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# Evaluation of Statistical Process Control In Terms of Quality: Application In A Business in the Textile Sector

*İstatistiksel Süreç Kontrolün Kalite Açısından Değerlendirilmesi: Tekstil Sektöründeki Bir İşletmede Uygulaması*

Ayşenur Erdil*

**Abstract:** Quality is one of the most significant decision-making criteria for customers in the comparison of competitive goods and services. The phenomenon of quality is universal, irrespective of whether the customer is a person, an industrial corporation, a retail store, or a military protection program. As a consequence, awareness and quality management are critical drivers that contribute to market performance, development, and an improvement in competitive position. Increased efficiency and efficient application of efficiency as an important part of the overall marketing plan lead to a significant return on investment. Statistical process control (SPC) is the most common technique for obtaining high quality products from a manufacturing process. SPC involves the use of statistical methods, such as management maps, to evaluate a method and/or its performance in order to take effective steps to obtain and retain statistical control. fter analyzing the major elements and crucial concepts of SPC through a detailed literature review, the objective of this study is to make it possible for a textile business to better implement these concepts. This research study was prepared for the introduction of the mathematical process management system to support ABC Textile Company in its aim to fulfill the quality criteria of today's textile industry. This research paper focuses on the main concepts of the performance Measurement SPC mainly addresses human mistakes that can occur in this type of textile research. Therefore, the topic of this study is discussed in accordance with aspects of organizational efficiency. This research studies will act as a building stone for the following studies in ABC Company as well as for those in the industry.

**StructuredAbstract:** Statistical Process Control (SPC) is commonly used in production or construction processes to measure how efficiently a component works according to its specification specifications. The core of the SPC is a continuous mathematical analysis of multivariate measurements to confirm that observations are carried out in a normal distribution. While no two components of the same nature and production will ever work exactly identically, it is to be assumed that the performance of the products will be followed by the same dissemination. Measurements gathered from various variations of the same product that does not conform with the normal delivery, indicating issues with the goods, employees, structure or equipment used in the manufacturing or testing process. Constant development continues hand-in-hand in the use of SPC procedures. It is vital that key employees on the production line be alerted as SPC allows early warning of possible issues and may take prompt steps to address the issue and deter the imminent problem from being a big concern. SPC can help to catch problems before they occur, instead of after they eventuate, by moving the regarding quality

*Dr. Öğr. Üyesi, İstanbul Medeniyet Üniversitesi, Siyasal Bilgiler Fakültesi, İşletme Bölümü
*Asst.Prof., İstanbul Medeniyet University, Faculty of Political Sciences, Department of Business Administration.*
ORCID 0000-0002-6413-7482
erdil.aysenur@gmail.com

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regulation closer to the truth. The objective of each business is to meet or exceed the expectations of the customer and to become a trustworthy provider or long-term business associate to the consumer, thereby meeting the demand of the consumers. For instance, an automobile producer must depend on its distributor of components for competitively priced spare parts at an expense cost. The manufacturer may engage in business anyway if the distributor also delivers low-quality products. The effective implementation of increased productivity and efficiency as an important part of the overall marketing plan leads to a significant return on investment. SPC is the most common technique for obtaining high quality products from a manufacturing process. ISK involves a method to take effective steps to achieve and maintain statistical control, and / or the use of statistical methods such as management maps to evaluate performance. SPC essentially deals with dumb decisions in any such apparel science. Consequently, in relation to aspects of organizational efficiency, the topic of this review should also be addressed. The retailer is ensured consumer satisfaction when using SPC tools, so the vendor may rely on a high quality product. In comparison to leveling the competitive landscape, control charts also reinforce the fact that people have already experienced and address confusions procedures. Decision-making is easier in an organization when everybody has access to all the information and is on the similar side. Knowledge in technology software for process control will drive yourself except for your competitors and relieve development difficulties. Whenever it applies to production knowledge, much more data is almost never a negative thing. Over almost everything, it is important to provide real-time insight in the production quality control systems, when it can only be a question of preventing customers from accruing unintended costs resulting through process disruptions and problems with created in order. In order to figure out the root cause of the issue that causes the failure, the production process must be interrupted or totally shut down. More time will be taken to locate and solve the problem. Production problems are faced during the production process with the advent of SPC equipment, and only a limited section of the production line has to be shut down. The working time of the actual problem region must be diverted to the replacement output assembly line. The entire assembly line never slows down completely, meaning that consistent production is sustained. If the production line problem area is under refurbishment, the same instances each hour per day of service are possible. The substitute assembly line may be withdrawn from the machine before it has been repaired, and normal service resumes. SPC control charts display statistical data in a statistical manner to monitor the quality of production. It detects and displays some unintended variations in the process so that customers can track various causes/accidents. Statistical data facilitates real-time insight into the concept of development baselines, the establishment of leverage over those baseline methods, the optimisation of the manufacturing process, the identification and resolution of errors or defects through relying on assumptions or guesswork/expectations. The dynamic nature of industry today compels companies to adopt an enterprise-wide quality management system that strives to achieve ongoing quality and productivity enhancement. Statistical process control (SPC) is certainly a lengthy and constant process. According to this study, this process control structure is oriented toward quality management. Thus, the purpose of this research is to illustrate a theory of management that reflects several parameters: Top management dedication to performance as a corporate practice through accelerated enabling capital action plans, Management of job processes and conditions enhancing worker participation in both efficiency and productivity, and Use of problem management and process improvement solutions by the team using mathematical techniques for both manufacturing and non-manufacturing operations. SPC, mainly deals with human mistakes for this kind of textile research. Therefore the topic of this study should be discussed in accordance with aspects of organizational efficiency. This research studies will act as a building stone for the following studies in ABC Company as well as for those in the industry

**Keywords:** Quality, Statistical Process Control (SPC), Textile, Management

**Öz:** Kalite, rekabetçi mal ve hizmetlerin karşılaştırılmasında müşteriler için en önemli karar verme kriterlerinden biridir. Kalite olgusu, müşterinin bir kişi, bir sanayi şirketi, bir perakende mağaza veya bir askeri koruma programı olup olmadığına bakılmaksızın evrenseldir. Sonuç olarak, farkındalık ve kalite yönetimi, pazar performansına, gelişmeye ve rekabetçi konumun iyileştirilmesine katkıda bulunan kritik bir itici güçtür. Artan verimlilik ve verimliliğin genel pazarlama planının önemli bir parçası olarak etkin bir şekilde uygulanması, önemli bir yatırım getirisine yol açmaktadır. İstatistiksel süreç kontrolü (İSK), bir üretim sürecinden yüksek kaliteli ürünler elde etmek için en yaygın tekniktir. ISK, istatistiksel kontrolü elde etmek ve korumak için etkili adımlar atmak için bir yöntemi ve/veya performansını değerlendirmek için yönetim haritaları gibi istatistiksel yöntemlerin kullanılmasını içerir. Bu araştırma, ABC Tekstil İşletmesinin günümüz endüstrisinin kalite kriterlerini yerine getirmesini desteklemek için matematiksel süreç yönetim sisteminin tanıtılması için hazırlanmıştır. Bu araştırmanın amacı, ISK 'nın temel unsurlarını ve önemli kavramlarını ayrıntılı bir literatür taraması ile analiz ettikten sonra, bir tekstil işletmesinin bu kavramları daha iyi uygulamasını mümkün kılmaktır. Bu araştırma makalesi, performans ölçümünün temel kavramlarına odaklanmaktadır İstatistiksel süreç kontrolü (İSK) ve Pareto Analizi (PA), temel olarak bu tür tekstil araştırmaları için çalışan ve üretim hatalarıyla ilgilenir. Bu nedenle, bu çalışmanın konusu ile ilişkili olarak kullanılan İSK ve PA yöntemleri kullanılarak organizasyon, kurumsal ve üretimin verimliliğine bağlı olarak tartışılmaktadır. Bu konuya yönelik çalışmalar, bu sektörde faaliyet gösteren bu şirket ve diğer şirketler için temel yapı taşı ve yol gösterici olacaktır.

**Anahtar Kelimeler:** Kalite, İstatistiksel Süreç Kontrolü (İSK), Tekstil, Yönetim

## Introduction

Quality can play a vital role in an organisation’s business living in today’s highly competitive environment. It is evident that companies that can quickly and successfully meet specific needs have a greater chance of survival. Consistent decreases in product or services differences are obvious in order to reach and preserve the desired high quality. The control chart was used thoroughly by professionals as a referenced tool for statistical process control to evaluate and even minimize production variations by identifying and reducing causes of variation (Ho and Case, 1994: 40-45; Montgomery, 1980: 40-43; Porteus and Angelus, 1997: 1215-1218).

Quality has been one of the most significant deciding criteria for customers when selecting between rival goods and services. The phenomena is common, whether it is an entity, an industrial corporation, a store store or a military defense program. Consequently, a crucial factor contributing to market performance, prosperity and an increased competitive place is recognizing and enhancing the efficiency. There is a significant investment gain from increased efficiency and the efficient application of efficiency as an important part of the overall market plan. Statistical Process Control (SPC), is the most popular way of getting high quality products from a manufacturing process (Montgomery, 1980: 40–43; Evans, 2008: 25-45; Trietsch, 1008: 1-16). The aim of introducing TQM is to provide consumers with better goods or services, which in turn would improve efficiency and reduce costs. As a result, the productivity of the company and the industry customer loyalty will be improved (Kumar et al., 2011: 36-46).

The fundamental issue in a quality-oriented company is how high we can meet the needs of customers. When customer expectations are defined, the way we can meet these expectations needs to be quantified. In a consistent way, a product appropriate for use should be manufactured, which implies that the product can manufacture with an appropriate differences of the specified Quality indicators in terms of its specified goal or nominal norms. The study attempts to illustrate the possibilities of using DMAIC (Define, Measure, Analyze, Improve, Control) model and SPC software to increase the efficiency of the processes. The benefit of this model is that it requires the different phases to use such quality management techniques (capacity map, histogram, control panel, etc.). The article discusses the possibility of enhancing the company's efficiency and high output used using these instruments and this concept is based on the realistic experience of the manufacturing industry (Gejdoš, 2015).

SPC is a commonly used method in manufacturing and construction; it enables the monitoring, control and improvement of a framework's performance. SPC is identified as an effective method to systematic and structured assessment and improvement, the research suggests that food businesses are struggling to implement SPC due to high "organizational change" and "lack of focus" in implementing the technology. The concept of organizational planning believed preparation plays an important role in minimizing opposition to the introduction of the latest technologies. The involvement of this research is to evaluate suitable methods of SPC along with a development of a self-evaluation sustainment platform in the food sector as a strategic approach for supervisors to prepare for SPC application. The Self-Evaluation Method presents a general framework for food suppliers to confirm that they are confident before beginning their SPC journey. It also helps quality managers in practice to develop appropriate methods for not only the efficient use of SPCs but also to improve the longevity of the business's use. This study can be extended in many ways. In consideration of generalizing its potential application in the food industry, a greater sample size of a range of professionals would be beneficial. Secondly, though understanding the importance of each preparation factor yet to be expressed, does a food corporation need to score high on any or all of the criteria for productive SPC deployment? In addition, further scientific work should tackle the relationship between these five positive effect. Lastly, it is unknown if related factors apply to the readiness level of individuals and programs since this analysis only examined organisational performance factors. Even though SPC is marketed in this sector as a team-based approach, its implementation requires organizational participation at the level of organization, project level, and person levels, contributing to the need for more future study (Smith, 2015: 408-412).

In many modern implementations, the methods developed by Shewhart and others during the first half of this century are still very useful. Their experience with other approaches and their versatility also counteract lack of productivity. Nevertheless, some of the methodologies developed recently, such as those for a number of associated quality features, multiple processes and sophisticated sample plans, should be considered in everyone changing manufacturing environments. The incorporation of new suggestions into the widely understood SPC essential inputs was too slow and resulted in a great deal of opposition of the significance of SPC in the existing production environment. SPC can be considered a very powerful mechanism to ensure reliability of systems (Montgomery, 2001).

