management commitment, process prioritization, control charting, teamwork and measurement system evaluation became critical success factors for successful implementation of SPC.

According to Raymond (1992), the use of analytic statistical analysis versus enumerative statistical analysis for valuating data from experiments and product studies. And also, he tried to generate data to acquire knowledge; analytical studies are conducted with the aim of prediction. Mitra (2016) defines quality, describes the history of the quality control movement, and discusses various aspects of management philosophies for quality improvement. Wood (1994) propose a framework that provides a methodology to implement a quality system for a supply chain process. Beamon and Ware (1998) proposes SPC chart guidelines in service processes. Does, Roes and Trip (1999) also note the need for commitment of top management before the initiation of an SPC project.

Most of this SPC implementation includes control chart as their prominent tool. For example, El-Din, Rashed and El-Khabeery (2006) reported that after analyzing and monitoring the process of steam generation in steel making, some problems were sorted out by using conventional univariate control charts and a single multivariate control chart. Omar (2010) indicated that the main aim in using the SPC charts is to increase consistency wherever possible and to decrease inconsistencies when they happen without unnecessary cost of slowing the mass rating process. For which, control charts are preferred to use. Brannstrom-Stenberg and Deleryd (1999) concluded in their research that organizations that have implemented SPC of their own free will, experience advantages to a greater extent. According to Sower, Motwani and Savoie (1994) the δ chart is an effective technique in addressing the limitations of X charts for short production runs. In conjunction with standard range charts, δ charts can provide effective means to monitor and control processes, which might otherwise be deemed unsuitable for SPC control charting. Later, many researchers have proposed different types of control charts, which can be classified into two categories: variable control charts and attribute control charts.

Advanced Control Chart

While the traditional Shewhart control charts are relatively insensitive to small shifts, the increasing emphasis on variability reduction, yield enhancement, and process improvement along with the success of the basic methods has led to the development of many other advanced level control chart. The advancement of the control chart depends on the two schemes; one is integrating economic design to the charting system and another is to make the charts useful in phase II process-monitoring situations. The addressed procedures are not really new, since they date from the 1950s, but they are generally considered somewhat more advanced techniques than the Shewhart charts.

Some reviews of those chart in literature are given below:

Shamsuzzaman (2005) considered integrated control chart system in his doctoral thesis. He developed the SPC schemes for the multi-stage and multi-stream manufacturing systems. Focusing both on the statistical and economical designs, the studies are conducted in two phases using the X chart in one phase and the joint x&S charts in another phase. In the first part, both statistical and economical designs of the integrated x control chart systems, varying in quality characteristic/process, design variables and schemes, are developed considering only mean shifts. Between the two models of statistical design of the integrated x chart, only the control limits are optimized in the first section (i.e., MSISL, MSDSL) and further extension of optimizing the sample size and sampling interval together with the control limits is carried out in the second section (i.e., MSISN, MSDSN). For the economical designs to measure the cost associated with the SPC schemes, three models (i.e., MEIIN, MEIIM, MEDSM) are developed monitoring single process and integrated, taking into consideration not only the whole probability distribution of the mean shifts that are modeled through the three-phase SPC scenario but also the optimal deployment of manpower and using Taguchi loss function to estimate the quality loss. The second part of the project is to design the integrated x&S control chart systems for monitoring process shifts in both mean and variance, aiming to the considerable improvement of the effectiveness of the whole system as well as the product quality. For the statistical designs, VSISL and VSISN chart systems are developed, each of which monitors one of the critical quality characteristics of a product that results in significant superiority to the conventional x&S chart systems. In the next step, two economic models (i.e., VEIIN, VEIIM) for a single process are first designed on random process shifts and their concept is then applied to the economical designs of the integrated VEISM chart system, where the models focus on the optimal deployment of manpower to SPC so that the expected total cost in minimized.

Wu, Shamsuzzaman and Pan (2004) developed an optimization design of ML X control chart in their work, where ML indicates the overall mean of Taguchi's loss function per out-of-control case, which is built as an objective function for the minimization of ML. The design algorithm is proposed based on the data of the process shifts (e.g., mean shifts), which is acquired from the observations of the out-of-control cases within a three-phase scenario. To overcome the inadequacy of previous design procedures, data of mean shifts are collected during the field operation of the control chart so that the performance of the control chart can be improved over the whole range of mean values.

A three-phase operational scenario for statistical process control (SPC) is utilized to establish the probability distribution of mean shift value, which makes the proposed chart superior to two-phase SPC and helps to attain first-rate performance. In this procedure, either non-parametric or, parametric approach is used to design the ML X chart, which can be used in later times to monitor the forthcoming process in phase three, so it is able to continuously update the ML X chart and maintain it as an optimal one. Three different studies are conducted regarding the comparison of ML X chart with three other charts in terms of a normalized value, factorial experiment and economic conditions, where ML X chart outperforms all the other chart and proved to be the most efficient one. Aside from the statistical design of control charts, the design algorithm of the ML X chart links the operating characteristics of the chart with quality cost by adjusting the sample size, sampling interval and control limits of the chart in an optimal manner. Although this economic feature doesn't make the design hard as it only requires limited number of specifications which are easy to handle and computerized smoothly.

Shamsuzzaman et al. (2020) worked with the optimization design of the X chart for monitoring electric power loss through transmission and distribution system. To continuously monitor and control power loss along with the evaluation of the economic performance, Duncan's model is employed to optimize the chart parameters; Sample size(n), Sampling interval(h), Lower control limit (LCL) and Upper control limit (UCL). The optimization process considers random process shifts, characterized by a Rayleigh distribution, to minimize MLC (the overall mean of the cost of power loss per unit time) and ensures that the false alarm rate of the control chart will not exceed the allowable level and extra inspection resources will be avoided. The interpretation of the control chart is done based on whether the plotted point falls above UCL or, below LCL, where the later one would indicate the possible process improvement. As a step of the design and application of the proposed chart, the control chart assumption is verified by showing that the data of power loss are normally distributed as literature suggests. The highly skewed data then, are used to build the control chart in Phase I and monitor the process in Phase II which gives us X & MR chart and, traditional and Optimal X chart respectively. Lastly, the comparative studies based on fractional factorial experiment show that the optimal X chart reduces the cost of power loss by more than 40% compared to the traditional X chart. In the whole process, one of the great challenges in implementing the proposed chart, which is to obtain a sample of power loss data can be solved by the smart grid system.

Except from modifying the conventional Shewhart charts, other alternatives like EWMA or, CUSUM charts are also broadly discussed and utilized in process monitoring and control phase. For example, Shamsuzzaman and Wu (2012) proposed a EWMA chart to minimize the mean number of defective units, denoted as MD, produced per out-of-control case. So, an algorithm for the optimization of the MD-EWMA chart is developed over the probability distribution of the random mean shift based on the sample data acquired during the operation of the control chart. Unlike the mostly used Shewhart-type charts and CUSUM chart, EWMA chart is often superior to the other charts for addressing small and moderate shifts as well as forecasting the observation besides monitoring, which helps the analysts to take preventive actions. The overall process of design is carried out by optimizing the charting parameters n, h, LCL and UCL, and weight factor λ based on the sample data of the mean shifts, manipulated by a parametric or nonparametric approach. The objective function MD is calculated in terms of the minimum allowable in-control ATS0 and maximum allowable inspection rate, where sample size n and weight parameter λ are independent variables. So, the entire optimization design is implemented as a two-level search, in which the optimal values of the two independent variables n and λ are sought, through the first level and second level single variable search, respectively.

Prior to the entire search and determination of all five parameters, MD is calculated from the optimal MD-EWMA chart and the performance of the chart is compared with three other charts. Even though the MD-EWMA chart is more difficult to implement, the produced design tables from the comparison studies shows the excellent performance of the chart in terms of reducing the mean umber of defective units produced per out-of-control case. As the reduction of the number of defective units will directly and immediately lower down the quality cost and benefit the industry, it puts the EWMA chart optimization design in more realistic position from a practical viewpoint, according to this work.

Saha (2017) used CUSUM chart, which shows a prompt and accurate response to detecting small shifts and even minor drifts, to optimize both the economic design of control chart and proper maintenance policy in production system. With this process quality control chart, two types of maintenance policy i.e., imperfect preventive maintenance and minimal corrective maintenance are carried out integrally. In the mentioned integrated economic model, Variable Sampling Interval at Fixed Times (VSIFT) is applied to design the sampling policy for CUSUM chart. As VSIFT is accepted as the most promising sampling policy and it can detect process shift substantially faster, combining joint Average Run Length (ARL) while considering both mean and variance gives the integrated model more effectiveness in determining the optimal values of the seven test parameters such that the average total cost per hour associated with test procedure may be minimized.

To minimize the expected total cost per unit time during the process, a total cost function is formulated incorporating Taguchi loss function and linear loss function for CUSUM-m and CUSUM-S2 chart. These two functions have helped in minimizing in control and out of control costs considering losses due to deviation from the target value for both mean and variance. At last, the credibility of the model is proven by the same values of the decision variables, incurred by two different algorithm approaches and the robustness of the model is also analyzed by a sensibility analysis.

Shamsuzzaman et al. (2019) proposed a different way of economical design. It addressed two individual EWMA scheme, called dual-EWMA scheme, to optimize sample size and sampling interval in addition to other charting parameters such as weighting parameter, and control limits of the dual-EWMA scheme. As the EWMA chart is employed in injection molding process in this study, the variation in the process output is unavoidable which leaves with the only option of online monitoring and controlling the process variability. During the optimization design process, it is carefully maintained in the specifications that the inspection cost and false alarm rate will not increase while the effectiveness of the charting schemes will be improved, using Average Extra Quadratic Loss (AEQL), for detecting a wide domain of mean shifts.

The optimization algorithm, which ensures the minimization of AEQL, is accomplished in three level searches; the first level optimization for n, second level for λ1, UCL1, λ2 and UCL2, and finally third level identifies the minimum AEQL. In the next step, the performance of the proposed scheme is investigated extensively by comparing the effectiveness of seven charting schemes through 3 different studies, in which dual-EWMA chart manifests the reliable supremacy of the proposed scheme and helps to identify optimal charting parameters under different operational scenarios. To facilitate the practical application of the proposed scheme, a design table is provided for different design specification values under the standard conditions. The design and application of the scheme are also illustrated through a case study where the charts are designed over two phases, phase I is for estimate the in-control (IC) process parameters and phase II monitors the process by using the obtained parameters to design optimal dual-EWMA scheme. Along with the usage of online SPC tools in the study, a computer program is also developed based on the proposed optimization algorithm that ease the design process of the charting scheme.

Lean Manufacturing

The middle concept behind the tilt is to maximize client fee on the product at the same time as minimizing waste. Lean may be simply defined as developing a greater price for customers by using the usage of fewer sources. A lean business enterprise understands patron value and focuses to fulfill their needs with minimal cost. The remaining purpose of lean manufacturing is to provide the choicest cost to the customer thru a perfect fee creation procedure that has 0 wastes. To perform this, implementation of lean is important. Lean thinking changes the point of interest of control for improving productivity from optimizing separate technology, assets, and vertical departments for you to optimize the waft of services and products through entire price streams that flow horizontally throughout technologies, property, and departments to clients. (Chahal, Sharma and Chauhan, 2013) The lean manufacturing device was first added by Krafcik (1988). This effective production device becomes drawn from the famous e-book titled the device that modified the world: The tale of Lean manufacturing (Womack et al., 1990) (ElMaraghy, 2014). Lean production is described as an idea of a production machine whereby all production personnel work collectively to do away with waste (Meyers and Stewart, 2002).

