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DSS-Based Process Control and FMEA Studies for Different Processes in the Field of Textile

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ABSTRACT

Today, in many textile firms, high defect rates and inefficiency stand out due to the intensive labor in the production processes. For this reason, to be able to detect failure modes and effects, number of defects and defect rates fast and intervene in the process just in time is vital for textile firms. Accelerating feedback by producing accurate and effective quality reports and helping senior management's decision processes will reduce appraisal costs and delivery time. In this study, Failure Mode and Effect Analysis and Statistical Process Control techniques have been integrated with a Decision Support System for different processes of textile. Thanks to the proposed integrated system in the fast fashion/textile sector, defect and/or failures will be prevented or detected on time by determining the sources of error with an effective database and monitoring system. So, process capability will increase by preventing material, operations and human-induced scraps.

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1. INTRODUCTION

In today's world where competition does not know any borders and similar companies proliferate, production with low cost, short delivery time and high quality is the main goal. The most important criterion for continuity in the market is customer demands. Customers no longer want to buy a different product than they request, and they avoid paying for the companies' wasted resources. In this environment where customer expectations increase, it will be possible to survive through the adoption and implementation of Total Quality Management (TQM). All activities such as determining the responsibilities and quality policies of the senior management, conducting the training activities related to quality management in every field and level, continuously improving the quality by the help of quality teams and KAIZEN studies and ensuring the full participation of the workforce in the quality improvement activities constitute the philosophy of TQM. Within this management philosophy, the set of activities that ensure the effective performance of quality control activities is called Quality Assurance System (QAS). In other words, QAS is a group of activities that includes planning, organizing, directing and controlling quality in order to provide products suitable for the consumer [1]. These activities are classified as managerial and operational. Activities such as quality planning, analysis of quality costs, market research, customer relationship management and supplier evaluation are included in the managerial activities; various methods such as Acceptance Sampling, Process Capability Analysis (PCA), Statistical

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Process Control (SPC), Design of Experiment, Quality Function Deployment, Failure Mode and Effects Analysis (FMEA) are also examined under operational activities.

Failures and hazards that arise from the risk factors such as material, human, machines and equipment are the main potential risks in production systems. To reduce the risks in a system, various methods have been discussed in the literature. As a well known and widely used method, FMEA aims to define and prevent failures in design, process and systems. Process FMEA focuses on potential failure modes of the process that are caused by manufacturing or assembly process deficiencies [2]. The implementation of FMEA in textile industry includes numerious studies such as spreading and cutting [3], sewing [4], weaving [5-6], knitting [7], spinning yarn production [8] and finishing process in fabric dying [9].

On the other hand, SPC identifies the source of the problems in a spesific process and prevents the production of nonconforming units. SPC provides decreasing in quality-related costs and increasing in productivity [10]. Basic SPC tools such as Control charts are widely used for high-quality production in many sectors, including textile production companies [11-13].

A DSS is computer-based programs used to support decisions and action plans in organizations and businesses. It analyzes the system by reviewing large amounts of data by compiling comprehensive data that can be used in decision making. Thus, DSS collects and analyzes data and generates comprehensive information reports. It increases efficiency with the advantage of timely problem solving and solution development. DSSs assist decision makers to improve quality of decision processes and tasks [14].

Database management system, model-based management system and dialog generation and management system are the main components of DSSs [15]. A decision maker gathers data from pure data sources (databases, text sources, information stores, etc.), then processes and makes it necessary for the decision. Finally, previously prepared templates, data processing methods, data mining studies, etc. are used to prepare possible scenarios that can support decision making process. The DSS concept uses a combination of human judgment and computer-provided information. Mete et al. [16] proposed a DSS based occupational risk assesment study of a gas pipeline construction. They developed a DSS based on Python package of Pythagorean fuzzy VIKOR for risk assessment. Febriani et al. [17] proposed an expert system that applies the FMEA method for developing quality control systems in brake disc production lines. The top 5 risk priority number (RPN) rankings of each quality defect play an important role in determining the recommended action in the expert system.

An integrated methodology, including DSS-based FMEA and SPC has been proposed in this study. This integrated approach includes various techniques such as Pareto charts, Cause-Effect Diagrams, Demerit Control Charts (DCC) for attributes and Process FMEA. It was carried out in a textile company that produces t-shirts, shirts, trousers, jackets, vests and coats for men and women. Handcrafting, which is common in the textile sector, is also valid for this company. Although the professional employees in the production line show great care during the production, slow feedbacks due to manual processing and reporting of defects in the quality control points cause serious quality problems. In the first application, a DSS-based Process FMEA was proposed for T-shirt production process. Critical failure modes and effects were determined and tried to be reduced by the help of DSS. In the second application, with the help of DSS, the number of defects, defect types and defect weights are recorded to the database in a fast and accurate way. Thanks to the data kept in the database, the process is dynamically monitored and it is determined whether it is under control. Pareto and DCC were used for monitoring the process in DSS.