The most widely used instrument for mathematical process management is the control charts. They require for a more effective trying to distinguish of irregular intervals from comprehensive causes of fluctuations in the value of a quality guarantee, i.e. facilitating legislation and development in process quality. It is expected that the behavior of the process is characterized by the point or one or more quantifiable principles when trying to apply Control Charts. These attributes are what researchers consider regulated standards. Control charts are used to track operations and to assess the need for corrections or process adjustments in order to produce improved overall performance or to minimize process variability. In control charts, the horizontal axis comprises the periods when statistical testing of controlled values occurred, and the vertical axis comprises values obtained of the appropriate sample characteristics. Control charts also provide sample characteristic parameters for contrast (Terek, Hrnčiarová, 2004; Sujová and Marcineková, 2015: 889 - 893).

SPC, primarily deals with human errors for this kind of textile science. Therefore the subject of this analysis should be considered in connection with facets of operational performance. These study studies will serve as a building block for the existing study in the ABC Business as well as those in the sector.

**Literature Research Upon Statistical Process Control**

In a wide range of industrial applications and simulation results processes, the statistical methods for evaluating the significance of univariate and multivariate methodologies were very well-described and implemented. Modifications of these methodologies were also analyzed in situations where there is autocorrelation in the information collected (Harris and Ross, 1991: 48-53; Montgomery and Mastrangelo, 1991: 179-203).

Zhou and Zhu (2008) have enhanced their model includes statistical model with an inaccurate control chart alerting case. The interconnected Linderman et al. design (EWMA control diagram, 2005) has also been constructed by Panagiotidou and Nenes (2009) in the field. The alerting limit was considered to have prompted to six notification in-control signal situations, out-of-control alert, in-control no signal, out-of-control no pattern, warning restriction alarm signal, and notification limit no notification.

Today, equipment disruption, fixing and durability deficiencies are the main daily issues caused by numerous manufacturing firms. These issues affect the time and expense of delivery of quality. The construction quality greatly influences the profitability of the business as 25 to 30 percent of the total cost of production attributable to the maintenance management. The statistical method to predict potential production performance is Statistical Process Control (SPC) and the continued improvement of product quality. SPC application aims at improving the quality of products, improving productivity, reducing waste, reducing defects and improving customer core beliefs (Tsacle and Aly, 1996: 447-450; Mirko et al., 2009: 1-4).

In the development of appropriate models using the framework of SPC and maintenance, the strong relationship between customer satisfaction and maintenance of production systems has made contributions. The total failure and maintenance activities are continuously provided in an integrative approach. Six various possibilities contribute to this framework. A new method is also described for the calculation of average costs per unit. Eventually, a multiplication instance is used to assess the system's sensitivity and to correlate the performance of the proposed model with the planed performance evaluation. For the integrated model, the results show considerable improvement (Mehrafrooz and Noorossana, 2011: 1245–1255).

In Srikaeo et al. (2005) research, Applying SPC methods was an advertising biscuit cooking study focusing on wheat. Those technologies included graphs, means analysis, control charts, framework ability research papers and Gauge R&R (Gage Repeatability and Reproducibility). The manufacturing significant variables included variables of the natural resources (what protein and moisture content) and population whose properties are studied (breakage strength, humidity and biscuit texture).

SPC is used with the seven quality control tools for analysis of defects. The Pareto diagram, cause and effect diagram, control chart, dispersion chart, control sheet, flow chart and histogram are seven quality control tools. OEE (Overall Equipment Effectiveness) is utilized to estimate performance of the vehicle. Expanding machine quality and process defects are examined for the cooperation of statistic process control (SPC), OEE, and AM (Autonomous Maintenance) to enhance productivity in terms of production process. The cause and effect diagram are also used to validate research being associated with existing production efficiency. This research examines the implementation in the current problems of seven quality monitoring tools, six significant losses of OEE (Overall Equipment Effectiveness) and DMAIC (Define, Measure, Analyze, Improve, Control) (Raguram, 2014; Azizi, 2015: 186–190).

SPC, an industrial technique for optimizing quality care can be readily extended to colorectal surgery, translating a typical outcome variable, such as length of stay, into a process variable to quickly detect and resolve variations. SPC originated as an industrial technique, where it was commonly used for quality management during processes such as Japanese automobile production. SPC stands out from most process management methods in that it uses aggressive monitoring to track and avoid defects and duplication resulting in cost-effectiveness. SPC may define typical causes of uncertainty from unintended (special) variance sources, which form an anticipated part of the process, and exclude them so that the framework is consistent and the outcomes are not substantially different from those predicted. SPC controls the ongoing phase of development, by means of graphical control charts, to achieve a process output, to track and minimize result differences, to increase consistency. SPC may help recognize the particular systemic activities contributing to outliers and unpredictable effects. Novel quality instrument - management (QI) approaches are required in this study to maximize costs and efficiency for healthcare. Our aim was to decide whether Statistical Process Control (SPC), an industrial QI, could turn length of stay (LOS) into a measure of the operation, identify outliers and their effect on surgical outcome. The SPC was executed on a 1/1/13-5/1/2018 organizational colorectal removal surgery database to mean and standard deviation and evaluate dependent variable across outliers and non-outliers. The LOS method output has been measured over time by control charts. Standard deviation (SD) of mean was set at ±1 Control Limits. In these parameters, interventions were stable (Davenport et al., 2006: 636-641; Sedlack, 2010: 18-26; Boudreaux-Kelly et al., 2015; Keller et al., 2019; Vetter and Morrice, 2019: 374-382;).

The Statistical Process Control (SPC) concept and servicing judgement are industrially integrated with the growing difficulty of the production process in establishing an integral pattern in different literatures for quality degradation and quality issues. An integrated framework of statistical process control and servicing choice is developed in the paper. The delayed tracking proposed policy suspends the sampling procedure to a planned time and relates to ten process design scenarios where equipment malfunction, in addition to a shift in quality, can take place. The failure of the equipment and the alert graph trigger maintenance activities and forecasting. The probability of events, cycle time and cycle costs of each scenario are achieved by essential calculations; a mathematical model is therefore developed, by using genetic algorithm, to reduce the estimated costs (Yin et al., 2015: 323–332). SPC is statistically based on the data-led approach and is one of the main detection systems in the system assessment and management region. The control chart in MSPC is designed to perform the detection of machining errors based on the data features of the above erratic model that can determine if the operation is out of control. If so, the operations will receive feedback. The error model is changed by remotely modifying the process and is used continuously for the monitoring of processes. Eventually, the efficiency of the additive manufacturing error control approach described in this report is shown by a machining instances with two processes (Shamsuzzaman and Wu, 2006: 269-278; Wang et al., 2012: 937–945).

Functional SPC measures the pharmaceutical process by considering only the influence of a particular element at the time using a Shewhart's map. It neglects to consider the interaction between the variables. Multivariate Statistical Process Control (MSPC) may be used to solve this problem. Everyone case study worries an APR evaluation, in which during one year 164 contemporary quantities containing six harmful substances, designed and produced in Morocco, were obtained (Kharbach et al., 2017: 446–454).

The traditional SPC, described as a process' ability to generate input within prescribed limits, is often carried out in order to check the manufacturing process' performance. This is not ideal for many industrial processes where multiple variables that are not conditionally perpendicular are created. However, the mechanism is, in fact, controlled by a large number of variables that can be dependent and due to the relationship between two variables (Pignatiello and Runger, 1990: 173-186; Laursen et al., 2010: 6503-6510; Kharbach et al., 2017: 446–454 ), raises the probability of missing out from the control behavior. Therefore, they should all be handled in a multivariate method respectively to improve the accomplishment of the application process and to achieve successful results (Kourti, 2009: 21-54).

MSPC concept was focused on exploratory factor analysis of data acquired under standard conditions using a series of four framework iterations. Tests with enforced irregularities in the dryer air pressure and temperature, in the granulator barrel temperature, velocity and fluid mass movement and in the powdered dosing module mass transfer were optimized to test the model’s controlling efficiency. The effects of the individual processing parameters was evaluated by examining contribution plots at particular time positions. Results suggest that in both control charts the perturbations applied were observed. The MSPC policy has been developed and adopted effectively overall. In addition, variations not correlated with the changes introduced were observed, particularly in the temperature control of the granulator tank (Silva et al., 2017:242–252).

The demand from consumers, government legislation and fierce competition on the market pushed food producers to adopt an effective strategy for improving quality. Although Statistical Process Control is generally understood for its performance in process control, many food businesses experienced difficulties in adopting such technique, where it was always the reason to be in the state of not ready. There has been a discussion about the importance of trying to decide a corporation's ability and willingness to introduce its Continuous Improvement (CI) methodologies like SPC towards to the effective implementation and maintenance of such methodology (Lim and Antony, 2016:133–139).

Teixeira et al. (2019)'s study describes the findings of a analysis undertaken inside an assembly line for automobile electronics. Getting screwed process required data displacement and rotating ratio were evaluated utilizing multivariate statistical process control based on principal component analysis (MSPC-PCA). The key aim was to derive useful information from a large range of associated variables so that unwanted process output changes could be observed early. A PCA (Principal Component Analysis) model was defined based on three principal components. The physical significance of each component was identified, and the underlying causes were inferred based on the process's technical knowledge. The physical significance of each variable was established, and fundamental causes were assumed focused on the process's technological expertise. Tools such as score plots and multivariate control charts for tracking the damaged screw boxes used in the data collection examined are possible to classify. In addition, eight volatility periods have been reported. Given that the out-of-control signals observed during these times correlate mostly to delays in initiation of tightening, four possible explanations were identified and evaluated to understand the actions. This study gained a deeper understanding of the behavior of the screwing process and tends to cause with greater effects on its stability (Teixeira et al., 2019).

A multivariate mathematical process analysis methodology associated with multi-way LPP (Locality Preserving Projections) is provided. The latest LPP is a linear technique for reducing dimensionality to maintain a data set neighborhood structure. The structure of the observational data is collected and more important, low-dimensional information is masked as opposed to PCA (Process Control Analysis) in the high-dimensional measurements. The underlying conceptual framework of the data analysis is derived from LPP in this analysis (Hu and Yuan, 2008: 797–807).

Data analysis of the production processes is very important for predictive process management and this will be compromised if the technician who uses the calculation instruments does not know how to properly use them. In comparison to conventional trainings, Augmented Reality (AR), provides you with guidance about how to use the technology in real time and how to use it based on how you calculate it. It's proposed for this work if the enhanced reality can improve a person's time to train and spend less money and better prepared people. Two groups of young scientists received guidance on a quality measurement system for this research study (Ramírez et al., 2015: 213–220).

Data-driven and named Just-In-Time - Statistical Process Control (JIT-SPC) is the suggested solution. Distance to normal operating data stored in the database from the present operating data is the objective of the JIT-SPC. This is because failure detection mainly depends on whether sample distribution occur near or not the existing data (Kano et al., 2011:13157–13162). Lim and Antony (2016)'s study illustrates the importance of SPC preparation to introduce it in the food industry, and evaluates its causes. Based on the latest research study, the SPC preparation variables were established and accompanied by a tri-round Delphi analysis involving SPC professionals (academic institutions, business, and professionals).

In Kaskavelis et al. (2000) research, the study looks at how the dynamic information reveal in a multivariate set of data could be used to enhance the productivity of a multivariate mean monitoring scheme. Increasing productivity of such a scheme requires the use of the covarian celcorrelation matrix of the time-lagged variables. In the present form, this will entail lagging of variables with respect to each other. A SPC Scheme is presented in which the distance from Mahalanobis is investigated based on optimally regression coefficient. Monte Carlo models are used to show the advantages of the process. In other industrial sectors, SPC has been applied with significant success (e.g. automobile, electronic and semiconductors), but it has not been broadly applied in the food sector and has implications for food scholars and practitioners (Surak, 1999; Grigg and Walls, 2007; Lim, et al., 2014). Where related questions were raised regarding the lack of current changes activities (e.g. Lean, Six Sigma and absolute quality management), one of the causes was that organizations were also not able to adopt this strategy (Lameei, 2005; Radnor, 2011; Antony, 2014). The first analysis of data collected from the Absorption Heat Transformer (AHT) is done using the method of analysis of the SPC. The purpose is here to describe whether the framework was performed in statistical check using a COP (Code of Practice) of 0.7 as a topics discussed (Hdz – Jasso et al., 2015: 1271–1286).