Specific systems used by manufacturers for manufacturing in industries with reducing waste are called lean manufacturing. It is not the philosophy about including the most effective few new strategies into a way to build products but truly changing the way of considering manufacturing (Abdullah, 2003). The impact of lean manufacturing on the cost of production mainly by way of putting off waste has been addressed by means of a number of researchers (Abdullah, 2003). Lean manufacturing mainly awareness on waste discount and seven sorts of waste are determined in industries. Overproduction, inventory, Over-processing, movement, ready, Defects, and Transportation are the seven wastes which might be focused with the aid of lean manufacturing Philosophy (Poppendieck, 2002). Lean has become a widespread phrase and this machine is utilized to the maximum of the companies. Saleh studied on Iraqi production corporations and found that the manufacturing corporations' opportunities of establishing the tilt structures are special. There is a fine dating among the wandering capital and lean foundations for all of the studied corporations (Saleh, 2011). In Brazil, the managers of the agricultural equipment zone have supported a transition toward the adoption of lean production practices. They have proven a massive improvement in their business overall performance together with the manufacturing fee (Forrester et al., 2010). Lean creation has been used in the Gaza Strip. It has reduced the steps in the manner. It decreased the complete mission with the aid of 57%, the non-price brought decreased from 81% to fourteen% in the challenge period, and the overall cycle time of the assignment was decreased by 75% (ElKourd, 2009). A study has been made on distinct nations and has determined that lean production has a big impact on value performance but Lean manufacturing has a widespread impact on cost performance (Hallgren and Olhager, 2009). After analyzing waste reduction lean gadget, it has determined that unneeded processing, transportation of materials and paintings in manner stock wastes and uncooked material inventory was the maximum well known waste for the manner enterprise sector (Rathi, 2009). Piercy and Richly researched and illustrated that services name facilities for the studied 3 monetary offerings groups can serve the traditionally competing priorities both of operational cost discount and expanded customer support exceptional (Piercy and Rich, 2008). It has been found by means of Czabke, in 2007, that everyone flowers have become extra efficient after imposing lean production in the US and Germany and therefore greater price effective and worthwhile (Czabke, 2007). Inside the studies, it has discovered that incredible improvements the usage of cost stream mapping in their respective vegetation in both Irish corporations and additionally inside the reduction of all kinds of wastes and inventory (McGrath, 2007). Every other result of lean production has been reached that it is far taken into consideration as a strategic device to improve the aggressive function of the employer. One of the maximum severe wastes is overproduction as it contributes to the opposite six wastes inside the production procedure where manufacturing charges money and there is no cause to provide gadgets that are not demanded (Berg and Ohlsson, 2005). Koh et.al. (2004) has reached the conclusion that lower manufacturing charges in any business enterprise, groups are offerings can be achieved when lean manufacturing production practices in that machine are used together with, TQM and JIT (Koh et.al. 2004). Stephen (2004) concluded that the gradual charge of company improvement is not because of lack of knowledge of six sigma or lean. As an alternative, the fault lies in making the transition from theory to implementation. The lean production makes a specialty of efficiency, aiming to produce products and services at the lowest cost and as fast as feasible. Yamashita analyzed for the satisfaction of merchandise and said that better quality products with fewer assets and capital are carried out via imposing lean production and lean manufacturing leads to reductions in value by means of lowering scrap, remodel, returns, and waste from the manufacturing process (Yamashita, 2004). Lean production device drive and impact on all the activities related to the production process of a company. It has also been noted that the driving pressure at the back of imposing lean devices inside the US changed into the price discount for the steel manufacturing businesses (amongst others) (Abdullah, 2003).

Kilpatrick concluded lean manufacturing in his paper that storing and inventory growing of merchandise cause ever-increasing charges in the form of invested capital, broken completed items, scrapped product, and steeply priced inventory control machine. It also assists to remove all defects and is critical to minimize lead-time changes into any other conclusion (Kilpatrick 1997). Joining concluded that on-time transport of products and purchaser delight progressed while lead instances and inventories dropped notably (Joing, 1995). Lean approach is a type of manufacturing method without waste. Waste ("Muda" in Jap) has seven sorts. Those are overproduction, waste of ready time, transportation waste, stock waste, processing waste, waste of motion, and waste from product defects. Despite the huge knowledge, equipment, available resources; many groups are struggling to live "lean" (Taj, 2007). Zakaria and Mohamed (2017) has summarized the tilt manufacturing as the maximum convenient way, which casts off unnecessary waste from production and it could offer what customers demand. He implemented lean production for reducing waste from digital assembly lines.

Root Cause Analysis

Productivity can be increased by adopting practices to reduce defects that will ultimately reduce wastage of raw materials. In order to properly diagnose a defect, it is necessary to start inspecting raw materials, investigate all manufacturing steps, final inspection and customer claims. It is essential to reducing scrap by defining corrective and preventive actions. First by Pareto analysis we can sort all different defects with their relative significance to the total rejection. Then Root Cause Analysis can be used to perform a comprehensive, systematic review of critical incidents (Wilson et al., 1993). It includes the identification of the root and contributory factors, determination of risk reduction strategies, and development of action plans along with measurement strategies to evaluate the effectiveness of the plans. It is an important tool for a thorough understanding of "what happened". A root cause is the most basic reason for an undesirable condition or problem. If the real cause of the problem is not identified, then one is merely addressing the symptoms and the problem will continue to exist.

Root cause analysis is an analytical first-rate checking tool that may be used to perform a corrective and complete process that's based at the evaluation of essential defects Wilson et al. (1993) (Wilson, Dell and Anderson 1996). In 2005, Canadian Root cause analysis Framework described that root because evaluation is a crucial element of information and finding the source of defects. Uday A. Dabade and Rahul C. Bhedasgaonkar (2013) analyzed the purpose impact diagram in the green sand-casting system. They have emphasized on casting illness analysis using a layout of Experiments and computer Aided Casting Simulation techniques (Dabade and Bhedasgaonkar, 2013)

Pareto Chart

Juran (1940) applied Pareto analysis for separating the "vital few" from the "trivial many". It shows the most frequent reason for rejection of raw materials. In this case 10 different categories or bins for raw material rejects and length rejects account for 50% of all rejection. In another case study in the foundry industry by Perzyk (2007), Pareto chart shows that the foundry staff should concentrate on reducing defects like ’sand inclusions’ and ‘gas holes’, which make up 72% of all defects. Pareto diagrams can therefore be particularly useful in defining the targets. Pareto charts show the most frequently occurring factors and help to make the best use of limited resources by pointing at the most important problems to tackle. Chandna and Chandra (2009) studied forging operations that produce six-cylinder crankshafts used in trucks and buses. With the help of Pareto diagrams critical areas are identified and forging defects of crankshaft have been prioritized by arranging them in decreasing order of importance.

Cause and Effect Diagram

Cause-And-Effect Diagram (CED) is applied to explore possible causes of defects through brainstorming sessions and to determine the causes, which have the greatest effect. The corrective measures reduce the rejection rate from 2.43% to 0.21%. Mahto and Kumar (2008) applied root-cause identification methodology to eliminate the dimensional defects in cutting operation in CNC oxy flame cutting machines. Rejection rate has been reduced from 11.87% to 1.92% on an average. CED presents a chain of causes and effects, sorts out causes, organizes relationships between Critical-To-Quality (CTQ) and root causes.

5 Whys

The oldest known scheme is sequence of seven “circumstances" defined by Hermagoras of Temnos as sources of information concerning an issue: who, what, when, where, why, in what way, by what means (Quis, quid, quando, ubi, cur, quem admodum, quibus adminiculis) (Five Ws, 2012). The technique was used to teach people who were required to have communication skills, such as: orators, confessors, journalists. It has also proven advantages in the systematic exegesis of a text. Another questioning technique of that kind is a scheme of 5 Why. It is credited to Sakichi Toyoda (1867-1930) and included by Taichi Ohno (1912-1980) to the collection of standards of Toyota Production System (Wikipedia, Whys), (Sakichi Toyoda, 2012). The method consists in repeating several times inquiries, which start with “why”. Usually, the answer to preceding question is used to formulate the next inquiry. The sequence of questions is expected to approach the basic cause of definite problem. The determination of the 5 Why scheme may be compensated by suggesting areas to be addressed in questions. A scheme 3L5Y used in automotive industry encompasses additionally aspects of manufacturing business and detection in process of generating problem (Frank, 2009). The general concept behind these techniques is to involve human mind in a process of searching some idea by formulating series of questions and this way to stimulate a problem-oriented thinking.

The literature proposes many root cause analysis tools, and 5- Whys Analysis is one of these (Doggett, 2004). It originated at Toyota Motor, during the development of the Toyota Production System (TPS). Later, this technique has been successfully implemented in many other industrial contexts to investigate and categorize the root causes of events with health, safety, environmental, reliability, and quality and production issues (Murugaiah et al., 2010) (Benjamin, Marathamuthu and Murugaiah, 2015). 5-Whys Analysis is still receiving attention in the literature (Low, Kamaruddin and Azid, 2015), and several authors have proposed a combined implementation with other analysis and improvement tools (Ding et al., 2013). The father of TPS, Taiichi Ohno, described the 5 Whys as '… the basis of Toyota's scientific approach…by repeating why five times, the nature of the problem as well as its solution becomes clear (Ohno 1988). Solving problems requires identifying their root causes and, later, developing and implementing adequate countermeasures. Root causes should not be confused with causal factors, as the latter contribute to a problem but are not necessarily the root cause of a problem (Heuvel et al., 2008). The 5-Whys Analysis supports the identification of causal factors and their underpinning root causes. Differently from other more sophisticated problem-solving techniques, the 5 Whys does not involve advanced statistical tools and, for such reason, is particularly suitable to be integrated into operational tools. Actually, this 'lack of rigor could be a drawback of 5-Whys Analysis, as the analysts are not required to test for sufficiency the root causes generated. However, several authors sustain that tangible and useful results could still be obtained without the use of statistical analysis (Murugaiah et al., 2010). In addition, this technique requires an adequate knowledge of the system under study and of the effect to investigate. If the cause is unknown to the analyst, using 5-Whys may not lead to any meaningful answers. By repeatedly asking the question 'Why?' a sufficient number of times (at least five times), it is possible to successively go through the symptoms (effect) of a problem, up to get to the root cause of the problem itself. However, a strong limitation of 5-Whys Analysis could be, in some cases, the assumption that effect has only one cause. This is not always the case, and a 5-Whys Analysis may not be able to discover common causes of a certain effect (Barsalou, 2014). Although it could be questionable the result repeatability of 5-Whys Analysis, a certain skill in applying the method would solve this issue. However, the purpose for which we use this tool in our approach offers a guarantee about its adequacy.

Analytical Hierarchy Process

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then (Taha, 2013; Kabir and Shihan, 2003). It has particular application in group decision making and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education.

Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, representing and quantifying its elements, relating those elements to overall goals, and evaluating alternative solutions.

Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood anything at all that applies to the decision at hand (Saaty, 1990). Once the hierarchy is built, the decision-makers systematically evaluate its various elements by comparing them to one another two at a time, concerning their impact on an element above them in the hierarchy. In making the comparisons, the decision-makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations (Kumar and Suresh, 2006).

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another rationally and consistently. This capability distinguishes AHP from other decision-making techniques (Mustafi, 1996).