In the proposed method, quality control personnel will log into the system with their user name and password. The defect types and numbers, which they encounter during the control are entered into the DSS interface. Defect types and numbers can be kept in a database and the results of analysis related to SPC studies will be reported on a daily basis. In this way, data entry errors and time loss at control points will also be eliminated. So, quality reports will be produced in a fast and error-free manner, helping the decision-making processes of the senior management. Process control activities supported and improved by DSS will contribute to the increase in production quality. DSS-based quality control techniques are not widely used in textile companies as in many areas. When the limited number of DSS-based studies are examined, no application of DSS-based FMEA and SPC studies including Demerit Control Charts, Pareto Charts etc. has been found in the textile industry to the best of our knowledge. Therefore, it can be said that the present study will fill an important gap in the literature within the scope of the textile industry.

2. MATERIAL AND METHOD

In this part of the study, SPC tools and Process FMEA are introduced.

2.1 Pareto and Demerit Control Charts

Pareto Chart, developed by Italian economist Wilfredo Pareto, is a bar chart used to distinguish the important causes of a problem from the less important ones. Pareto diagrams created on the basis of check sheets play an important role in determining vital fews, rather than trivial many, causing big losses (80% -20% rule).

Control charts are one of the important SPC techniques for process monitoring. They can be used to check whether the process is under control or not [18]. Out-of-control signals indicate assignable causes in the process. Assignable causes may result in process shifts and/or excess variability. The shifts and the excess variability can be reduced when the assignable causes eliminated. Univariate control charts can be used for monitoring single quality characteristic, whereas multivariate control charts monitor more than one quality characteristics in a single chart [13].

Control charts for attributes such as P, NP, C, and U charts are used to identify and eliminate the causes of various types of defects [19]. P and NP are used to monitor go/no-go type data (defective numbers and defective rates) based on the binomial distribution. On the other hand, C and U charts are used to monitor defect count data using Poisson distribution. By the help of DCC, instead of monitoring the number of non-conformities, a demerit statistic, a linear combination of the counts of defect types, is used to simultaneously monitor the counts for different defect types. As seen in Table 1, various types of defects can be classified into the following categories [20]. Additionally, relevant studies for various DCC forms using fuzzy structures in different sectors can be examined [21-25].

The most commonly used weights are assigned to classes respectively in the last column of Table 1.

The weights of classes and the defect numbers in each class are used to calculate demerit points. In the traditional approach, demerit points are plotted on a control chart with ±3σ control limits. Demerit statistics are calculated using the weighted demerit points [13].

ciA, ciB, ciC and ciD represent the number of defects in Classes A, B, C, D in the ith inspection unit, respectively. Defects in classes are independent of each other.

The formulation of DCC are shown in Equations (1-6):

d_i: weighted total number of demerits in inspection unit i,

n: the total number of inspection units,

D: the total number of demerits

u_i: the number of demerits per unit i

$$d_i = 100 \times c_{iA} + 50 \times c_{iB} + 10 \times c_{iC} + 1 \times c_{iD} \quad (1)$$

$$D = \sum_{i=1}^{n} d_i \quad (2)$$

$$u_i = \frac{D}{n} \quad (3)$$

$$UCL = \bar{u} + 3\sigma \qquad CL = \bar{u} \qquad LCL = \bar{u} - 3\sigma \quad (4)$$

$$\bar{u} = 100 \times u_A + 50 \times u_B + 10 \times u_C + 1 \times u_D \quad (5)$$

$$\sigma = \sqrt{\frac{[(100]^2 \times u_A + 50^2 \times u_B + 10^2 \times u_C + u_D)}{n}} \quad (6)$$

u_A, u_B, u_C and u_D represents the average number of A, B, C and D type defects.

2.2 Process FMEA

FMEA can be defined as a methodology that enables to evaluate potential hazards/failures in a system, design, process, or equipment. Occurrence (O), Severity (S) and Detectability (D) are three main inputs in FMEA [26]. Occurrence refers to the probability of the failure mode for a defined period. Detectability is a measure of the ability to find potential failures before the system or customer is affected. Severity is an indication of the importance and emergency impact of failure on system or user.

Each of the risk factors S, O, and D, is evaluated using a 10-point scale. By the multiplication of three factors (S, O and D), the RPN is calculated. Higher RPN values have a higher risk priority and more importance than lower RPN values. The RPN values are the indication of priority level for improvement and corrective actions are developed from this comparative results.