The interconnected methodology has been developed and developed in different stages for the pulp and paper industry. First, the structure dynamic behavior was developed into a statistical model to analyze as much as possible. The differential equation gained was then used to execute two aspects of the above constructs, the controls and the standard statistical flow charts. Researchers are presenting one situation showing the advantages of the EPC/SPC implementation of system design. By applying the methodology implemented to the real data, process engineers can now use a great technique for decision-making if certain disorders affect the manufacturing process and have apparent consequences on the quality, productivity and competitive advantage of their products (Matos, 2008:399–404).

In promoting health surveillance in transport networks, researchers propose a double-part multivariate longitudinal process analysis system. The first component includes an approximation of regression and of models ARIMA – GARCH (Autoregressive Integrated Moving Average - Generalized Autoregressive Conditional Heteroskedasticity) to describe, forecast and monitor the fluctuations in data induced by ordinary specific operating conditions, involving masses of traffic, environmental impacts and disruption when repeated measurements are made. The other aspect of the system includes using multivariate controller maps, which concurrently measures the generalized developments of certain models so as to predict potential specific factors or unique occurrences, such as unusual or irregular traffic, weather or injury incidence (Chen and Durango-Cohen, 2015: 78–102).

In Spedding and Chandrashekar (2005) research, the study outlines a simulation model called Prosim allowing a user to set up a framework of SPC for research elements, subsystems and their interrelationships. The systems and components are collaboratively defined and analyzed. A catalog of standard SPC artifacts has been generated with templates for the X-bar series, an exponential weighted average going, pchart and other SPC techniques to better describe the application power. The PC-based method is technically and in practical terms checked and is useful for the configuration and problems of a production system. It is also a important platform for teaching and study. The incorporation of new suggestions into the widely understood SPC essential inputs was too slow and resulted in a great deal of opposition of the significance of SPC in the existing production environment. SPC can be considered a very powerful mechanism to ensure reliability of systems.

The effect model of loss discussed in Cassady's research corresponds to a "jump" in the mean of the consistency variable. The consistency metric follows a standard rule under normal operating conditions and the distribution between the control limits (Upper Control Limit UCL and Lower Control Limit LCL) is respectively. When a problem happens, the mean displacement tends to cause product rates to rise with a quantification (online platform) beyond the restrictions. To perform maintenance, the control diagram must detect the problem (Cassady et al., 2000: 471-478). In certain cases, a standard legislation will model the quality metric (measurements of customers' essential feature). The indicator therefore has a certain dispersion (standard deviation of) around the mean lo. The control diagram will be used to detect abnormal behavior and to send a maintenance warning signal. The challenge is to modell the alteration of the predictor due to a device malfunction in order to refine the management and control table. Firstly, the prediction of loss. The rule of durability used in a Weibull system, in most studies. This state permits the faithful representation of different mechanical behaviour. In this situation a Weibull probability controls the time T (time before failure) (Hawkins and Zamba, 2003; 143-149).

Top management supports the chamber experts believe with the literature, describing top management cooperation and motivation as a significant element in the development of SPCs in this industrial sector (Lim, et al., 2014). SPC implementation is considered to be more of a process than a project, the research on project management sheds light on stages of SPC deployment, particularly with regard to the life cycle of the project, which is important to the SPC deployment path. It has been found that the top management needs multiple forms of assistance at specific stages of the application process (Pinto and Prescott, 1988). The SPC specialist stresses that top management engagement is of great significance in the implementation process but less so in the preparation period, in accordance with Maskin and Sjöström's (2002) report. The top management support for the SPC capability stage is considered far more appropriate. Instead, in the context of the SPC and its application, the top management should also provide a strong signal and entirely reasonable information that are appropriate to the needs of education of the receptors (De Boeck et al., 2015). This increases the acceptability of workers on the methodology and decreases the reluctance to SPC business adoption (Psomas and Fotopoulos, 2010; Kafetzopoulos et al., 2014). The SPC readiness factors identified are top management support, sense of urgency, measurement system, employees involvement and organisational culture readiness. The developed conceptual self-assessment readiness tool enables food practitioners to identify the current state of organisational readiness and facilitate the companies to plan strategic changes and preparation activities for the adoption of SPC in their businesses (Lim and Antony, 2016:133–139).

Nowadays businesses are continuously searching for optimum manufacturing productivity and profitability. To accomplish this objective, maintenance actions taken nim to improve the products quality. This study provides a literature analysis of the methods used to improve a production tool's operation and quality management, based on quality indicator measures. The main purpose of this work is to determine the quality signals that are judicious for modeling a production system. In case of faults in the manufacturing process, repair will recover the system under standard conditions. With the literature Review, different failure effect frameworks, that is, how a disappointment modifies the quality indicator, will be described. They are used to create a modeling method (Dutoit et al., 2019: 242–252).

**Intent and Objective of Statistical Process Control**

Statistical Process Control (SPC) is the use of statistical methods such as control charts to evaluate a process or its performance in order to take suitable measures to attain and sustain a statistic control condition. In a variety of areas, the SPC approach of quality management rather than one of evaluation processing benefits. These are listed as below (Trietsch, 1998: 113-165; Thompson and Koronacki, 2002; Oakland, 2008: 90-159; Montgomery, 2013:235-279).

1. Enhance consumer loyalty by delivering a product which is more hassle free.
2. Controlling the process reduces waste, rework, and maintenance costs.
3. Reduce running costs by increasing the pace of instrument upgrades and modifications.
4. Maximize efficiency by defining and reducing the causes of the factors beyond management.
5. Set a reliable and clear quality norm.

6. Eliminate or minimize the need for consumer to undergo evaluation.

Dr. Walter Shewhart, a statistician, worked at Bell Telephone Company's labs in the USA in the 1920's. He had done a lot of work on the definition of heterogeneity in the natural surroundings, and Bell was requested to use the same methods to figure out why there is so much heterogeneity occurred in the mobile phones they made. Research scientist Shewhart directed him to the belief that while each process reveals variance, some process exhibits regulated variance whilst others show unregulated variation. Regulated variance follows a constant and stable trend over time, and is thus still present in the process. Dr Shewhart contributed this difference to the factors of chance that influence the process. Uncontrolled variance, on the other hand, reveals a trend that varies over time, and this means that the mechanism itself is both unpredictable and unreliable (Evans, 2008: 113-165; Oakland, 2008: 90-159; Montgomery, 2013: 235-279).

***Monitoring the Process:*** A representation of a process over time is represented by a control chart. One must be able to view the image to use control charts effectively. A control chart shows you whether you have mathematical influence over the method. An example of a reliable mechanism (in mathematical control) is the chart above. The center of SPC consists in process analysis, i.e. illustrating data on process output against pre-established parameters. The aim of such observation is to capture, in addition to its output, details about the procedure including its inputs and underlying results (Oakland, 2008: 1-20; Levinson, 2011: 1-56; Montgomery, 2013: 235-279).

An instance of implementation of the control charts can be described as follows:

A control chart is a numerical way to screen out normal variance in a process. The most common form of statistical process control is to take samples at regular intervals and display the sample mean on a control map. Manufacturers and other industries can assess whether a procedure is safe and consistent by filtering out repetitive uncertainty. The method may be modified to produce higher quality performance at a lower cost if the deviation is more than normal. Process stability is characterized as a condition in which a process has demonstrated a certain degree of efficiency in the past and is supposed to continue to do so in the future. One of the goals of using a control chart is to attain and sustain process stability (Evans, 2008; Montgomery, 2013: 235-279).

A stream of data falling under control limits dependent on plus or minus 3 standard deviations (3 sigma) of the centerline characterizes this accuracy. The basic structure of a statistical control map as seen in Figure 1. Method data is gathered over time at some intervals and shaped into rational subgroups arranged by time.

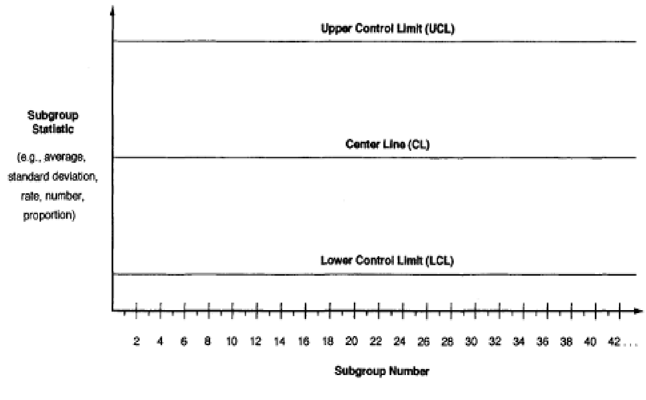


**Figure 1:** General Format of Control Charts (Benneyan, 1998)

General model for a control chart

$$UCL = \mu + k\sigma$$

$$CL = \mu$$

$$LCL = \mu - k\sigma$$

Where μ is the mean of the variable, and σ is the standard deviation of the variable.

UCL = upper control limit;

LCL = lower control limit;

CL = center line.

Where k is the range, explained in terms of standard deviation units, of the control limits from the central line. We talk of 3-sigma control charts when k is set to 3. Historically, k = 3 in industry has become an established standard.

***Interpreting the Data:*** The patterns created by the plots marked on a completed control chart for individual observations can tell us a great deal about the process, which is being monitored (King, 2011: 1-28; Levinson, 2011: 1-56). For example, this graph from a Mean and Range Control Chart shows that the natural limits (i.e. the area between the Upper and Lower Control Limits) of the process for producing the textile product-fabric lie between 98 and 128 cm.This tells us that virtually every textile product-fabric produced by this process will meet the customer's specification (95-115cm) without difficulty. In fact, statistical probability actually predicts that 99.7% of the beams will fall within these control limits. Indeed, one fabric-sheet produced was 128 cm in length and the plot for this sheet lies above the graph's Upper Control Limit. This is a very clear indication that something is going wrong with the process, even though this beam would still meet the customer's specification

***Deciding on Action:*** If you have tracked a process and correctly understood what the information informs you about its results, you must then decide about the necessary steps to take. If, say, the system has showed signs of dramatic progress (e.g. almost all tests reaching the mean), you should investigate to see if there has been a shift that has caused this. For example, it may be that a better environment for a critical aspect has been discovered, or that someone has discovered a more successful way to execute a simple task. You must then ensure that this upgrade is permanently integrated into the operation.

The community used a Cause and Effect -Fishbone Diagram (Figure 2) instead of actually brainstorming a list of explanations to ensure that we got out all the possible causes of the result we were concerned with the "late jobs”. On the other hand, any evidence of a Special Cause having an adverse effect on the process should be investigated and once the problem is identified, determined efforts made to eliminate it as far as possible from the process. It is important to settle on the result that you are attempting to solve. Including in your argument details about "what", "why", "how much" and "where."