In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

Basically, AHP has got following steps:

a) **Model the problem as a hierarchy:** The first step in the analytic hierarchy process is to model the problem as a *hierarchy*. In doing this, participants explore the aspects of the problem at levels from general to detailed, then express it in the multileveled way that the AHP requires. As they work to build the hierarchy, they increase their understanding of the problem, of its context, and of each other's thoughts and feelings about both.

b) **Evaluate the hierarchy:** Once the hierarchy has been constructed, the participants analyze it through a series of *pair-wise comparisons* that derive numerical scales of measurement for the nodes. The criteria are pair-wise compared against the goal for importance. The alternatives are pair-wise compared against each of the criteria for preference. The comparisons are processed mathematically, and *priorities* are derived for each node.

c) **Establish priorities:** At last, priorities are established by the calculating the values of each node, which will see in our next chapter.

RESEARCH METHODOLOGY

The research methodology adopted for this study is done by the case study and brain storming. The case study was conducted on a garment factory named “Ananta Garments Limited” located at Ashulia, Dhaka. At first preliminary investigation was carried out at the cutting, sewing, washing, finishing and packing section to identify the area where most of the defects occurred. It is found the sewing section is highly suffered from defect and rework problems. For this reason, we decided to work on a sewing line to minimize the defect percentage by using the DMAIC approach of Six Sigma methodology. We collected the secondary data of the sewing section which was provided by the management of the factory. The data was collected for one of the production lines only. According to our observation and using the end line quality data provided by the management we identified some repetitive defects that occur in the sewing section the information and data collected were arranged so that further study and analysis could be performed. Three mostly used Six Sigma tools namely Pareto Analysis, Cause-Effect Diagram and 5 Whys analysis were used in our analysis part. Pareto analysis was used to identify the top occurring defects. Brainstorming session was conducted to identify the probable causes and then potential root causes were identified by online inspections. Cause Effect Diagrams were constructed for those defects. Finally, 5-Whys Analysis was implemented for two of the major defects to provide a fact based and structured approach to problem identification and correction that focuses on not only reducing defects but also in eliminating them. After identifying the major causes of the top occurring defects, we provided some respective suggestions to minimize the frequency of the defects. The suggestions were made based on the brain storming session which was arranged by the management of the factory. Experts of the factory from different areas were present in that session. At the end of our study, an AHP based questionnaire was undertaken among industry leaders to determine the most suitable lean six sigma tool for implementation in RMG industries.

Control Chart

Although relatively simple, the control chart is a powerful tool for decision support. It combines time series analysis with a graphical presentation of data by plotting successive indicator measurements in chronological order. By distinguishing special causes from common causes of variation, the control chart categorizes variation according to the action needed to reduce it (Mohammed, Worthington and Woodall, 2008) Special causes are supposed to reflect substantial variation in care that deserves further investigation, whereas variation related to common causes is expected to arise due to other misleading factors, including random events. Three horizontal lines are drawn on the chart to determine whether or not care is in statistical control; they are termed the central line, the upper control limit (UCL) and the lower control limit (LCL). An indicator data point lying outside of the control limits suggests that some special cause of variation has been detected and that care is out of control. This requires finding and acting on one or more assignable causes to reduce variation. After controlling all special causes of variation, care should be subject only to common-cause variation related to unknown or unmeasured factors. In this case, if the level of performance is still regarded as unsatisfactory, the classical way to further improve care is to reorganize the whole process. This implies choosing simplicity in the restructuring of care, considering that simple systems would be more reliable than complex ones (Berwick, 1991).

There are three main approaches in setting control limits on a *p*-chart with a variable sample size (see supplementary material, Appendix for detailed formulas). The first one consists in calculating constant control limits based on the average of the sample sizes. This assumes that the sizes of successive samples do not vary greatly. However, in the case of an unusually large variation in the size of a particular sample or if an indicator is positioned close to the approximate limits, then interpretation must be conducted cautiously (Ryan, 2011). To avoid such pitfalls, there is a second approach, which consists in determining variable control limits for each sample i based on its specific size n_i. In this case, the control limits will be drawn in stair-steps to reflect the changes in sample size over time. The more the sample size increases, the closer to the central line the limits will be. Generally, calculations of the *p*-chart limits are based on a normal approximation of the binomial distribution.

Types of Control Charts

Control charts, implemented in the industry, can be classified into two types depending on the available quality characteristics. Quality characteristics are one or more elements that define the intended quality level of a product. In most manufacturing companies, including the garment industry, quality characteristics are categorized into variable and attribute characteristics.

1) Variable quality characteristics: Quality characteristics that are measurable and are expressed on a numerical scale are called variable. The circumference of waist, waistband height, inseam, out seam, leg opening, back rise, front rise, hip position and so on, which are expressed in inches, are examples of variable characteristics in the trousers. Corresponding to this type of variable characteristics, variable control charts like Shewhart X-bar chart and R chart are used to monitor the process mean or variance.

2) Attribute quality characteristics: Quality characteristics that cannot be measured or expressed on a numerical scale are called attribute characteristics. They are mostly expressed as good/ bad, Acceptable/Rejected, Passed/Failed. A quality characteristic is said to be an attribute if it is classified as conforming, or nonconforming. Nonconformity is assured when the quality characteristic does not meet its stipulated specification. These are mostly products having one or more defects. The control charts for fraction non-conforming (p chart), number of non-conforming units (np chart), number of non-conformities (c chart), and number of non-conformities per unit (u chart) are the widely used attribute control charts.

Selection and Implementation of Control Chart

Data type is discrete showing the defective items per subgroup of sample. Taken as the record of defective proportions or attribute data. As defective items are being counted, P-chart is selected. Data type is discrete showing the defective items per subgroup of sample. Taken as the record of defective proportions or attribute data. As defective items are being counted, P-chart is selected.

After studying the defects with their critical parameters and designing the check point, an appropriate SPC control chart for both variable and attribute quality parameters based on various dimensions were implemented. Considering the factory situation and analyzing the advantages and disadvantages of different methods of SPC implementation, it was noted that implementing the manual SPC methods became much more appropriate. This system mostly involved the plotting of data on control charts manually, using the prepared graph paper. The advantages of these systems were very simple and good when implemented for the first time. This system has certain advantages when applied in industrial sectors, where various quality faults occur. Delivering offline and on-the-job training for quality checkers and supervisors has to be carried out for proper implementation of SPC and error reduction. After plotting the selected control chart separately for variable and attribute parameters, the data pattern was checked by run tests to justify the randomness properties of the collected data, within the lower and upper control limit. Immediate and permanent action plan was devised and maintained for special variation.

Initially, to determine whether the production line is in-control or out-of-control, we collected defect related data for the month of December, 2020 from one of the sewing lines and constructed a P-chart with the help of those data, which is shown in Figure 1.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Sample Size	746	1012	1027	883	886	643	838	206	454	749	1038	1189	1100	1098	833	954	784	639	998	1155	1208	1165	1351	1120	972
No of Defect	229	274	259	254	241	221	268	74	208	211	210	287	294	245	226	269	160	128	199	212	225	217	252	239	199

P-chart is implemented using the data set, where UCL and LCL is designed based on the following formulation-

$$p = \frac{Defect}{Observation}$$

$$CL = \bar{p} = \frac{total\ defect}{total\ observation}$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

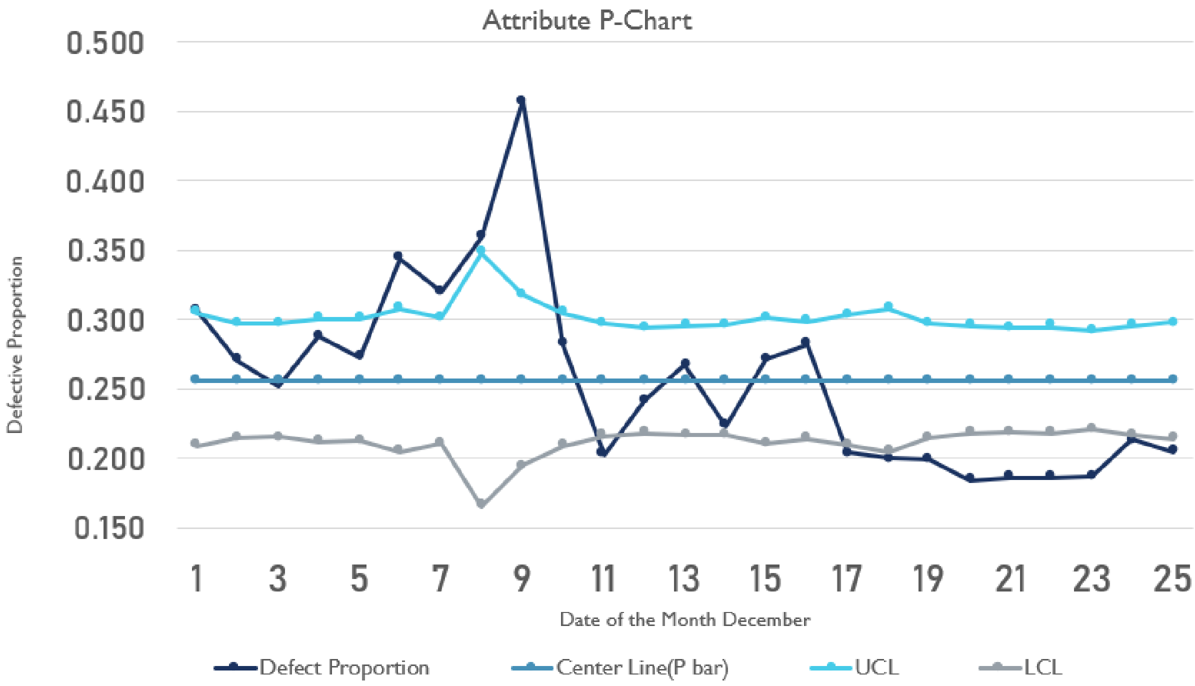


Figure 1 P-control chart showing defect proportion

Defect Identification

Following several brainstorming sessions with the operators and management officials, the defects which causes rework and reduces the efficiency are as oil strain/spot, skip stitch, pleat, dirty spot, point up down, open seam, needle cut, raw edge, join stitch, insecure stitch, uneven stitch, shading, needle mark, broken stitch, uncut thread, puckering, label missing, reverse etc.