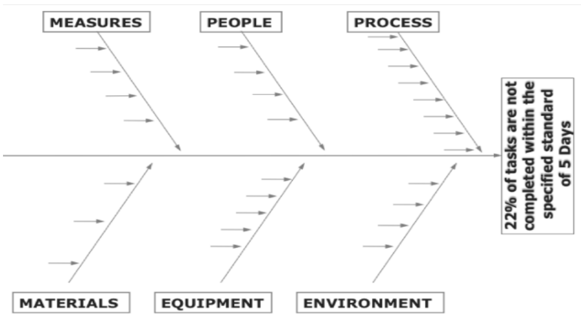


**Figure 2:** Cause and effect diagram (How a Cause & Effect, 2020)

The method is also referred to as a fishbone, since divisions are used to ensure that the team examines the challenges entirely. These types become the key bones of fish. The following six big bones were used by the group for this plan for their diagram (Montgomery, 1980: 40–43; Thompson and Koronacki, 2002; Oakland, 2008: 90-159; Montgomery, 2013: 235-279; How a Cause & Effect, 2020):

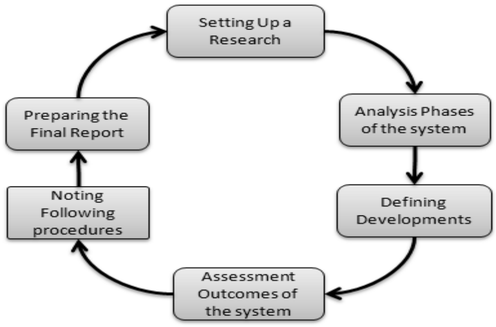


**Figure 3:** Action list

Cause and Effect Diagrams provide a fast and visually efficient way to present a summary of many different people's views. While they do not have the answer to a dilemma, their potential triggers can be established and where to start searching for the solution can be shown. Therefore, they will provide the basis for an Activity List (see Figure 3) that describes what tasks need to be completed, by whom and when these tasks should be completed. The purpose of implementing statistical process control (SPC) to a process is to increase the consistency of process results by providing the process operates at full performance. The theory of quality improvement can only be accomplished effectively by effective, clear and reliable implementation of the collection of techniques within SPC (Montgomery, 2013: 235-279; Oakland, 2008: 90-159; Thompson and Koronacki, 2002; Montgomery, 1980: 40–43). Without tracking- monitoring it, you do not tell how well a method is currently running. And to understand what is happening in the process, you must view the effects of the tracking. You can't handle what you're unable to calculate, however, you will determine what action. If any, has to be taken until you know what is happening. And after the action has been taken, you may monitor the success of the procedure under the new requirements set down by that action. A cyclical, continuous phase is the implementation of the SPC (Oakland, 2008: 90-159; Thompson and Koronacki, 2002; Montgomery, 1980: 40–43).

**Process Control Charts**

The process control chart is a tool used to record and display data on the operation of a process over time in a way that is simple to use and interpret. It is used to asist in;

- bringing the process under control by displaying the variation within the process

- identifying problems or potential difficulties by distinguishing between Special and Common Causes

- keeping the process under continous control

By drawing attention to situations which either require immediate action to remove special causes, thus returning the process to a stable condition or require management action to reduce the level of common cause variation in order to increase quality and contribution to continous improvement (Montgomery, 2013: 235-279; Trietsch, 1998: 113-165).

***Control Chart:*** The process control diagram is a technique used to monitor and view details about a process business operations over time in a format that is easy to use and read. It can be used to help monitor the process by showing the variation in processes which identifies problems or possible difficulties by discriminating between unique and specific conditions. Thus control charts, which were developed by the the American statistcian Dr. Shewart in the 1920's, present a picture of what is happening in a process (Evans, 2008, King, 2011:1-28; Thompson and Koronacki, 2002).

***Attribute Data:*** Although variable charts may show the position and scale of the difference, attribute charts only show whether an object succeeds or fails, and not how well or how terribly it does so. Attribute data with regard either: non-compliance with the specified standard, or the number of products in the survey that do not comply with the norm (Evans, 2008, King, 2011:1-28; Thompson and Koronacki, 2002). Consequently attributes data has only two possible values: yes / no; there / not there; pass / fail; go / not go, etc.

The characteristic's disappearance (e.g. inability of a lightbulb to work) or appearance (e.g. marks on paintwork) is then measured, and the effects are reported and displayed on an attribute diagram. Wide sampling sizes (commonly hundreds of various things) are required to get an accurate image of the process output utilizing attribute data. There are four basic types of chart for the monitoring of Attribute data: Number of Defects (c) Chart, Number of Defects per Unit (u) Chart, Number Defective (np) Chart, Proportion Defective (p) Chart (Evans, 2008, King, 2011:1-28; Thompson and Koronacki, 2002).

***Control Limits:*** All Process Control Charts have the same underlying objectives are presented as below (Montgomery, 1980, Montgomery, 2013: King, 2011:1-28; Thompson and Koronacki, 2002):

-- Presenting data as to whether or not a mechanism works in a predictive process management environment

-Signaling the existence of Specific Causes of Difference in the Process to enable corrective action

-Focusing steps to increase process flexibility

-- Retaining statistical monitoring by continuing to track the efficiency of the mechanism against the control limits.

The maps accomplish these aims by using Control Limits, which are essential lines drawn into the map before any data is plotted. If any points falls above the upper control limit or below the lower control limit, a special cause is present in the process. In order to find the special reason and permanently eradicate it from the operation, steps should be taken. If there is a point outside the range parameters, the other checks for out-of-control conditions do not need to be added. The regulation limit points are not declared to be out of mathematical regulation.

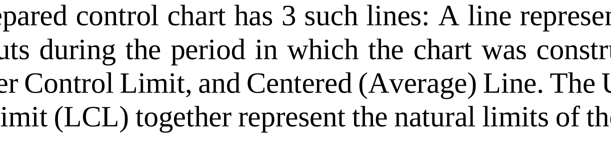


**Figure 4:** Chart that shows control limits (Interpreting Control Charts, 2020)

Each graph on a prepared control chart has 3 such lines: A line representing the average of all the sample process outputs during the period in which the chart was constructed. These are an Upper Control Limit, a Lower Control Limit, and Centered (Average) Line. The Upper Control Limit (UCL) and Lower Control Limit (LCL) together represent the natural limits of the process. The UCL and LCL lie at equal distances above and below the line representing the processes grand mean. The Upper and Lower Control Limits for the graph are then calculated using the relevant mathematical formulae (which include the values of both end), as shown in the chart footings. Again, once these values have been calculated, they are both recorded in their respective boxes and added to the appropriate graph. The area between the UCL and the LCL represents the range of variation, which is inherent in a process: Common Cause variation. In simple terms, as long as the plots remain within this area, the process can be said to be stable (i.e. to be in a state of statistical control). Plots, which appear outside the UCL and LCL, signal the presence of a special cause. There are exceptions to this, however, where specific patterns or trends in the plots highlight the (potential, at least) presence of Special Cause variation affecting the process (Interpreting Control Charts, 2020, see Figure 4).

**Process Analysis**

The objective of the process analysis is to analyze a difference in process performance and determine the capacity to reliably generate parts on schedule and within the parameters of the blueprint. The techniques of research discussed in this section are process capacity and analyses of process efficiency. A power analysis should be conducted first while researching a process, followed by a performance review of a process. It is believed that the equipment is in its usual working environment, for both process capacity and process efficiency tests (Stapenhurst, 2005: 1-10; Oakland, 2008: 90-159; Trietsch, 1998: 1-16).

***Variation:*** All processes generate measuring parts which differ. Method research relies on variance or diffusion of process production. Most of this heterogeneity is due to the various parameters present in the method, ie. Machinery, tools, procedures, people and the environment. We may classify the causes of this heterogeneity into two major categories: (i) Difference due to different factors; (ii) Varying due to different reasons

1. Variation due to common causes

2. Variation due to special causes

Variance due to particular causes (also called spontaneous, normal or intrinsic causes) is the amount of the statistical variation in the parameters of the various systems. The variance that each parameter contributes is of little significance separately, but together they generate a normal random dispersion in the results. It is difficult to recognize particular underlying factors, which typically involves a structural shift in the removal process. This means that special experiments and steps must be done to reduce the prevalent factors. They are not "controllable out." Variation attributable to individual causes (also called assignable or abnormal causes) is the result of various non-random events happening in the process (King, 2011: 1-28; Thompson and Koronacki, 2002; Montgomery, 2013: 235-279).

***State of Statistical Control:*** If a process output demonstrates variance attributable to common reasons exclusively, its output is considered to be "stable," "in a statistic control state" or "in control." The performance appears to improve itself as that is the situation and projections can be provided with certainty. The control diagram is the principal method used to evaluate a mathematical management mechanism (Evans, 2008; Montgomery, 2013: 235-279).

*(i) Process Capability:* Process capacity is a statistical assessment of the variance in common purpose that a mechanism experiences. Since the mechanism is in a state of predictive operation, an reliable estimate of process capacity can not be made. However, a process flexibility analysis may be performed as a method for evaluating whether a numerical management condition exists and as a method for problem-solving. It is suggested that capability be calculated from a system development, which is performed under controlled conditions for a limited period of time and is often considered short-term functionality (Oakland, 2008: 90-159; King, 2011: 1-28; Thompson and Koronacki, 2002).

*(ii) Process Performance:* Process performance is a quantitative tool of the two forms of variance that a phase, in subgroups, and within subgroups exhibits. Output is calculated by a process analysis, which is performed under standard operational conditions over an sustained period of time. Quality involves the results of multiple operators, modifications and improvements to the instruments, varying quantities of material and other differences that can arise over time. A long-term capacity analysis should be performed in order to simply measure the variance within the subcategory (Levinson, 2011: 1-56; Stapenhurst, 2005: 10-20).

*(iii) Process Classification:* A process capacity Analysis (Process Capability Study) has the aim of evaluating the variance of a mechanism arising from its main sources. a process capability research is to measure the variation of a process resulting from its common causes. The variance in common purpose is evaluated to assess if the system is capable of manufacturing parts under the stated parameters, precautions should be taken to remove or minimize particular sources of disputes prior to the analysis. Instances of such measures involve: (1) The system should be worked- be operating as defined for the instruments, speeds, feeds, configuration. (2) Incoming content-material should be from the similar sample. (3) The employee should have the training to do the work (Levinson, 2011: 1-56; Oakland, 2008: 90-159; King, 2011: 1-28).

***Data Collection:*** The data should be obtained as per the following Structure (Evans, 2008; Trietsch, 1998: 1-16; 113-165; William, 2011: 1-56):

*1. Subgroup size* -The subgroups can consist of 5 consecutive pieces or more. Specific cases, however, can involve subgroups larger or smaller. Throughout the research subgroup size should stay constant.

*2. Total sample size* -Calculation can be done over a brief span of time (for example, during one shift) on at least 50 consecutively made pieces. To analyze the results, the 50 measurements which maintain the original production pattern are classified into 10 sub - groups of five parts each (total of 50 components).

***Statistical Control Analysis-Control Chart Interpretation:*** The data must be in a state of statistical regulation before evaluating the functionality (or performance) of a mechanism. The control charts built on the previous page can support to decide whether predictive analysis is in effect for the results. If the control chart does not display statistical control, it is important to establish particular causes of variation and to improve monitoring methods in order to avoid their recurrence. Generally, the processing of additional data is needed. The simplest state to detect out of control is when one or more positions are outside the control boundary. All aspects can, however, be under control limits, and yet have an unpredictable operation. This happens when the points within the control limits obey a non-random sequence, including a run sequence. Instances of four out-of-control situations are addressed below and on the following chapters, including patterns, runs and embracing the control line (Evans, 2008; Trietsch, 1998: 113-165; Levinson, 2011: 1-56).

***Points Outside Control Limits:*** When one or more points are marked beyond control chart limits this suggests a possible source of variance. To get the machine back under order, this specific cause needs to be investigated and addressed. Figure 5 ilustrates points beyond the boundaries of the regulation for the textile product-fabric of ABC business.