Industrial Application of Pareto chart and Cause-and-Effect Diagrams

The application of Pareto charts and cause-and-effect diagrams are found in a variety of industries. These are simple tools yet interesting and have real life applications. Paul and Azeem (2009) applied Pareto chart and cause-effect analysis for identifying and analyzing defects of a pharmaceutical product. They found that capping, edge-chipping, and broken tablets have been found as the vital problems for producing defective products. Ahmed and Ahmad (2011) studied the minimization of defects in lamp production process by the application of Pareto analysis and cause-and-effect diagram. Using Pareto analysis, they analyzed the defects and found major and minor contributors to those defects. Then applied cause-effect diagrams for each defect and found the main factor. They suggested that the cause-and-effect diagram is very useful in indicating the appearance of abnormalities of the process in the form of excessive variations of process parameters. James, Mathew, and Mathew (2013) conducted a case study on a male contraceptive manufacturing industry. The rejection rate for one month was collected. They identified critical defects, using a cause-and-effect diagram. A modification in the dipping process and a model for the electric infrared heater were introduced as a solution for reducing the critical defects. Kiran et al. (2013) applied root cause analysis for reducing breakdowns in a male contraceptive manufacturing industry. They analyzed the breakdown occurred during production by Pareto chart. A root cause analysis was conducted to find out the root cause of breakdowns and some other parallel improvement opportunities were also identified. Joshi and Kadam (2014) studied minimization of defects in the manual metal casting process. Pareto principle and cause-effect diagram were used to identify and evaluate different defects and causes for these defects. Finally, it was found that operations were done with some negligence and carelessness. They suggested that reduction of all defects might be more than 70% after implementation of the remedy of automation. Baishya and Dutta (2015) analyzed the downtime of machines in a production line of a fast-moving consumer good (FMCG) company. They identified downtime losses, factors concerning losses and cost associated with them by Pareto analysis. A cause and-effect diagram was also used to find out the root causes of those factors. Finally, some suggestions were provided along with training programs for operators and autonomous maintenance, the two pillars for total productive maintenance (TPM). Das and Gopinadhan (2016) presented a study in a textile spinning and weaving mill. The actual production was lower than target production. Using Pareto analysis, they were identified as the factors that were responsible for production losses. They used DMAIC technique for productivity increase and why-why analysis to identify the root causes. They identified power failure and worker absenteeism as the major causes for loss of productivity. By implementing their suggestions, the utilization of spindles was increased by 4%. From the literature, it is clear that Pareto analysis and cause-and-effect diagram are essential tools to analyze and identify the defects in a manufacturing or process industry. A successful application of them reduces unwanted stoppage time losses and increases the availability of machines for a long period of time, thereby increasing productivity. Pareto analysis and cause-and-effect diagrams are regarded as two basic tools of total quality management (Patyal & Maddulety, 2015).

The above discussion on the industrial application of Pareto chart and cause-and-effect diagram motivates us to apply the tools for the problem at hand. Thus, this paper applies Pareto chart and cause-and-effect diagram tools for the study of defects in an RMG industry.

Pareto Chart

In nineteenth-century Italy, the Italian economist Vilfredo Pareto observed that about 80 percent of the country's wealth was controlled by about 20 percent of the population. This observation led to what is now known as the Pareto Principle; it is also known as the "80-20" rule. It consists of a simple series of bars whose height indicates the impact of defect/problem. Data in the Pareto chart is arranged in descending order and shows variables in graphical form. The frequency of every defect is visible and its height shows the impact of every problem. Juran and Gryna applied this concept to the causes of quality failures. They stated that 20 percent of the causes account for 80 percent of the failures. In general, the Pareto principle, applied to quality, suggests that the majority of the quality losses are mal-distributed in such a way that a "vital few" quality defects or problems always constitute a high percent of the overall quality losses (Roush and Webb, 2006). The intent of a Pareto analysis is to separate the vital few from the trivial many. Thus, the Pareto analysis can assist to identify the most important effects and causes to stratify the valuable data which can be used to prioritize the product-process improvement efforts. So, from Pareto charts, it can be figured out that, first we have to focus on the major problems and eliminate them from the process as soon as possible. If the major problems are eliminated, then 80% of defects will be reduced.

Among some common scenarios where this trend could be observed are:

- 80 percent of the total number of quality related problems are caused by 20 percent of sources;
- 80 percent of the total sales of a company originate from 20 percent of its customers; and
- 80 percent of the numbers of absenteeism are caused by 20 percent of the workforce.

The Pareto chart is useful for non-numeric data, such as “cause”, “type” or “classification” and is useful to prioritize where action and process changes should be focused and is commonly used for identifying the downtime and other wastages (Hall et al., 2000). It is one of the most often-used statistical analysis tools within Toyota, which is simple, yet powerful.

Pareto Analysis for Defect

A Pareto chart, also called a Pareto distribution diagram, contains a vertical bar graph in which values are plotted in decreasing order of relative frequency from left to right. Pareto Chart is used to graphically summarize and display the contribution of each type of defect. It is a bar graph. The lengths of the bars represent occurrence and are organized with longest bars on the left and the shortest to the right. In this way the chart visually shows which defects are more significant.

By using Pareto Chart major types of defects were identified which is shown in chart. Those defect types are Faulty Stitching, Broken Fabric/Holes, Uncut and Loose Thread, Peat/Puckering, Up-down / Hi-low and Raw Edge Out were found out to be some of the most frequently occurring defects. These types of defect occur due to some specific causes.

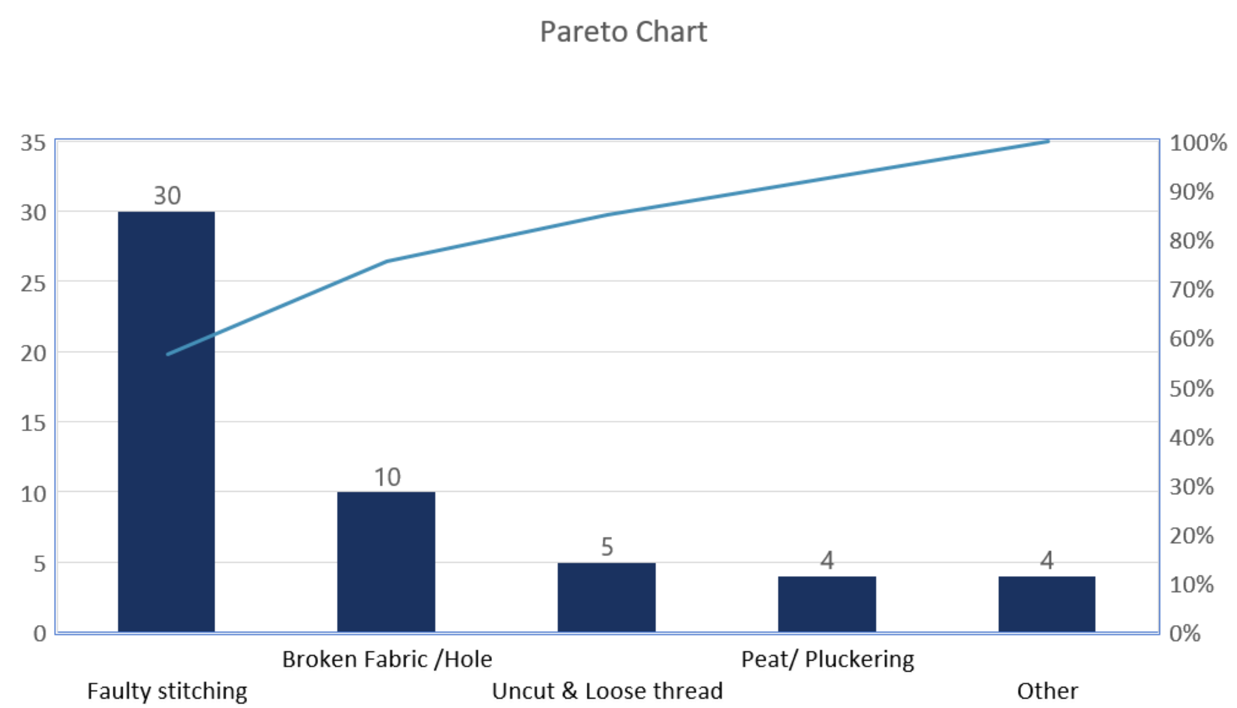


Figure 2 Pareto Chart for major defects

Cause & Effect Diagram

A cause is a fundamental condition or stimulus of some sort that ultimately creates a result or effect. Most analyses are worked in both directions, from cause to effect or effect to cause in order to discover and document causes, effects, and cause-effect linkage. Cause-effect analyses are usually summarized in a Cause Effect (CE) Diagram. The CE diagram was developed for the purpose of representing the relationship between an effect and the potential or possible causes influencing it. Cause & Effect diagram is a chart that identifies potential causes for particular quality problems.

Cause and effect diagram was invented by a Japanese professor named Dr. Ishikawa. This tool is also known as Ishikawa or Fishbone diagram because of its graphical structure. Fishbone diagram is a one kind of cause-effect diagram which contains many causes for a specific effect or problem. It looks like the shape of a fish. That's why it is called fishbone diagram (2021). Cause and effect diagram is an organized or structured picture with lines and twigs (resembling fish bones) used to stratify and group causes. The effect is typically contained in a box on the right side, while the causes appear on the left side. It is an important tool used to figure out the root causes of a problem. In this technique all the possible causes of a problem are taken into account and try to find out the reason of every cause which makes the problem happen. This technique can be applied by two methods i.e., 4M's Method or 6M's Method. If problem is small than 4M's Method is enough to find its root cause. The 4M's includes Men, Material, Machine and Method. But we will go for 6M's method if problem is very complex and its scale is very high. In 6M's technique there will be addition of Measurement and Mother Nature. M's of fishbone diagrams will be increased as per requirement which includes Money, Management etc. In this regard, various subcritical factors can be illustrated by cause and in the analysis phase, the identification of the root cause makes an impact on the rejection rate of the produced goods. In this regard, various subcritical factors can be illustrated by cause-and-effect diagram. Consequently, the brainstorming sessions can be conducted to identify the major critical factors that make an impact on the rejection rate. Hence, in the brainstorming sessions the solutions for rectifying the defects can be discussed seriously.

From the Pareto Analysis, Faulty Stitching and Broken Fabric / Hole were found to be the major reasons of causing most of the defects. Thus Cause and Effect Diagrams were constructed for both these major causes, which are represented in Figure 3 and Figure 4.

Cause and Effect Diagram for Faulty Stitching

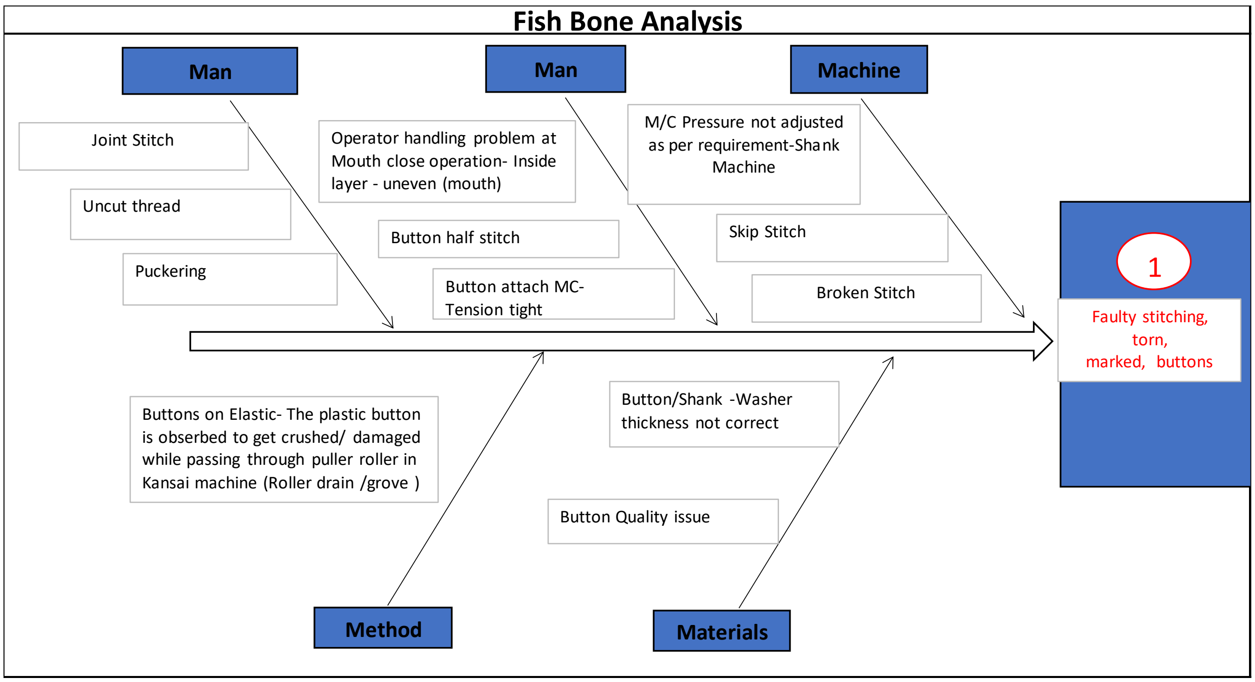


Figure 3 Cause and Effect diagram for Faulty Stitching

Cause and Effect Diagram for Broken Fabric / Hole

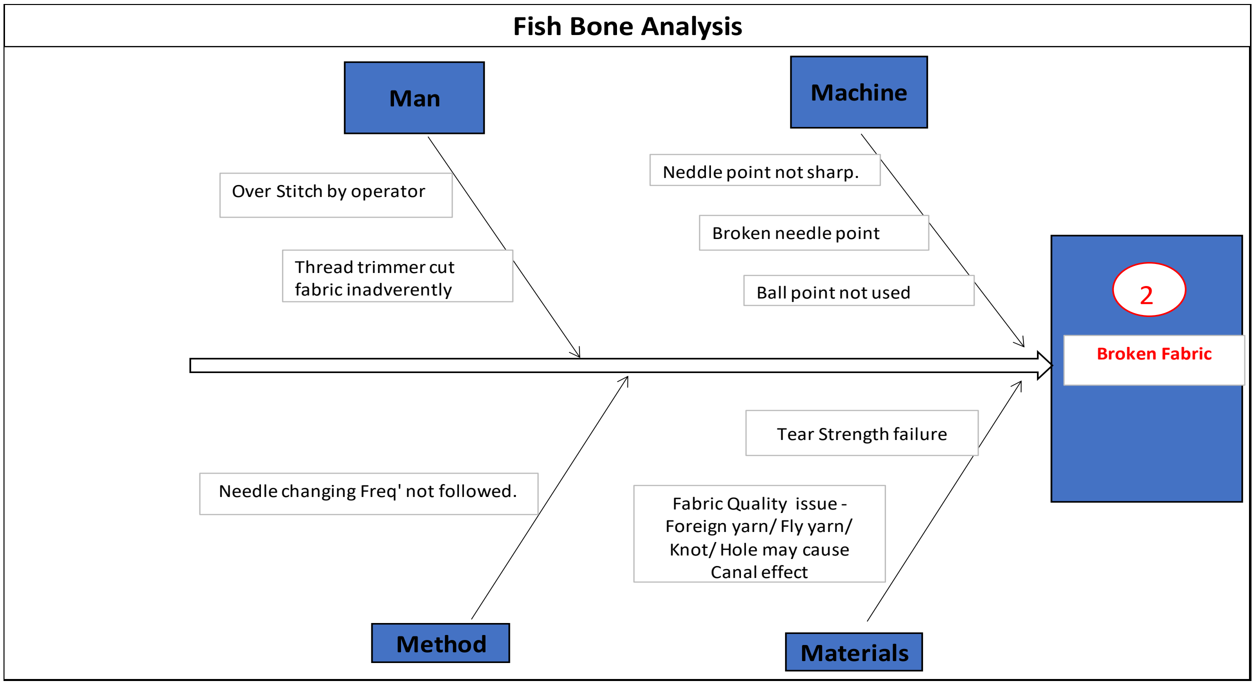


Figure 4 Cause and Effect diagram for Broken Fabric/Hole

Root cause analysis and 5-Whys

Solving problems requires identifying their root causes and, later, to develop and implement adequate countermeasures. In this regard, root cause problem solving (RCPS) can be considered as a structured problem-solving approach using simple standardized tools to identify and resolve critical problems encountered in manufacturing operations. RCPS analysis tools commonly used are cause-and-effect (CED) diagram, interrelationship diagram, current reality tree and the 5-Whys analysis (Murugaiah et al., 2010). Among them, the 5-Whys analysis has been successfully implemented in many industrial contexts to investigate and categorize the root causes of events with health, safety, environmental, reliability, quality and production issues (Benjamin et al., 2015; Murugaiah et al., 2010). Ohno (1988) described the 5-Whys as "the basis of Toyota's scientific approach...by repeating why five times, the nature of the problem as well as its solution becomes clear". Thanks to its ease of use, 5-Whys is still receiving attention in the literature (Gangidi, 2019), and several authors proposed a combined implementation with other analysis and improvement tools (Braglia et al., 2017). Differently from other more sophisticated problem-solving techniques, the 5-Whys does not involve advanced statistical tools and is particularly suitable to be integrated into several industrial contexts. Moreover, differently from Ishikawa Diagram, i.e., a CED diagram, the 5- Whys does not represent cause categories that should be evaluated as having been potential contributors to the sequence of events. These categories change from user to user. So, a typical issue of the Ishikawa Diagram is that if the correct categories for the event at hand are not selected, key causes and contributing factors could be overlooked (Barsalou, 2014). Finally, 5- Whys quickly identifies the root cause of a problem, without using extraordinarily tedious and time-consuming tools such as, for instance, the Failure Mode and Effects Analysis. Actually, the “lack of rigour” could be a drawback of 5-Whys analysis, as the analysts are not required to test for sufficiency the root causes generated. In addition, this technique requires adequate knowledge of the system under study and of the effect to investigate. If the cause is unknown to the analyst, using 5-Whys may not lead to any meaningful answers. Finally, according to Latino et al. (2019), people tend to use this tool as individuals and not in a team, and they rarely back up their assertions with evidence

5 Whys

Five whys is a Root Cause Analysis Tool. It is not a problem-solving technique. The outcome of a 5 Whys analysis is one or more root causes that ultimately identify the reason why a problem occurred. Even though the discipline is called 5 Whys’, it is not always necessary to reach 5 before the root cause of a problem is fully explained. It may take more or less than 5 why’s to get to the bottom of it. It depends on the complexity of the process or the problem itself

The basic formulation of “Improvement Story by 5 Why" may be as follows:

(1) Why IT may be so important?

(2) Why IT may not be suppressed?

(3) Why IT may happen?

(4) Why IT may not be corrected?

(5) Why IT may not be prevented?

A basic purpose of the scheme is to arrange data concerning organization's capability to improve. The objective is to study the process and its environment with regard to improvement potential and barriers. A context of the analysis may be the auditing process of improvement or monitoring a particular improvement project. The analysis can be done retrospectively or in parallel to the running process of problem solving. In the Improvement Story :(1) input data are representing process and its environment and diagnosis of actual or potential problem; and (2) output data are systematized characteristics concerning: importance and mechanisms of problem, and respective containment, corrective and preventive measures. The classical 5 why scheme consists of stepping down into details of problem circumstances – questions are dependent on another question. In the Improvement Story, each basic question concerns another aspect of improvement: relating to severity, occurrence, and ability to detect the problem and block its effects, ability to eliminate and to prevent mechanisms of the problem. They are closely related to the spirals of the Improvement snail

In general, lean manufacturing tools tend to require less quantitative analysis than six sigma tools. Toyota for example believed in simple tools and solutions whenever possible and placed great emphasis on root-cause problem solving aimed at permanent solution using the 5-whys analysis (Alukal, 2007). Some authors even argue that the 5-whys technique does not even involve data segmentation, hypothesis testing, regression or other advanced statistical tools and can lead to the root cause of a problem by repeatedly asking the question "why" at least five times (Dolcemascolo, 2006). In fact, criticism has been levelled at lean manufacturing that it does not value statistical analysis (Nave, 2002). However, this study will emphasize the point that tangible and useful results could still be obtained and implemented successfully without the use of statistical analysis. In our study although the traditional 5-whys analysis requires the "why" question to be asked five times, in the analysis above the why questions was only asked four times for both the circle and body sheet. The reason for doing so was because the 5-whys figure above clearly identifies friction as the first level root cause for both the circle and body sheet. The asking of the "Why" could be stopped if common sense tells us that no more "Why" questions are needed to solve the problem (Pylipow and Royall, 2001).

In this regard, the classic as well as lean manufacturing approach to root cause analysis is to question “Why?” for five times, hence the 5-whys analysis. Prompt addressing of problems before asking enough why questions are often short-lived and will generally recur. The root cause of a particular problem, in this study, scrap loss, is usually deep and needs corrective as well as preventive action. In this study the 5-whys analysis is used to analyze the root causes of the scrap to identify the right solution to adopt.

For the 2 major defects, Faulty Stitching and Broken Fabric / Hole, the following 5 Whys Analysis diagrams have been constructed based on brainstorming sessions and thorough observation of the operators.

5 Whys Analysis – Faulty Stitching

Skip Stitch

1st Why: Machine maintenance preventive maintenance not done properly as per schedule

2nd Why: Machine mechanic do not have required competency to do rotary hook setting etc. correctly

3rd Why: Most mechanics are old and they have not undergone any Skill development training and Skill mapping done

4th Why: Requirement for Training and competency mapping not identified earlier

Corrective Action Plan

- Awareness meetings with the maintenance team.
- Competency mapping, developing skill matrix for maintenance staff and identifying training needs.
- Imparting skill development training as per requirement by experienced mechanics.
- Maintenance in charge is instructed to strictly follow the preventive maintenance schedule and take immediate actions where ever necessary

5 Whys Analysis – Faulty Stitching

Joint Stitch

1st Why: Operator negligence. Operator not careful in opening stich and stitching on previous stitch

2nd Why: Operator not checking own stitch garments and do not adjust thread tension correctly.

3rd Why: Operator lack of focus

4th Why: No follow up and monitoring by controller/supervisor and line chief

Corrective Action Plan

- Operators instructed to follow "Self-Inspection" methodology.
- Line chief instructed to strictly maintain self-inspection and no Joint stitch in sewing.
- TQC instructed to verify correct thread layout and take corrective action where ever necessary. Skill development training for New TQC.

5 Whys Analysis – Faulty Stitching

Button attach machine tension tight

1st Why: Machine thread tension too high, this causes half stitch. Manual thread tension set high

2nd Why: Some times Machine computer thread tension set high to reduce gathering at bottom.