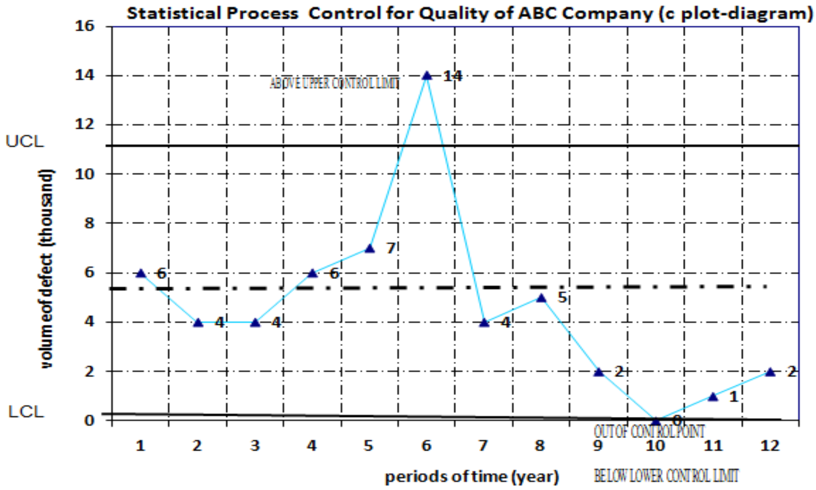


**Figure 5:** Points Outside Control Limits (UCL, Centerline, LCL, Out Of Control Point Below Lower Control Limit)

In some processes, a control chart may show a steady movement of points towards one of the control limits. This non-random pattern is called a trend and may be caused by tool wear, machine deterioration, process conditions, etc.

One trend pattern is 12 consecutive points that continue to increase or decrease. However, a point goes beyond the control limits (UCL-upper control limits) before reaching the seventh period of time and beyond the control limits (LCL-lower control limits) before eleventh period (see Figure). Although trends are usually noted on the X chart, they can also occur on the R chart. A trend on the X chart reflects a change in the process average. A trend on an R chart suggests an increase or decrease in the process variability.

**Process Performance Study**

Process performance is characterized as the statistical spectrum of variance which a process exhibits under standard conditions over an extended period of time. The aim of a process performance analysis is to analyze the process variance induced by the influence of multiple workers, equipment changes modifications, varying quantities of material and other variations that may emerge over time.

***Problem Solving And Improving Quality/ Productivity:*** The following technique for solving problems can support achieve the aim of unchallenged excellence (Evans, 2008; Trietsch, 1998: 1-16; Levinson, 2011: 1-56; Montgomery, 2013: 235-279).

*1. Define Problems and Set Priorities:* If there is a difference between the current situation and the ideal condition, a problem occurs. Helpful methods to set these goals include Pareto Diagrams, Check Sheets and Check Lists.

*2. Analyze Method:* "What does it do?" Methods demonstrating how a system is performed include the Run Chart, Histogram, and Monitoring Charts. Evaluating the effects of using these methods will define areas of interest or areas in which change is needed. Samples contain a long-term cyclic cycle illustrated by using an X-R map or drastic variations in percentage of non-compliance rate correlated with a given time of day.

*3. Determine Root Causes:* "Why Does Process Perform As It Does?" The root cause must be decided after the problem has been found. Tools include Graphs of Cause and Effect, Failure Trees, Scatter diagrams, model architecture, variance analysis, and regression analysis can be incredibly helpful. These strategies are used to distinguish the impact on the final output of processing parameters, and to determine the true cause of the problem.

*4. Identify Alternative Solutions: Many* solutions become obvious once the problem and its causes have been identified. To arrive at the right approach use collaboration and community decision making.

*5. Implement Plan-Take Action:* Anyone dealing with the question at hand should have a good idea of "what can be done. Who should do it and what the job is to be finished.

*6. Assess Action:* "Does the situation get better" all too frequently, improvements are made and the situation is thought to be corrected. If proved to be incorrect, this presumption will lead to problems of much greater severity.

Therefore, after improvements are made, follow-up action is expected to ensure the desired result is brought on by the improvements. This can be achieved by compiling data before and after the transition, allowing observations so as to calculate the influence of the changes.

*7. Keep the problem solved - Change the system:* The system can be changed to make the adjustment irreversible after a problem has been resolved or at least decreased in severity. Sometimes the complete value of a good transition is not understood because in essence the improvement seems to be either immediate or supplementary. A positive change only happens if anyone accepts the transition as a healthier way of doing things every day.

Several tools are helpful in monitoring the results to assure change is bringing about desired results. These include in-process statistical tools such as the X-R control chart and M-R chart. A survey of gages or process parameter specifications and a regular audit of incoming and outgoing materials may also be part of the answer. Whichever tool is chosen, it must efficiently and effectively monitor the system (Evans, 2008; Trietsch, 1998: 1-16; Levinson, 2011: 1-56; Montgomery, 2013: 235-279).

***Monitoring the Process and Feedback System:*** One concept associated with a company-wide Quality System is in-process monitoring aimed at preventing problems or nonconformance to specification from recurring, as opposed to the concept of detection resulting from techniques such as 100 percent inspection. Typical prevention tools include the Average and Range (X-R) chart, the Median Range (M-R) chart and Pre-Control. Another important feature of an SPC system is the implementation of a mechanism that supplies the provider with input on quality changes and product efficiency from the consumer. This method should be a joint endeavor that yields results for all in terms of quality management. An successful communications system should encourage prompt, constructive contact between a manufacturer and a customer, resulting in fast, efficient problem-solving. Evidence of follow-up events may involve attempts to establish such a support network. The report does not only answer challenges but also attempts to fix issues and increase consistency (Evans, 2008; Trietsch, 1998: 1-16; Levinson, 2011: 1-56; Montgomery, 2013: 235-279).

***Continual Quality Improvement:*** Effective implementation of Statistical Process Control (SPC) incorporates the idea of "Continuous increase of efficiency." The problem-solving practices, the use of in-process control methods and a feedback mechanism are consistent with this definition. Continual Quality and Developments property also include these items (Evans, 1980; Trietsch, 1998: 113-165; Stapenhurst, 2005: 10-20; Oakland, 2008: 90-159; Montgomery, 2013: 235-279):

- Continuous Elimination of Variance- for better efficiency, waste elimination.

- Increased Productivity- longer life and increased reliability.

- Use modern technologies- to help improve productivity and minimize differences wherever and whenever possible.

- Utilize New Technology (Streamline Processes and Practices) meaning attempts to increase efficiency can be made easier.

- Developing a plant strategy- aligned with the ongoing quality management program.

-Take care that everybody understands the theory and is motivated to live up to it. This policy should represent an environment where workers are motivated to become involved.

- Train Personnel in their work roles- high quality requirements, emerging technology, use of computational methods and strategies for empirical problem solving.

**Implementation**

The methods of Statistical Process Control (SPC) can provide significant payback to those companies that can successfully implement them. Management involvement and commitment to the quality improvement process is the most vital component of SPC's potential success. A team approach is important, as it is usually difficul for one person alone to introduce process improvements. The basic SPC problem solving tools become widely known and widely used throughout the organization. Continuous training in SPC and quality improvement is necessary to achieve this widespread knowledge of tools. The control strructure of SPC Application is presented in Figure 6 (figure 6 is modified by author due to Oakland, 2008: 90-159; Stapenhurst, 2005: 1-10; Trietsch, 1998: 1-16; Evans, 2008).

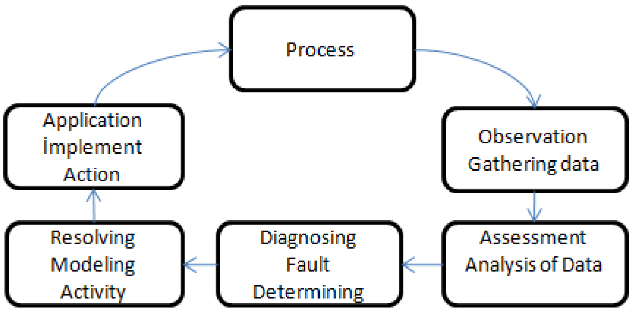


**Figure 6:** Control System view of SPC Implementation

The objective of an SPC-based quality-improvement program is continuous improvement on a weekly, quarterly, and annual basis. SPC is not a one-time program to be applied. Quality improvement must become part of the culture of the organization. The importance of management leadership and the team approach are overemphasized. Successful quality improvement is a top-down management-driven activity. Measuring success and progress is also important. Moreover, successful improvements must be communicated throughout the company. Motivation can be provided by this way. In implementing a company-wide SPC asssessment. There are several elements which usually presents in all successful efforts. These elements are listed as follows (Oakland, 2008: 90-159; Stapenhurst, 2005: 1-10; Trietsch, 1998: 1-16; Evans, 2008):

-Management Leadership.

-A Team Approach.

-Education of Employees.

- Emphasis on continuous improvement.

***Quality Control Steps****:* Quality improvement should include all processes and in a company. As for ABC Business in Textile sector, quality should be considered for following steps:

*Product development:* While designing new products, cloths and materials should be controlled in terms of quality. Here we should consider effects of materials to each other compatibility of new products with machines, equipment, tools and fixtures.

*Quality control just before the manufacturing process:* Examination of sealed sample, orders of cloth and cloth quality control, semi-products quality control quality control of subcontract items.

Quality control of manufacturing process

Quality control done by customer representatives of ABC Business in Textile sector.

Quality control done by customers.

Quality control done by customers at their facilities.

Quality control done by retailers.

As mentioned before, Statistical Process Control (SPC) is a long and continuous program. There are many processes that quality control could be implemented. Improvement of quality should cover all procedures from within a business. As for the consistency of ABC Textile Business, the following measures should be applied. These are listed as below;

(i) Product development: cloths and fabrics should be regulated in terms of quality when developing new goods. Here we should recognize consistency of modern goods with devices, machinery, instruments and structures with the impact of resources on each other.

(ii) Quality management directly prior to the production process: inspection of shipped sample, quality management of textile and fabric orders, quality control of outsourcing goods by semi-products.

(iii) Manufacturing process quality management: Quality management by Customer Representatives of ABC Textile Business, Customer Quality Management, Customers conduct quality management at their stores.

SPC is a long and continuous program, as already stated. There are several methods that should be incorporated for quality management. Since we have time constraints, we agreed to narrow our focus to the development process.

***Manufacturing Process:*** As mentioned previously, the development process is performed at a facility located in the Marmara Region, Turkey. We also observed that the manufacturing line (excluding the cutting processes) consists of 46 processes as a result of a long analysis. Two key aims of this analysis are to understand how to use SPC by conducting this thesis specifically and to assist in the application of SPC by company sector. It is then agreed, for all purposes, to select and enforce certain essential processes. For the purposes of the study, this would be enough and will be a framework for the subsequent SPC analysis at the organization. Moreover, because of the short time span, it will be ideal. In reality, the analysis contains some of the processes between them.

Rating them on the basis of the following criteria;

- Number of defects on average
- Consequences (cost) of those defects
- Its effects to the other processes
- Complaints coming from the customers

Now, to understand what is planning on, it would be easier to look at the systems. The forms of defects and their effects were chosen to control the process. This is a product of a big brain storming exercise. Operators and quality chiefs were generally aware of the effects of the errors. But in sequence, they weren't described and registered. So, designers got together and agreed on all of the ramifications. For future research, this was mainly for their benefit.

***Control Chart Applications:*** Statistical Process Control (SPC) is a general action for improvement. The entire process within the business should be extended to it. As we mentioned earlier, designers will extend the SPC approaches to restricted systems for some purposes. One of the essential SPC methods is control charts. They are an established tool for enhancing efficiency and are successful in avoiding defects.

It is not possible to numerically represent certain consistency attributes conveniently. In such instances, each object inspected is typically graded as either compliant or non-compliant with the requirements for that quality element. In previous parts, manufacturing processes were specified. It can be clearly found that it is not possible to quantify numerically the consistency characteristics of nearly all of the systems. Thus, control charts should be based on data from attributes.

P control charts may be implemented, with attribute data, to the processes. Designers preferred p charts for faulty fractions. In order to identify each component as either non-conforming or conforming to standards, the word "defective" or "nondefective" is sometimes used.

***(i)The p Chart of Textile Product-Fabrics***

The textile product-fabric process is decided by the production engineer and quality chiefs as the most important phase on the production line, according to the above-mentioned protocol. So for this method, we applied the p control map. In this method, a gap of one cm is left for the near stitch and a gap of three cm for the distance. They are synonymous with each other and with corners.