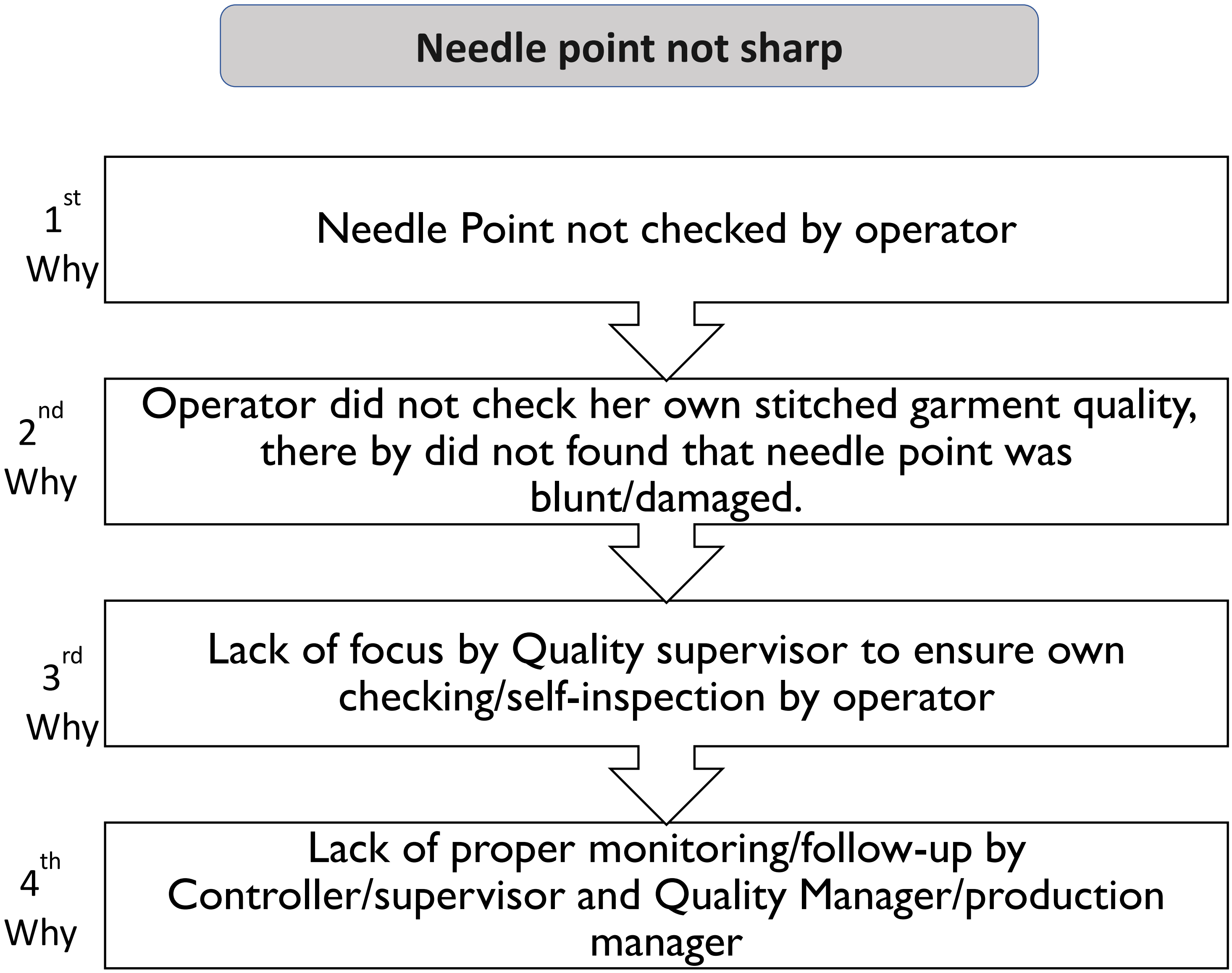
3rd Why: Machine not set properly by mechanic/in charge and not detected and corrected immediately.

4th Why: Tension not checked and set properly by quality controller during process quality check.

Corrective Action Plan

- Machine tension parameters will be checked by Quality controller during quality process check, during new stylesheet-up.
- Button In charge will check thread tension daily before start of shift and after lunch and fill checklist on each machine.

5 Whys Analysis – Broken Holes/Fabrics



Corrective Action Plan

- Fixed needle change frequency for critical fabrics at 2 Hours
- Awareness meeting with concerned line supervisors / line chief / checkers and operators
- Quality Manager will conduct random line audit to ensure needle change frequency is maintained

5 Whys Analysis – Broken Holes/Fabrics

Needle changing Frequency not followed

1st Why: Sewing Operator/Supervisor not aware on needle change frequency

↓

2nd Why: TQC did not notice the problem and failed to give call out

↓

3rd Why: Line quality controller failed to generate awareness regarding needle change frequency

↓

4th Why: Requirement of Needle change frequency not discussed in PPM

Corrective Action Plan

- Fixed needle change frequency for critical fabrics at 2 Hours
- Awareness meeting with concerned line supervisors / line chief / checkers and operators
- Quality Manager will conduct random line audit to ensure needle change frequency is maintained

AHP Questionnaire

Though the resources are very limited in our developing country, production system has been showing very vigilant and visible leadership in terms of acquiring knowledge and absorbing new technology in their fields. But still, there is scope remaining for finding the best lean six sigma tool for implementation according to the circumstances of the RMG industries of our country using multi criteria decision making (MCDM) process.

There are several techniques now available in the literature to deal with multi criteria decision-making problem (Goodwin and Wright, 1998; Saaty, 1990; Keeney and Raiffa, 1976; Van Laarhoven and Pedrycz, 1983). Some of the well-known techniques are Multi Attribute Utility (MAU) model, Simple Multi Attribute Rating Technique (SMART), Analytic Hierarchy Process (AHP) and Fuzzy Hierarchical Decision Making (FHDM) method. Among these AHP is possibly the most familiar and extensively used MCDM method. It is simple and easily comprehensible. In spite of some criticisms leveled against it (Belton and Gear, 1983; Belton and Gear, 1985; Harker and Vargas, 1987), this method has been widely applied in many MCDM problems, e.g., technology selection, vendor selection, project management, plant layout, maintenance strategy selection, transportation fuels and policy etc.(Kabir and Shihan, 2003)

In this part of our thesis, we would like to study different lean six sigma tools and find out the best lean six sigma tool for implementation in RMG industries of Bangladesh using Analytical Hierarchy Process (AHP).

Analytical Hierarchy Process (AHP) is a multi-criteria decision-making process, which could be very effective tool on these analyses. Analytical Hierarchy Process (AHP) is designed for situations in which ideas, feelings, and emotions affecting decision process are quantified to provide a numeric scale for prioritizing the alternatives.

Considered Lean Tools for Implementation

There are various lean six sigma tools, suitable for implementation in the current perspective of the RMG industries in Bangladesh. Some of them are:

Value Stream Mapping: Value stream mapping is a flowchart method to illustrate, analyze and improve the steps required to deliver a product or service. As with other types of flowcharts, it uses a system of symbols to depict various work activities and information flows. VSM is especially useful to find and eliminate waste. Items are mapped as adding value or not adding value from the customer's standpoint, with the purpose of rooting out items that don't add value.

5 Whys: The 5 Whys typically refers to the practice of asking, five times, why the failure has occurred in order to get to the root cause/causes of the problem. There can be more than one cause to a problem as well. In an organizational context, generally root cause analysis is carried out by a team of persons related to the problem. No special technique is required.

Cause and Effect Diagram: The cause-and-effect diagram is a graphical brainstorming tool used to help capture the possible causes of a problem. This tool can be used in the analyze stage to determine underlying causes of a problem or in the improve stage to identify potential failure modes. The cause-and-effect diagram is also known as the fishbone diagram because on paper it takes the shape of a fish skeleton.

5S: The 5S system is a method of organizing workplace materials for quicker access and better maintenance. This system is essential for eliminating waste that is produced by poor workstations and tools in poor condition. The 5 S's are: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), Shitsuke (Sustain).

Decision Criteria

The choice of most appropriate method for a particular product in a particular market/country may depend on following criterions or variables:

Adaptability of workers: Disseminating proper education about the improvement tools and then providing adequate training is necessary for successful implementation of improvement tools. The success of the improvement tools greatly depends on the workers' knowledge of the improvement tools and also on the adaptability of the workers' in implementing these new tools and techniques.

Easy to implement: The Managers will only decide to implement an improvement tool in their production lines, only if these tools can be implemented without greatly disrupting the usual processes of production. The tools must be operator friendly and also shouldn't hamper the productivity and quality of the produced goods.

Cost Saving: Cost of implementing an improvement tool directly influences the price and profit of a product. So, the decision makers of any industry will greatly scrutinize the financial impacts of implementing an improvement tool and will only decide to implement a tool, if it brings about far reaching benefits to the industry.

Techniques of Data Analysis

As discussed before, different lean six sigma tools may have different methodologies. Perception on most appropriate lean six sigma tools for implementation in RMG industries of Bangladesh is a qualitative decision which may vary designer to designer. AHP is used to convert qualitative decisions into quantitative decision. Thus, various responses from various industry leaders may lead to a conclusion on most appropriate lean six sigma tools for implementation on the current perspectives the RMG industries of Bangladesh. Similar works has been done before on Renewable Energy (Kabir and Shihan, 2003)

In this research we are also going to use following steps of AHP (developed by Saaty) to find out the most appropriate product design methodology:

I. Define the decision problem and determine its object.

II. Define the decision criteria in the form of a hierarchy of objectives. This hierarchical structure consists of different levels. The top level is the objective to be achieved. This top level consists of intermediate levels of criteria and sub-criteria, which depend on subsequent levels. The lowest level consists of list of the alternatives.

III. For making pair-wise comparisons, structure a matrix of size (n x n). The number of judgments required to develop the set of matrix is given by n (n – 1) / 2.

IV. Obtain the importance of the criteria and sub-criteria from experts' judgment by making pair wise comparison. This comparison is made for all levels. Verbal judgments of preferences are shown in Table 1.

V. Determine the weight of each criterion. By hierarchical synthesis, the priority vectors are calculated. These values are the normalized eigenvectors of the matrix.

VI. The consistency is determined by using the eigen value, λmax. For finding the consistency index, CI, the formula used is; $CI = (\lambda max - n) / (n - 1)$, where n is the size of the matrix. The consistency ratio (CR) is simply the ratio of CI to average random consistency (RI). The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent; then the matrix has to be reviewed to obtain a consistent matrix. These are calculated for all the matrices structured from the hierarchy. Some computer packages are available nowadays to implement this calculation procedure.

Table 1 Pair-wise Comparison Scale for AHP Preferences

Numerical Rating	Verbal Judgments of Preferences
9	Extremely Preferred / Important
8	Very Strongly to Extremely
7	Very Strongly Preferred / Important
6	Strongly to Very Strongly
5	Strongly Preferred / Important
4	Moderately to Strongly
3	Moderately Preferred / Important
2	Equally to Moderately

1	Equally Preferred / Important

Table 2 Average Random Consistency

Size of Matrix	01	02	03	04	05	06	7	8	9	10
Random Consistency	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In Table 2, the average random consistency of the respondents of a questionnaire with relation to the number of matrixes has been shown. On the other hand, Figure 5 represents the flow of steps that needs to be followed when undertaking an AHP based questionnaire survey.

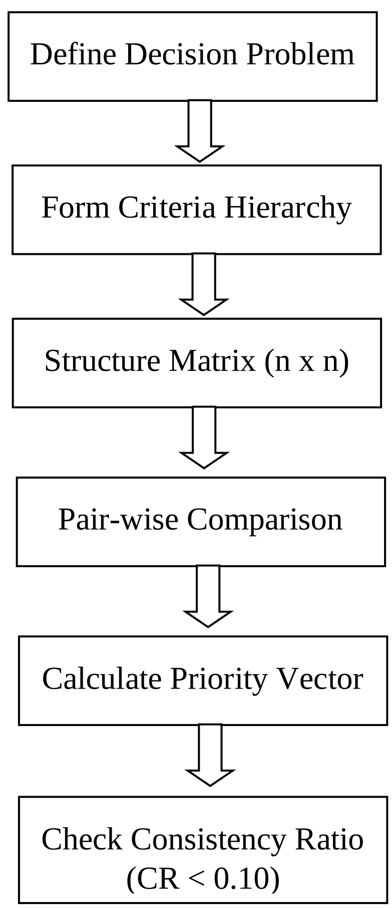


Figure 5 Flow of Steps for AHP Analysis

Questionnaires

Analytical Hierarchy Process (AHP) is designed for situations in which ideas, feelings, and emotions affecting decision process are quantified to provide a numeric scale for prioritizing the alternatives. And this scale might be best captured by a questionnaire which fulfills following two objectives:

i. To maximize the proportion of subjects answering our questionnaire—that is, the response rate.

ii. To obtain accurate relevant information for our study & analysis.