Forms of Defect are listed as below;

(i) Wrinkledness of the stitches

(ii)Close and far stitches that are not identical to the edges

(iii) Obliquity of parties

(iv) Stres-Tension being too high or too low for two sides

***(ii) Data Collection***

Collecting data is the first step to creating the p chart. In SPC implementation, sampling is a very critical problem. Procedures of sampling for the processes;

*Rational Sampling:* A fair sample is a series of measures, the rational variance of which can only be due to a constant scheme of similar causes. That is, all findings should be from the same community within a survey. Subsequent measurements should be collected in such a manner that the probability of some unique triggers occurring between the measurements is maximized.

*Sample Size Choice:* To determine special assignable causes, the size of each subgroup (n) must be large enough. N, on the other hand, must be small enough to be economical and to ensure that subgroups are exposed only to variants in the popular purpose.

***(iii) Interpretation of the Chart***

Designers search specifically at points outside of limits, cycles, patterns and developments when interpreting P control charts. Developers do not find any out-of-balance points as they evaluate the chart, hence the process seems to be in good statistical regulation. The method only tends to be susceptible to common-cause variance. But at 19 percent, the average flawed percentage fraction is very high. Since the process is under predictive charge and the average fraction faulty incidence is unfavorable, the approach should be questioned. There should be a reform to the framework. This of include improvements in operating practices and processes, increased standards of instruction for operators, different types of equipment and infrastructure or better input products. Many of these are the liability of management.

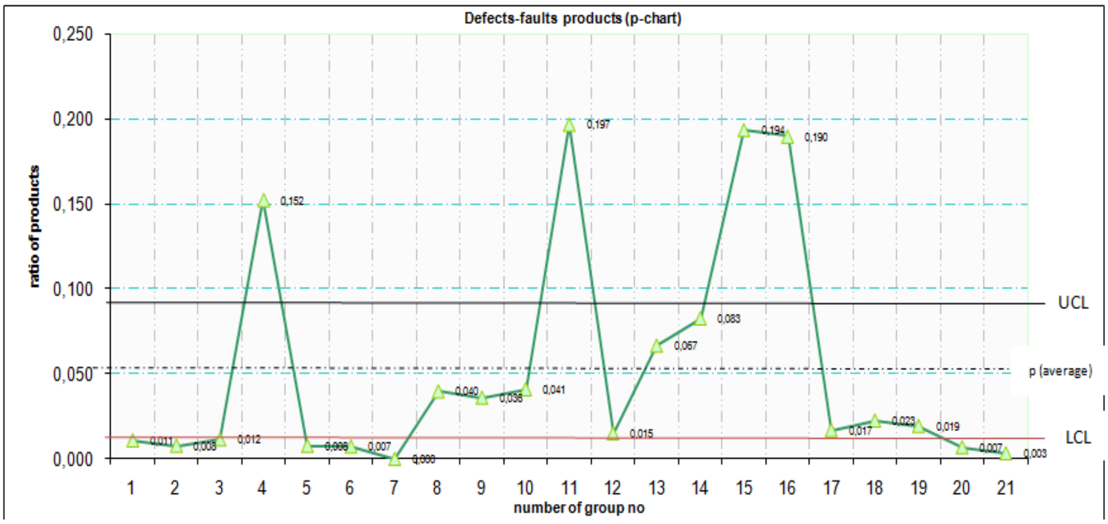


**Figure 7:** P Chart for the fraction-ratio defective of Process

This process should be intervened because there are points outside of UCL (Upper Control Limits) and LCL (Lower Control Limits). Operator change may be caused by the difference of raw material, different control elements, change of measurement methods, narrowed standards, etc. In the continuation of the production for this purpose, it should be tried to reduce the defect rate.

Fraction detectives for production are determined by dividing the number of defectives to the total number of items detected. These fraction detectives are plotted on the p chart as in Figure 7.The control limits and the centerline are found out to be as above;

The UCL of the defect ratio of this production is 0,09455; LCL is 0,01515 and average (CL-center line) is 0,05485 with p control chart. The calcultions control limits of the numbers of this type products of this apparel company Production between 2018 and 2019 is examined as above in figure 7.

$$\bar{n} = \sum n/k = \frac{numberofco\ ntrolledpr\ oducts}{numberofgr\ ouppedi}$$

$$Average : \bar{p} = \frac{numberofde\ fectsprodu\ cts}{numberofco\ ntrolledpr\ oducts}$$

$$Limits : \bar{p} \mp 3 \times \sqrt{\bar{p} \times \left(\frac{1-\bar{p}}{\bar{n}}\right)} \qquad \text{Formula (1)}$$

This process should be intervened because there are points outside of UCL and LCL. (UCL: 0,09455; LCL: 0,01515 and average (CL-center line): 0,05485 – by Formula (1)) Operator change, difference of raw material, different control elements, change of measurement methods, narrowed standards etc. It may be caused by the reasons. Efforts should be made to reduce the defect rate in the continuation of the production for this purpose.

When the control diagrams are used to control the machine set-up times in a production process in ABC Textile factory, where delays occurring during machine setting are seen to significantly affect the work flow in some cases, the process is under control in the light of the data. During the fabric production process in the textile factory, the points to be considered in the machine setting times:

- Periodic changes in measurement conditions

- Comparison of the outputs of different processes

- Systematic errors in the calculation of control limits or points.

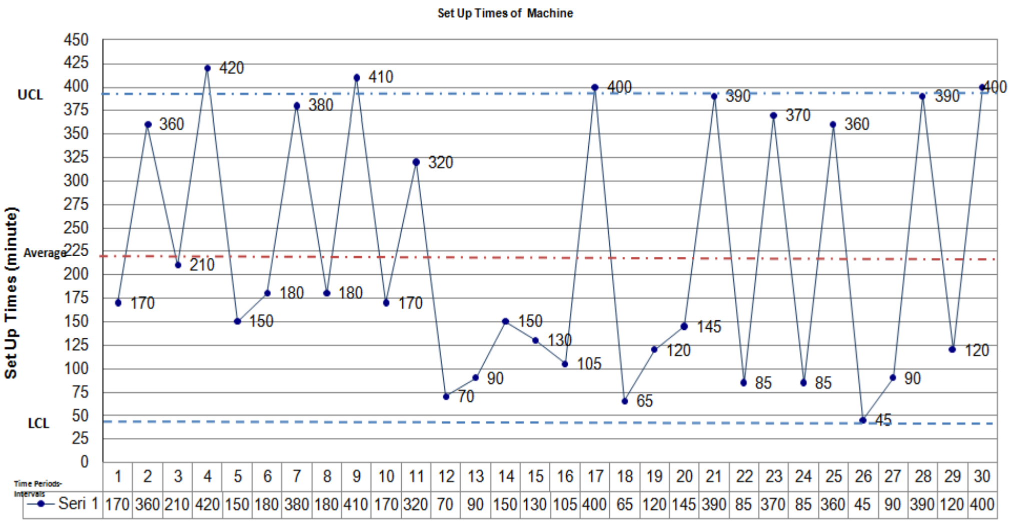


**Figure 8:** Set Up Times of Machines via X-R Chart analysis

SPC (X-R Chart) analysis result, there is no point out of limits. The control Limits are calculated with this chart formulas. (UCL (Upper Control Limit: 387,4325; LCL (Lower Contorl Limit): 48,87 and Average (Center Line): 218,66. However, since there are points close to the average and each other, the process should be intervened and controlled. The reasons for this may be due to the differences in tool breakage, change in machine feet, different operator, part changes and continuous adjustment times (see Figure 8).

**Making Cause and Effect Diagrams (General Steps) and Oriented Quality via Pareto Analysis**

*(i) Cause and Effect Diagram:* A fishbone diagram, also called a cause and effect diagram or Ishikawa diagram, is a graphical technique for categorizing the possible causes of a problem in order to determine the root causes. Usually used for root cause research, a fishbone diagram blends the process of brainstorming with a form of mind map design. These diagrams are considered one of the seven fundamental quality instruments and are used in the process of Six Sigma Analysis.

In the cause and effect diagram, the potential causes of defect in the consistency characteristic (result) are organized in such a manner that all interactions are shown (Quality Improvement, 2020; Fishbone diagram, 2020) .

*Step 1:* The consistency attribute (defect form) was determined by us. This is something that we wish to strengthen and monitor. We may have noticed that most of the defectives were due to defects in this case. We must recognize the triggers in order to remove this issue (close and far stitches not being parallel to each other and to edges).

*Step 2:* By boxing in the quality function (defect) on the right side, designers have built the diagram. Developers've drawn an arrow that stretches to the box from the left. Then, Developpers have examined key factors that may trigger the issue with the defect form that guides a branch arrow to the main arrow. The key potential sources of the issue have been categorized into factors such as materials, machinery, procedures, individuals, and the environment. A branch would be created by each individual group.

*Step 3:* developers have reported about each of these divisions in the detailed reasons that can be considered as the causes. They have reported about both of these causes in even more comprehensive ways.

*Step 4:* Designers have eventually checked to ensure that all variables that can induce dispersion are included in the diagram.

*Step 5:* For more study, designers will classify and pick the most plausible causes from this well-defined diagram of potential causes. Designers should look for items that have changed and anomalies from the standard or trend while analyzing the cause. Designers should try to treat the causes of the issue and not the symptoms.

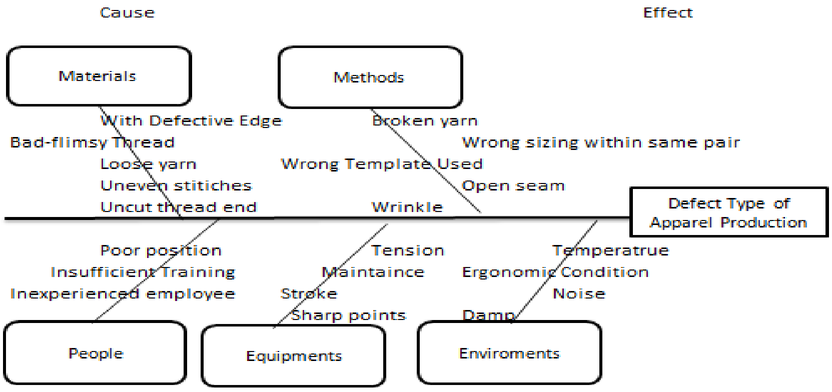


**Figure 9:** Cause and Effect Diagram

In conclusion, our objective is to get results. A diagram of cause and effect is an assist to specifically illustrate the relationship between the problem's causes and effects. Corrective steps should be taken after the sources of the problem have been found. In this ABC Apparel-textile Business, this diagram contributes to every process of the Production system (see Figure 9).

| Defects-Failures | Number of Defects -Faults | Cumulative Percentage |
|---|---|---|
| Wrinkle | 250 | 11,72 |
| Open seam | 240 | 22,97 |
| Bad-flimsy Thread | 230 | 33,76 |
| Broken yarn | 125 | 39,62 |
| Loose yarn | 125 | 45,48 |
| Wrong sizing within same pair | 123 | 51,24 |
| With Defective Edge | 120 | 56,87 |
| Damp | 87 | 60,95 |
| Stroke | 78 | 64,60 |
| Tempereture | 78 | 68,26 |
| Tension | 76 | 71,82 |
| Ergonomic Condition | 76 | 75,39 |
| Uneven stitiches | 75 | 78,90 |
| Uncut thread end | 70 | 82,18 |
| Ergonomic Condition | 65 | 85,23 |
| Inexperienced employee | 65 | 88,28 |
| Poor position | 63 | 91,23 |
| Insufficient Training | 55 | 93,81 |
| Maintaince | 54 | 96,34 |
| Wrong Template Used | 43 | 98,36 |
| Sharp points | 35 | 100,00 |

**Table 1:** Cumulative percentage of Defects-Failures for Pareto Analysis

*(ii) Pareto Analysis:* Users first need to grasp the elements and the interaction between them to create a Pareto map. The Pareto map, literally, is a bar line. Being a bar line, the x-axis and y-axis are made up of two primary factors. To plot the various divisions into which the data is broken down, the x-axis is used. The number of instances or the count for each particular group is seen on the y-axis. The bars, starting from left to right, are arranged from the highest frequency to the lowest frequency (see Figure 10 and Table 1). A line graph is used to represent the average percentage of the total number of events after ordering the bars in decreasing order according to their frequency. The line graph is a visual sub-tool that is used to spot automatically if the 80/20 law is observed by a certain collection of Results (How to Do Pareto Chart Analysis, 2020)

If users find multiple related problems or a particular issue of multiple causes, Pareto analysis should be used. If there are enough events that you can categorize and count them, this method can be used. In other words, if there is only one root trigger, this strategy would not work. The purpose of Pareto Analysis is to analyze and decide the degree of occurrence of the problems. In exchange, this gives you the data you need to organize your initiative to ensure that you invest your time where it can have the most beneficial effect.