A questionnaire with above two objectives was prepared for data collection. It consists of several tables which were designed according to AHP. It started with few sentences explaining the purpose of the questionnaire, and what the data will be used for. Much effort was given to provide a clear structure to the questionnaire and much concentration was also given to make the questionnaire simple and easy. (Actual Questionnaire is presented with details in Appendix A)

Validation

The validity of the questionnaire was established as follows:

i. It was scrutinized by experienced product designers.

ii. The supervisor of the study provided advice on items to be reshaped, deleted or added questions.

Data Collection Procedure

The questionnaire was mailed to researcher’s fellow designers, with whom he worked with before. It was also explained to the participants over prolonged telephonic discussions. As it was a voluntary work and somewhat lengthy/critical, many of the designers did not respond promptly. In those cases, the participants were given follow-up. Getting the full data in hand, many of them were also followed up again to keep the CR < 0.1. And all data transfer in-between took place by mail.

Preface of Calculation

This chapter presents method used in finding out the most appropriate lean tools appropriate for implementation in the current aspects of the RMG Industries of Bangladesh by using AHP. The data from the questionnaire were tabulated within a scale of 0 to 9. Separate tables were used to compare different methodologies based on different criterions. Prior to these methodology comparisons, those criterions were also compared among themselves in tabulated format.

Data Analysis

Following the standard AHP methodology, the PDMs have been compared with each other in turn for each criterion and their preferential weights have been determined. The result of the analysis according to the participants is presented in Tables 3.A.1 – 3.B.6 in detail.

In Table 4.A.1 Pair-wise Comparison Matrix for Criteria by Participant A and corresponding Priority Vectors are shown in together.

Participant-A

Table 3.A 1 Pair-wise Comparison Matrix for Criteria

	Adaptability of workers	Easy to implement	Cost Saving	Priority Vector
Adaptability of workers	1.000	4.000	0.500	0.315
Easy to implement	0.250	1.000	0.140	0.082
Cost Saving	2.000	7.000	1.000	0.603

CR = 0.002	∑= 1.00

Table 3.A 2 Pair-wise Comparison Matrix for Adaptability of workers

	Value Stream Mapping	5 Whys	Cause and Effect	5S	Priority Vector
Value Stream Mapping	1.000	0.167	0.200	3.000	0.098
5 Whys	6.000	1.000	2.000	6.000	0.502
Cause and Effect	5.000	0.500	1.000	7.000	0.348
5S	0.333	0.167	0.143	1.000	0.052
CR = 0.065					∑= 1.00

Table 3.A 3 Pair-wise Comparison Matrix for Design for Easy to implement

	Value Stream Mapping	5 Whys	Cause and Effect	5S	Priority Vector
Value Stream Mapping	1.000	0.167	0.250	3.000	0.102
5 Whys	6.000	1.000	3.000	7.000	0.571
Cause and Effect	4.000	0.333	1.000	5.000	0.274
5S	0.333	0.143	0.200	1.000	0.054
CR = 0.063					∑= 1.00

Table 3.A 4 Pair-wise Comparison Matrix for Design for Cost Saving

	Value Stream Mapping	5 Whys	Cause and Effect	5S	Priority Vector
Value Stream Mapping	1.000	0.143	0.200	0.333	0.056
5 Whys	7.000	1.000	2.000	5.000	0.513
Cause and Effect	5.000	0.500	1.000	4.000	0.318
5S	3.000	0.200	0.250	1.000	0.113
CR = 0.039					∑= 1.00

Table 3.A 5 Priority Matrix for Choice of Appropriate Tool (Final Result)

	Adaptability of workers	Easy to implement	Cost Saving	Overall Priority Vector
Value Stream Mapping	0.596	0.093	0.125	0.405
5 Whys	0.225	0.566	0.286	0.323
Cause and Effect	0.115	0.279	0.527	0.207
5S	0.065	0.063	0.061	0.064

Participant-B

Table 4.A 1 Pair-wise Comparison Matrix for Criteria

	Adaptability of workers	Easy to implement	Cost Saving	Priority Vector
Adaptability of workers	1.000	0.333	5.000	0.278
Easy to implement	3.000	1.000	7.000	0.649
Cost Saving	0.200	0.143	1.000	0.072
CR = 0.068				∑= 1.00

Table 4.A 2 Pair-wise Comparison Matrix for Adaptability of workers

	Value Stream Mapping	5 Whys	Cause and Effect	5S	Priority Vector
Value Stream Mapping	1.000	0.250	0.143	3.000	0.098
5 Whys	4.000	1.000	0.333	5.000	0.502
Cause and Effect	7.000	3.000	1.000	7.000	0.348
5S	0.333	0.200	0.143	1.000	0.052
CR = 0.065					∑= 1.00

Table 4.A 3 Pair-wise Comparison Matrix for Design for Easy to implement

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Cause and Effect	4.000	0.333	1.000	5.000	0.274
5S	0.333	0.143	0.200	1.000	0.054
CR = 0.063					∑= 1.00

Table 4.A 4 Pair-wise Comparison Matrix for Design for Cost Saving

	Value Stream Mapping	5 Whys	Cause and Effect	5S	Priority Vector
Value Stream Mapping	1.000	0.143	0.200	0.333	0.056
5 Whys	7.000	1.000	2.00	5.000	0.513
Cause and Effect	5.000	0.500	1.000	4.000	0.318
5S	3.000	0.200	0.250	1.000	0.113
CR = 0.039					∑= 1.00

Table 4.A 5 Priority Matrix for Choice of Appropriate Tool (Final Result)

	Adaptability of workers	Easy to implement	Cost Saving	Overall Priority Vector
Value Stream Mapping	0.098	0.102	0.056	0.073
5 Whys	0.502	0.571	0.513	0.514
Cause and Effect	0.348	0.274	0.318	0.324
5S	0.052	0.054	0.113	0.089

Result and Discussion

Statistical P-control chart

From the P-chart, some of the data shows the defect proportion of approaching the line of UCL and LCL. Therefore, the data is often out of control, indicating the several number of defects.

To find out the major defects, several brainstorming sessions were carried out with the management team and also the operators. After thorough investigation and combined meetings, we found that, the following defects were the most prominent ones:

- Faulty Stitching
- Broken Fabric/Holes
- Uncut and Loose Thread
- Peat/Puckering
- Up-down / Hi-low
- Raw Edge Out

Pareto chart

From some brainstorming session and annual reports, the Pareto chart gives a clear graphical representation of the vital few reasons behind the defects. In the previous phase, we determined a number of prominent reasons for the occurrence of the defects. After implementation of the Pareto chart, we identified that 20% of the defects causes 80% of the problems. The following 2 defects are responsible for more than 80% of those problems:

- Faulty Stitching
- Broken Fabric/Holes

Cause and Effect Diagram

Cause and Effect diagram has been provided in the previous chapter 03 for two of the most prominent defects, namely, Faulty Stitching and Broken Holes / Fabrics.

Cause & Effect diagrams are constructed based on the root causes identified by the physical inspection and brainstorming sessions. The causes behind the defects were tried to be identified as accurately as possible. There are some vital causes those have the highest frequency and mostly responsible for the defects.

From the Cause-and-Effect Diagrams, it is observed that there were several man, machine, material and method related causes for the defects but no measurement and environment related causes were found. Carelessness and lack of skills – termed as operator handling problem were the main man related causes those have the highest frequency of occurrence. Blunt Needles, Broken Needle Points and excessive pressure on pressure foot are some of the major machine related causes. On the other hand, skip stitch, broken stitch and irregular interval of needle changing are the major method related causes identified by the inspection. The identified causes are clearly represented in the Cause & Effect diagram that is shown in figure 2.

5 Whys Analysis

5 Whys Analysis has been described in the methodology part. 5 Whys Analysis had been done for 3 root causes of the Faulty Stitching defect and 2 root causes of the Broken Fabric / Hole defect Effective corrective action plans were suggested for the remedy of all the root causes.

The corrective action plans for some of the major defects can be briefly summarized as:

Faulty Stitch:

Skip Stitch: Use needle which design to facilitate loop formation, Adjust the needle height and testing before bulk sewing, Check needle is properly mounted on the sewing machines with right eye position, Choice of sewing thread in accordance with the needle size, select good quality thread which is free from flaws, Repair damage machine parts, reduce gap between presser foot and the hole of needle plate, Provide adequate training to the operators.

Joint Stitch: Control the speed of machine, use right needle, correct feed control, improve the skill of operator, use good quality sewing thread, and provide standard quality specification

Broken Fabric / Hole:

Needle Not Sharp: Provide thread cutter to every operator and make used to; to cut thread properly, start regularly checking system to check the auto trimming machine is properly functioning or not, improve quality inspection system.

For successful implementation of the corrective action plans, the following steps should be incorporated in the production setup:

- ✓ Creation of Quality Management (QM) environment
- ✓ Introduction of workers with TQM
- ✓ Use of statistical process control (SPC) tools
- ✓ Information sharing in decision taking
- ✓ Encouraging cooperation and teamwork
- ✓ Customer focus as an element of design
- ✓ Modification of reward systems
- ✓ Selection of right raw materials
- ✓ Benchmarking
- ✓ Building continuous improvement goal

Result of AHP analysis

AHP questionnaires and data analysis have been provided in Methodology part.

Data analysis from the responses gives the final results for each participant. The overall priority vector shows the preferential ranking of all segments. It appears that 5Whys analysis is the most preferred LSS tool to start with SPC implementation in our developing country. Besides, Value Stream Mapping and Cause and Effect are also picked by some engineer. So, analysis from most of the participant's data shows that 5Whys is the most preferred option for the LSS implementation in the context of Bangladesh.

Summarized Biography of Respondents

Four participants experienced in the readymade garments industry responded to the questionnaires administered. The engineers who responded to the questionnaires were Bangladeshi males. Their age group ranged above the 30 plus category. Their experience as production experts ranged between 5 to 12 years. Each engineer has intensive experience in the field with the full ability to answer the questionnaire.

And they have provided effective information to complete the questionnaire according to their experiences.

Final result of AHP Analysis

Based on the 4 expert opinions as derived from AHP analysis, it was found that 72% preferred the 5Whys Analysis and rest chose the two other tool. As shown in figure 4.1. Besides, CR value is less than 0.1 in each case. Thus, the result may be approved for current situation of Bangladesh.

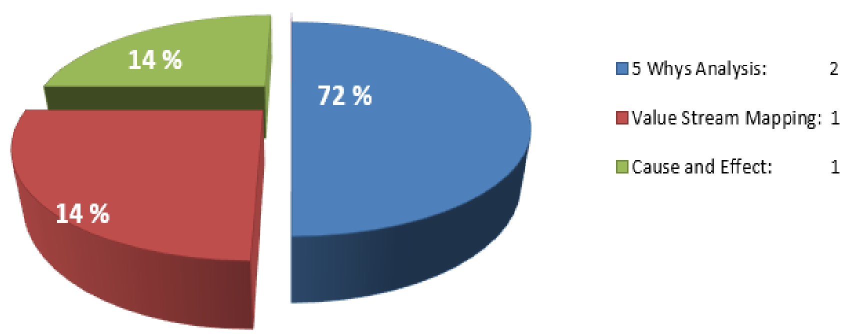

Figure 4.1: LSS tool preference ratio.

In case of criteria, the most important factor for prioritizing segment was taken 'Adaptability of Workers' by the most of the engineers.