Because of the high level of defects, the system is not adequate to support operational targets. And we wanted to more closely and deeply examine the plan. We also collected data on defect forms and their number of occurrences as we collected data from the process. Designers designed a Pareto Analysis based on these statistics. You can see the Pareto Analysis data in Figure. The study found that 80% of all defects accounted for one form of defect (close and car stitches not parallel to the edges). As in Figure 10 and via Table 1, a Pareto Chart is formed.

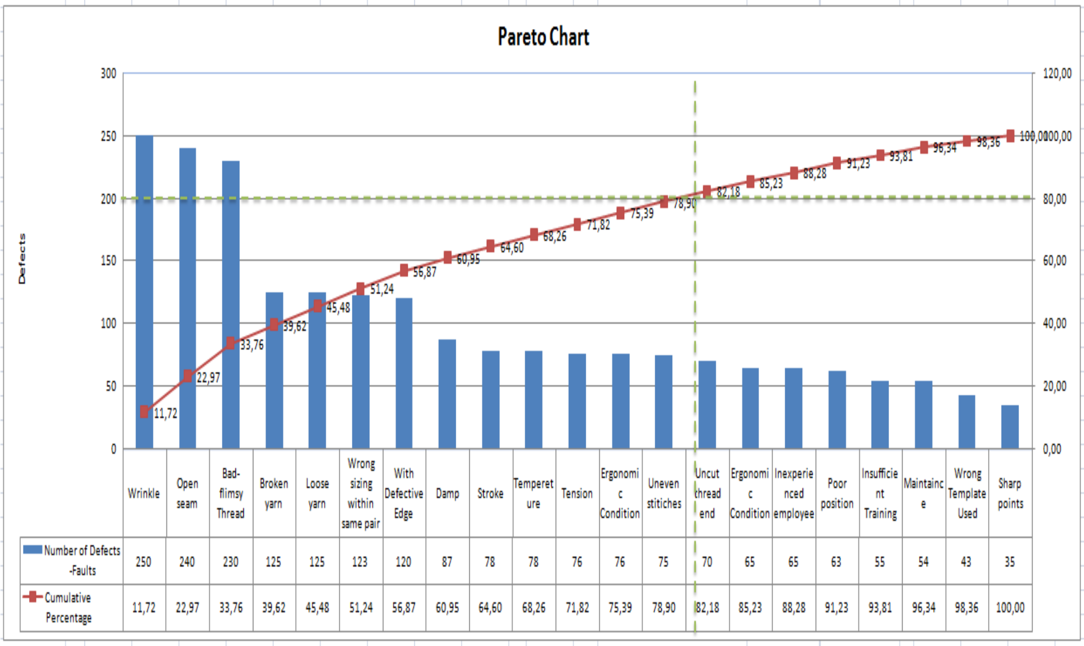


**Figure 10:** Pareto Analysis of ABC Business ın Textile Industry

The weight of cumulative percentage (CPW) can be arranged into a Pareto diagram to demonstrate which technical requirements are most important and the risk prioritization of characteristics to eliminate the defects from the products. While evaluating the high-priority absolute weights supported requirements point sources between the values of these criteria in PA, conformity with 80% threshold risk variable, the initial 13 failure-defects point sources prominence (Figure 9).

The values of cumulative percentage weight can be organized into a Pareto diagram to show which types of defects-causes are most important and the risk prioritization of requirements. These are labelled and sorted with CPW that are called Wrinkle, Open seam, Bad-flimsy Thread, Broken yarn, Loose yarn, Wrong sizing within same pair With Defective Edge, Damp, Stroke, Temperature Tension, Ergonomic Condition and Uneven stitiches respectively.

Thus the process should be thoroughly and closely checked. Defect has been determined to be the key point for improving the operation. It is necessary to define the root causes of the defect and take corrective steps. It should also be remembered that almost 80 percent of human accidents are caused. The Textile industry is typically a labour-intensive market. So employees should be constantly informed, they should be adequately encouraged. The system can also be enhanced by improvements in job processes and procedures.

**Evaluation and Conclusion**

In manufacturing or development systems, statistical process control (SPC) is widely used to calculate how reliably a component performs according to its design requirements. The center of the SPC is the continuing statistical study of parametric measurements to check that the measurements are carried out in a normal distribution. Although no two products with the same design and development will ever function precisely the same, it should be expected that the same general distribution will accompany the output of the products. Measurements taken from multiple versions of the same product that may not meet a standard distribution which suggest a problem with the products, staff, structure or machinery used in the production or testing process. In the use of SPC processes, constant enhancement goes hand-in-hand. It is important that key staff on the production line are notified as SPC provides early notice of potential problems and can take immediate measures to fix the problem and avoid the imminent problem from being a line-stopping concern. SPC may help capture complaints before they happen, instead of after they have happened, by shifting the responsibility for quality control closer to real-time.

To find out the root cause of the problem causing the malfunction, the manufacturing process must be halted or shut down entirely. It can take more time to find and resolve the problem. Production difficulties are caught during the production process with the introduction of SPC tools, and only a small portion of the production line needs to be shut down. It is necessary to redirect the work cycle of the real issue area to a replacement manufacturing assembly line. The entire manufacturing line never entirely shuts down, ensuring that continual manufacturing is preserved. If the issue region of the production line is under maintenance/reconstruction, the same units per hour/per day of operation is probable. The replacement manufacturing assembly line may be taken out of the machine until restored, and regular service returns. SPC control charts present statistical information in a statistical form for tracking production efficiency. It recognizes and shows any unexpected differences in the method so that suppliers can screen for multiple causes/accidents. Statistical data allows real-time insight to set production baselines, create control over those baselines, optimize the production process, detect and fix defects or faults without depending on judgments or guesswork / expectations.

The aim of each organization is to fulfill or surpass the requirements of the customer and to become a reliable supplier or long-term business partner to a client, thus fulfilling the needs of the customer. For example, for high quality spare parts at a cost-effective price, a car maker must rely on its parts supplier. The producer can take its business elsewhere if a supplier often ships low-quality components. The retailer is ensured consumer satisfaction when using SPC tools, so the vendor may rely on a high quality product.

In addition to balancing the playing field, control charts often affirm the fact in what citizens already learned and refute misconceptions concerning procedures. Decision-making is easier in the enterprise because everyone has access to the same data and is on the same page. Intelligence in manufacturing by applications for process management would set you apart from your rivals and ease production challenges. When it comes to knowledge in production, so much data is never a bad thing. Over all, it is paramount to obtain real-time visibility into the output quality management systems as it can be just the thing to keep you from incurring unforeseen costs arising from process breakdowns and difficulties with product consistency. The classic 80/20 law is based on Pareto Analysis. That is 20 percent of the issues cause 80 percent of the incidents in many cases. For instance, let's suppose, users have a problem, depending on a variety of reasons, with a defective product. Users decide that there are eight factors by evaluation and obtaining measurements. Instead of arbitrarily targeting the factors, a Pareto study might reveal that 80% of the problems could be solved by the top three causes.

**References**


Antony, J. (2014). Readiness factors for the lean six sigma journey in the higher education sector. *International Journal of Productivity and Performance Management,* 63(2), 257-264. http://dx.doi.org/10.1108/IJPPM-04-2013-0077/full/html

Azizi, A. (2015). Evaluation ımprovement of production productivity performance using statistical process control, overall equipment efficiency, and autonomous maintenance. *Procedia Manufacturing,* 2, 186–190. http://dx.doi.org/10.1016/j.promfg.2015.07.032

Benneyan, J. (1998). Use and interpretation of statistical quality control charts, *International Journal for Quality in Health Care,* 10(1), pp. 69-73. http://intqhc.oxfordjournals.org/content/10/1/69.full.pdf.

Boudreaux-Kelly, M., Wilson, M., & Bokhari, M. (2015). Statistical methods of risk-adjusted statistical process control charts to assess surgical performance in consecutive colorectal operations at a single institution. *JAMA Surgery,* 150 (3), 271-272, https://doi.org/10.1001/jamasurg.2014.1773

Cassady, R., Bowden, R., Liew, L. & Pohl, E. (2000). Combining preventive maintenance and statistical process control: a preliminary investigation. *IIE Transactions*, 32, 471-478, https://doi.org/10.1080/07408170008963924

Chen, Y. & Durango-Cohen, P. L. (2015). Development and field application of a multivariate statistical process control framework for health-monitoring of transportation infrastructure. *Transportation Research Part B: Methodological,* 81, 78–102. http://dx.doi.org/10.1016/j.trb.2015.08.012

Davenport, DL., Bowe EA., Henderson, WG., Khuri, S.F. & Mentzer, RMJ. (2006). National surgical quality improvement program (NSQIP) risk factors can be used to validate American society of anesthesiologists physical status classification (ASA PS) levels. *Annals of Surgery*. 243(5), 636-644, https://doi.org/10.1097/01.sla.0000216508.95556.cc

De Boeck, E., Jacxsens, L., Bollaerts, M. & Vlerick, P. (2015). Food safety climate in food processing organizations: Development and validation of a self-assessment tool. *Trends in Food Science & Technology,* https://doi.org/10.1016/j.tifs.2015.09.006

Dutoit, C., Dehombreux, P., Lorphèvre, E. R. & Equeter, L. (2019). Statistical process control and maintenance policies for continuous production systems subjected to different failure ımpact models: literature review. *Procedia CIRP,* 86, 55–60. https://doi.org/10.1016/j.procir.2020.01.050

Evans, J. (2008). Statistical process control for quality ımprovement: a training guide to caring spc, prentice hall, cincinnati, Pearson Technology Group; 1st Edition, 204 p., ISBN-13: 978-0135589908

Fishbone diagram-Ishikawa cause and effect, https://whatis.techtarget.com/definition/fishbone-diagram) (Access Date: 12.05.2020).

Gejdoš, P. (2015). Continuous quality ımprovement by statistical process control. *Procedia Economics and Finance*, 34, 565–572. https://doi.org/ 10.1016/s2212-5671(15)01669-x

Grigg, N. P. & Walls, L. (2007). Developing statistical thinking for performance improvement in the food industry. *International Journal of Quality & Reliability Management*, 24(4), 347-369. http://dx.doi.org/10.1108/02656710710740536

Harris T. J. & W. H. Ross. (1991). Statistical process control procedures for correlated observations. *The Canadian Journal of Chemical Engineering,* 69, 48-57.

Hawkins, D. M. and Zamba, K.D. (2003). On small shifts in quality control, *Quality Engineering*, 16, 143-149, https://doi.org/10.1081/QEN-120020780

Hdz – Jasso, A. M., Contreras – Valenzuela, M. R., Rodríguez – Martínez, A., Romero, R. J. & Venegas, M. (2015). Experimental heat transformer monitoring based on linear modelling and statistical control process. *Applied Thermal Engineering*, 75, 1271–1286. http://dx.doi.org/10.1016/j.applthermaleng.2014.09.013

Ho, C. & Case, K. E. (1994). Economic design of control charts: A literature review for 1981–1991. *Journal of Quality Technology*, 26, 39–53. https://doi.org/10.1080/00224065.1994.11979497

How a Cause & Effect Diagram Helped Reduce Defects by 19% https://goleansixsigma.com/achieving-a-19-improvement-in-response-time-using-a-cause-and-effect-diagram/ (Access Date: 10.09.2020).

How to Do Pareto Chart Analysis, https://tallyfy.com/pareto-chart-analysis/, (Access Date: 10.09.2020).

Hu, K. & Yuan, J. (2008). Multivariate statistical process control based on multiway locality preserving projections. *Journal of Process Control*, 18(7-8), 797–807. http://dx.doi.org/10.1016/j.jprocont.2007.11.002

Interpreting Control Charts, https://www.spcforexcel.com/knowledge/control-chart basics/interpreting-control-charts (Access Date: 10.09.2020).

Kano, M., Sakata, T. & Hasebe, S. (2011). Just-ın-time statistical process control: Adaptive monitoring of vinyl acetate monomer process. *IFAC Proceedings* Volumes, 44(1), 13157–13162. http://dx.doi.org/10.3182/20110828-6-it-1002.01756

Kafetzopoulos, D. P., Gotzamani, K. D. & Psomas, E. L. (2014). The impact of employees' attributes on the quality of food products, *International Journal of Quality & Reliability Management*, 31(5), 500-521. https://doi.org/10.1108/IJQRM-05-2012-0057

Kaskavelis, E., Martin, E. B., Morris, A. J. & Jonathan, P. (2000). On the statistical process control of multivariate autocorrelated processes. *IFAC Proceedings*, 33(10), 165–170. https://doi.org/10.1016/s1474-6670(17)38536-1

Keller, D. S., Reif de Paula, T., Yu, G., Zhang, H., Al-Mazrou, A. & Kiran, R. P. (2019). Statistical process control (SPC) to drive improvement in length of stay after colorectal surgery. *The American Journal of Surgery*. https://doi.org/ 10.1016/j.amjsurg.2019.08.029

King, M. (2011). Process control: A practical approach, John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom, p.1-28, ISBN 978-0-470-97587-9.

Kharbach, M., Cherrah, Y., Vander Heyden, Y., & Bouklouze, A. (2017). Multivariate statistical process control in product quality review assessment – A case study. *Annales Pharmaceutiques Françaises*, 75(6), 446–454, http://dx.doi.org/10.1016/j.pharma.2017.07.003

Kourti T. (2009). Multivariate statistical process control and process control, using latent variables. In: Brown SD, Tauler R, Walczak B, editors. Comprehensive chemometrics. Oxford: Elsevier; 2009. p. 21-54.

Kumar, R., Garg, D. & Garg, T.K. (2011), TQM success factors in north Indian manufacturing and service industries, The TQM Journal, 23(1), 36-46, https://doi.org/ 10.1108/17542731111097470

Lameei, A. (2005). Assessment of organization readiness for TQM implementation. *Iranian Journal of Public Health*, 34(2), 58-63.

Laursen, K., Frederiksen, S.S., Leuenhagen, C. & Bro, R. (2010) Chemometric quality control of chromatographic purity. *Journal Chromatogr A*, 1217, 6503—6510, http://dx.doi.org/10.1016/ j.chroma.2010.08.040

Levinson, W. A. (2011). Statistical process control for real-world applications, Taylor and Francis Group, LLC, p.1-56. ISBN 13: 978-1-4398-2001-8.

Lim, S. A. H. & Antony, J. (2016). Statistical process control readiness in the food industry: Development of a self-assessment tool. *Trends in Food Science & Technology*, 58, 133–139. https://doi.org/10.1016/j.tifs.2016.10.025

Lim, S. A. H., Antony, J. & Albliwi, S. (2014). Statistical process control (SPC) in the food industry– A systematic review and future research agenda. *Trends in food science & technology*, 37(2), 137-151. http://dx.doi.org/10.1016/j.tifs.2014.03.010

Linderman, K., McKone-Sweet, K. E. & Anderson, J. C. (2005). An integrated systems approach to process control and maintenance. *European Journal of Operation Research*, 164, 324–340. https://doi.org/10.1016/j.ejor.2003.11.026

Matos, A. S., Requeijo, J. G. & Pereira, Z. L. (2008). Integration of engineering process control and statistical control in pulp and paper industry. 18th European Symposium on Computer Aided Process Engineering, 399–404. http://dx.doi.org/10.1016/s1570-7946(08)80071-5.

Maskin, E. & Sjöström, T. (2002). Implementation theory, Chapter 5, Handbook of social Choice and Welfare, 1, 237-288.

Mirko, S., Jelena, J., Zdravko, K. & Aleksandar, V.(2009). Basic quality tools in continuous ımprovement process. *Journal of Mechanical Engineering*, 55(5), 1-4.

Mehrafrooz, Z. & Noorossana, R. (2011). An integrated model based on statistical process control and maintenance, *Computers and Industrial Engineering*, 61(4), 1245–1255. https://doi.org/10.1016/j.cie.2011.07.017

Montgomery D. C. & C. M. Mastrangelo. (1991). Some statistical process control procedures for autocorrelated data and discussion. *Journal of Quality Technology*, 23(3), 179-204.

Montgomery, D. C. (2001). Introduction to statistical quality control (fourth ed.). Wiley.

Montgomery, D. C. (1980). Economic design of control charts: A review of literature survey. *Journal of Quality Technology,* 12, 40–43.

Montgomery, D. C. (2013). Introduction to statistical quality control, seventh edition, John Wiley & Sons, Inc, p.235-279, ISBN: 978-1-118-14681-1.

Oakland, J.S. (2008). Statistical process control, Sixth Edition p.1-20., p.90-159, ISBN–13: 978-0-7506-6962-7.

Pignatiello, JJ. & Runger, GC.(1990). Comparisons of multivariate CUSUM charts. *Journal of Quality Technology*, 22, 173-186. https://doi.org/10.1080/00224065.1990.11979237

Psomas, E. & Fotopoulos, C. (2010), Total quality management practices and results in food companies. *International Journal of Productivity and Performance Management.* 59(7), pp. 668-687, https://doi.org/10.1108/17410401011075657

Porteus, E. L. & Angelus, A. (1997). Opportunities for improved statistical process control. *Management Science*, 43, 1214–1228. https://www.jstor.org/stable/2634634?seq=1&cid=pdf-reference.

Panagiotidou, S. & Nenes, G. (2009). An economically designed, integrated quality and maintenance model using an adaptive Shewhart chart. *Reliability Engineering and System Safety*, 94, 732–741. https://doi.org/10.1016/j.ress.2008.07.003

Pinto, J. K. & Prescott, J. E. (1988). Variations in critical success factors over the stages in the project life cycle. *Journal of management,* 14(1), 5-18, https://doi.org/10.1177/014920638801400102

Radnor, Z. (2011). Implementing lean in health care: Making the link between the approach, readiness and sustainability. *International Journal of Industrial Engineering and Management*, 2(1), 1-12. http://www.ftn.uns.ac.rs/ijiem/.

Quality Improvement, https://qi.elft.nhs.uk/resource/cause-and-effect-diagram-fish-bone/ (Acces Date: 12.05.2020).

Raguram, R. (2014). Implementation of overall equipment effectiveness(OEE). *Middle-EastJournal Science Research*, 20(5), 567-576.

Ramírez, H., Mendoza, E., Mendoza, M. & González, E. (2015). Application of augmented reality in statistical process control, to ıncrement the productivity in manufacture. *Procedia Computer Science,* 75, 213–220. http://dx.doi.org/10.1016/j.procs.2015.12.240

Stapenhurst, T. (2005). Mastering statistical process control a handbook for performance ımprovement using cases, *Elsevier Butterworth-Heinemann*, 1-20, ISBN 0 7506 6529 7 p.1-10 /chart types 10-20.

Surak, J. G. (1999). Quality in commercial food process. *Quality progress,* February, 25-29.

Shamsuzzaman, M. and Wu, Z.(2006). Control chart design for minimizing the proportion of defective units. *Journal of Manufacturing Systems*, 25(4), 269-278.

Sánchez-Fernández, A,. Baldán, F. J., Sainz-Palmero, G. I., Benítez, J. M. & Fuente, M. J. (2018). Fault detection based on time series modeling and multivariate statistical process control. *Chemometrics and Intelligent Laboratory Systems*, https://doi.org/10.1016/j.chemolab.2018.08.003

Sedlack, JD. (2010). The utilization of six sigma and statistical process control techniques in surgical quality improvement. *Journal for Healthcare Quality*, 32, 18-26, https://doi.org/10.1111/j.1945-1474.2010.00102.x

Silva, A. F., Sarraguça, M. C., Fonteyne, M., Vercruysse, J., De Leersnyder, F., Vanhoorne, V. & Lopes, J. A. (2017). Multivariate statistical process control of a continuous pharmaceutical twin-screw granulation and fluid bed drying process. *International Journal of Pharmaceutics*, 528(1-2), 242–252. https://doi.org/10.1016/j.ijpharm.2017.05.075

Sujová, A. & Marcineková, K. (2015). Modern methods of process management used in slovak enterprises. *Procedia-Economics and Finance Journal*, vol. 23/2015, Elsevier Ltd., 889 - 893. ISSN 2212-5671, https://doi.org/10.1016/S2212-5671(15)00381-0 Prístupné online: http://ac.elscdn.com/S2212567115003810/1-s2.0-S2212567115003810-main.pdf?_tid=f5abbcea-295b-11e5-9d7c00000aacb362&acdnat=1436791244_e20038b90e4840c6597448c04b90d27d

Smith, I. (2005). Achieving readiness for organisational change. *Library Management, 26*(6/7), 408-412, http://dx.doi.org/10.1108/01435120510623764

Spedding, T. A. & Chandrashekar, M. (2005). A component-based simulation environment for statistical process control systems analysis. *Robotics and Computer-Integrated Manufacturing, 21*(2), 99–107, http://dx.doi.org/10.1016/j.rcim.2002.11.001

Srikaeo, K., Furst, J. E., & Ashton, J. (2005). Characterization of wheat-based biscuit cooking process by statistical process control techniques. *Food Control, 16*(4), 309-317. http://dx.doi.org/ 10.1016/j.foodcont.2004.03.010

Thompson, J.R. & Koronacki, J. (2002), Statistical process control: the deming paradigm and beyond, Chapman and Hall/CRC, 2nd edition, ISBN: 1-58488-242-5.

Trietsch, D. (1998). Statistical quality control A loss minimization approach, World Scientific publishing Co. Pte Ltd., p.1-16, p.113-165, ISBN 9810230311.

Tsacle, E.G. & Aly, N. A. (1996). An expert system model for ımplementing statistical process control in the health care ındustry. *Computers industry engineering*, 1(1), 447-450.

Terek, M. & Hrnčiarová, Ľ. (2014). Štatistické riadenie kvality. Bratislava: IURA EDITION s.r.o. Bratislava 2004, 234s, ISBN 80-89047-97-1.

Teixeira, H. N., Lopes, I., Braga, A. C., Delgado, P. and Martins, C. (2019). Screwing process analysis using multivariate statistical process control. *Procedia Manufacturing, 38, 932–939.* https://doi.org/10.1016/j.promfg.2020.01.176

Vetter, TR. & Morrice, D. (2019). Statistical process control: No hits, No runs, No errors. *Anesthesia & Analgesia*, 128, 374-382, https://doi.org/10.1213/ANE.0000000000003977

Wang, P., Zhang, D., LI, S., & Chen, B. (2012). Machining error control by ıntegrating multivariate statistical process control and stream of variations methodology. Chinese *Journal of Aeronautics*, 25(6), 937–947. http://dx.doi.org/10.1016/s1000-9361(11)60465-2.

Yin, H., Zhang, G., Zhu, H., Deng, Y. & He, F. (2015). An integrated model of statistical process control and maintenance based on the delayed monitoring. *Reliability Engineering and System Safety*, 133, 323–333. http://dx.doi.org/10.1016/j.ress.2014.09.020

Zhou, W. H. & Zhu, G. L. (2008). Economic design of integrated model of control chart and maintenance management. *Mathematical and computer Modelling*, 47, 1389–1395.