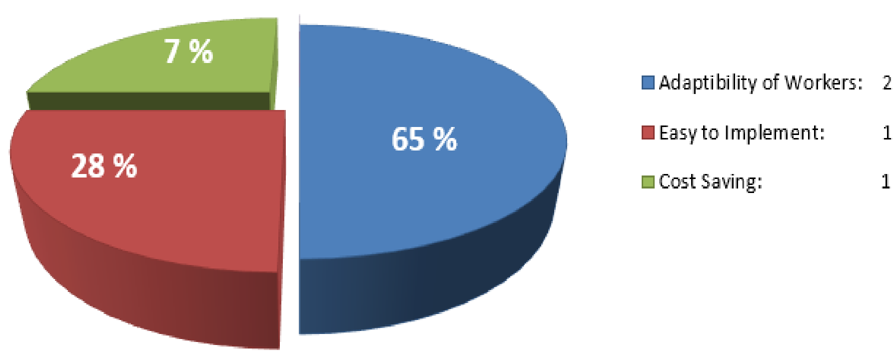

Figure 4.2: Criteria preference ratio.

Conclusions and Recommendations

Summary

Successful implementation and growing organizational interest in Lean Six Sigma methods have been exploding in last few years factors influencing successful lean six sigma projects include management involvement and organizational commitment, project management and control skills, cultural change, and continuous training understanding the key features, obstacles, and shortcomings of lean six sigma provides opportunities to practitioners for better implement six sigma projects. However, integrating the data-driven, structured lean six sigma processes into organizations still has room for improvement. It integrates the lesson learned from successful lean six sigma projects and considers further improvements to the lean six-sigma approach.

Quality is the most important question for customer satisfaction. Not only in apparel manufacturing industries but also in any production; minimizing defects is very important for ensuring the quality of products. The importance of the garment industry in the economy of Bangladesh is very high. The explosive growth of the RMG industry in the country, however, has not been sufficiently supported by the growth of backward linkage facilities. So, manufacturing the quality product is mandatory to sustain in this global competitive market. Good Quality increases the value of a product or service, establishes brand name, and builds up a good reputation for the garment exporter, which in turn results in consumer satisfaction, high sales and foreign exchange for the country.

The defects in apparel industries are one type of major loss or minimize the profit. The first concern for any manufacturer should be to produce and deliver quality products at the right time. However, defects in product usually lead to rejection, rework, time-consuming, extra working time and customer dissatisfaction. In order to solve all of these problems and minimize waste, lean tools are applied in apparel industries. This paper has analyzed the garment sewing defects using lean six sigma tools: Pareto chart, cause-effect diagram, 5Whys Analysis implementation and Control Chart for minimizing defects and resulting increasing quality and making more profit.

Conclusions

From this study the following conclusions may be drawn:

I. Literature reviews of advanced control charts suggest the most effective charting parameters for optimization process.

II. Comparison of different control charts presents some powerful chart designing methods for implementation.

III. Due to logistical frailties and invasion of COVID-19, P-chart was implemented to instead of advanced control chart.

IV. Major Defects were identified by brainstorming sessions and then further analyzed using Pareto Chart, Cause & Effect Diagram and 5 Why analysis technique.

V. The three Root Cause Analysis tools were pretty successful to measure and analyze the problems as well as to provide efficient corrective action plans.

VI. AHP based Questionnaire Survey was undertaken among industry leaders to outline the use of LSS tools in RMG industries of Bangladesh.

Further Recommendation

Similar study and analysis might be performed for:

a. Prior to implementing Quality Management Tool, intervention of control chart can be done for both Phase 1 and Phase 2 implementations in the industries, based on the findings of most practical design approach, useful charting parameter or, distribution & cost function, presented in the literature review of advanced control chart.
b. Methodology of the problem-solving technique, involved in Measure and Analysis stages, can be taken from the work done. For further improvement process, findings and decisions can be used for other stages like- Implementation and Control.
c. Continuous Improvement Process can be implemented following the process flow and demonstrating the improvement by using Control Chart after implementation stage.
d. Preventive Maintenance Policy or, Corrective Maintenance Policy can be adopted in the sewing line along with other section of the RMG industries.

e. In Bangladesh, the analysis based on the root cause analysis lean tools, can be carried out further by implementing the Lean tools suggested by AHP survey, which expresses the expert’s opinion.

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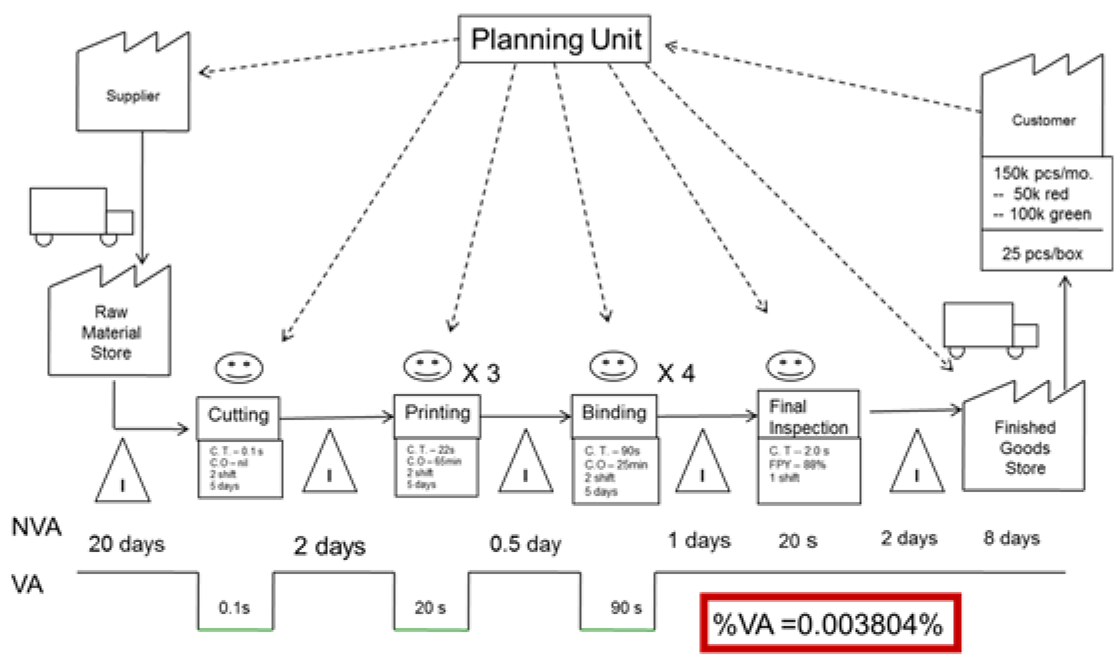
Appendix A

Analytical Hierarchy Process (AHP) is designed for situations in which ideas, feelings, and emotions affecting decision process are quantified to provide a numeric scale for prioritizing the alternatives.

The Questionnaire designed according to Analytical Hierarchy Process (AHP)

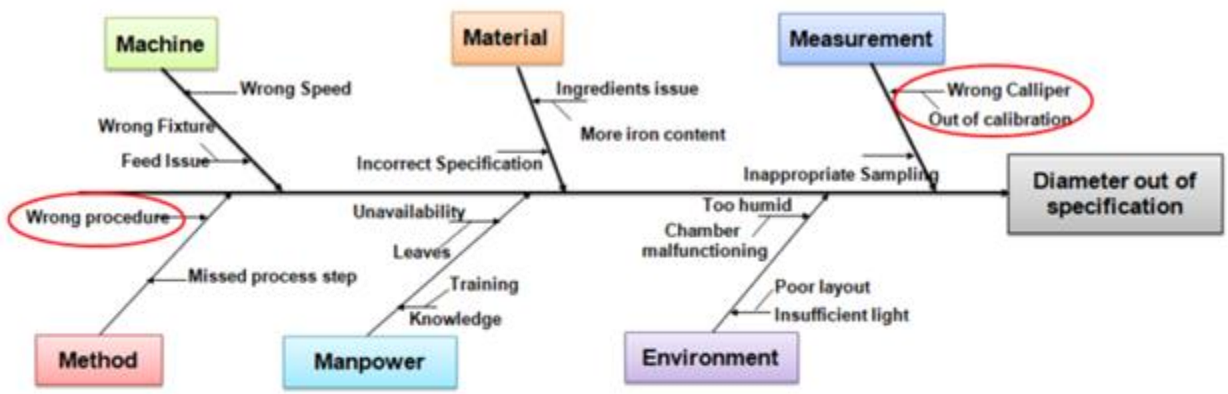
There are various lean six sigma tools, suitable for implementation in the current perspective of the RMG industries in Bangladesh. Some of them are:

Value Stream Mapping: Value stream mapping is a flowchart method to illustrate, analyze and improve the steps required to deliver a product or service. As with other types of flowcharts, it uses a system of symbols to depict various work activities and information flows. VSM is especially useful to find and eliminate waste. Items are mapped as adding value or not adding value from the customer's standpoint, with the purpose of rooting out items that don't add value.



5 Whys: The 5 Whys typically refers to the practice of asking, five times, why the failure has occurred in order to get to the root cause/causes of the problem. There can be more than one cause to a problem as well. In an organizational context, generally root cause analysis is carried out by a team of persons related to the problem. No special technique is required.

Cause and Effect Diagram: The cause-and-effect diagram is a graphical brainstorming tool used to help capture the possible causes of a problem. This tool can be used in the analyze stage to determine underlying causes of a problem or in the improve stage to identify potential failure modes. The cause-and-effect diagram is also known as the fishbone diagram because on paper it takes the shape of a fish skeleton.



5S: The 5S system is a method of organizing workplace materials for quicker access and better maintenance. This system is essential for eliminating waste that is produced by poor workstations and tools in poor condition. The 5 S's are: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), Shitsuke (Sustain).

These improvement tools may be judged by following criterion:

Adaptability of workers: Disseminating proper education about the improvement tools and then providing adequate training is necessary for successful implementation of improvement tools. The success of the improvement tools greatly depends on the workers' knowledge of the improvement tools and also on the adaptability of the workers' in implementing these new tools and techniques.

Easy to implement: The Managers will only decide to implement an improvement tool in their production lines, only if these tools can be implemented without greatly disrupting the usual processes of production. The tools must be operator friendly and also shouldn't hamper the productivity and quality of the produced goods.

Cost Saving: Cost of implementing an improvement tool directly influences the price and profit of a product. So, the decision makers of any industry will greatly scrutinize the financial impacts of implementing an improvement tool and will only decide to implement a tool, if it brings about far reaching benefits to the industry.

Please fill out the following table with a scale of 1 to 9. Read from left of a row with respect to column. If the topic of row and topic of column seems equal important to you, just put 1. If row item is 2 times more important than column topic, write 2. If column item is 2 times important than the row item please put 1/2 and so on.

	Adaptability of workers	Easy to implement	Cost Saving
Adaptability of workers	1		
Easy to implement		1	
Cost Saving			1

Please fill out the following table in the same manner (at a scale of 1 to 9) considering
Adaptability of workers:

	Value Stream Mapping	5 Whys	Cause and Effect	5S
Value Stream Mapping	1			

5 Whys		1		
Cause and Effect			1	
5S				1

Please fill out the following table in the same manner (at a scale of 1 to 9) considering **Easy to Implement:**

	Value Stream Mapping	5 Whys	Cause and Effect	5S
Value Stream Mapping	1			
5 Whys		1		
Cause and Effect			1	
5S				1

Please fill out the following table in the same manner (at a scale of 1 to 9) considering **Cost Saving:**

	Value Stream Mapping	5 Whys	Cause and Effect	5S
Value Stream Mapping	1			
5 Whys		1		
Cause and Effect			1	
5S				1