3. RESULTS AND DISCUSSION

3.1 Application in a Textile Firm

The company, where DSS-based SPC studies are carried out, produces shirts, trousers, jackets, vests and coats for men and women. This firm which is competing with global brands in the industry, serves more than 180 stores in Turkey and abroad. The DSS was brought together with the user via Excel VBA. DSS-based integrated approach proposed by the authors is given in Figure 1. In the following subsections, DSS-based applications for the jacket and basic T-shirt processes of the textile firm are presented. Excel VBA macros are used for the design of DSS.

Table 1. Defect types

Class	Defect	Impact	w
A	Very Serious	Failed to function, subsequent equipment damage, injuries/deaths to personnel	100
B	Serious	High degree of customer satisfaction	50
C	Moderately Serious	Degraded product performance, increased maintanence cost	10
D	Minor	The effects can be negligible	1

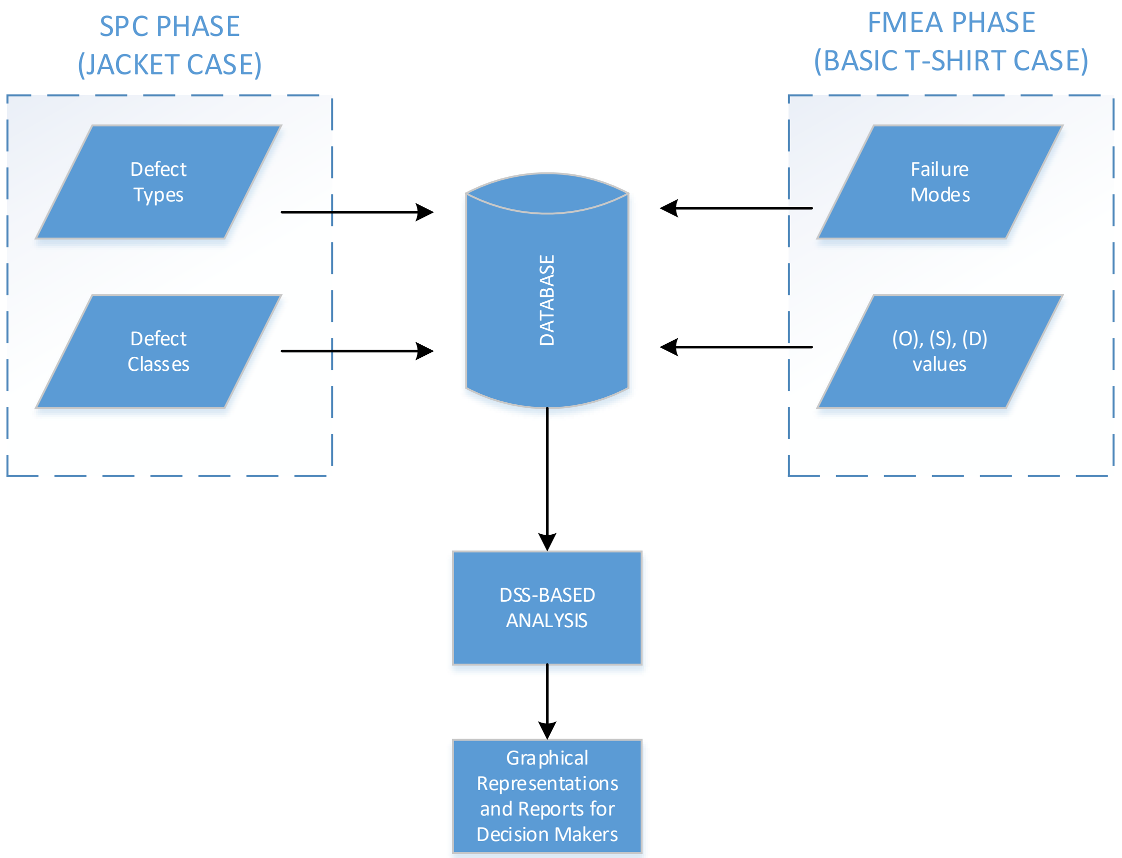

Figure 1. Flowchart of the DSS-based SPC and FMEA

3.1.1 DSS-based Statistical Process Control

When observing the production lines specific to the products, it is seen that many operations at the quality control points are manual. The controllers record the types and numbers of defects they encounter while examining the semi-finished products in a form which is designed specifically for the firm. It causes slow feedback and does not offer instant analysis and reporting. Since there is no computer-aided application or database, the reliability of the data is low. Computer aided production/control system is of great importance in terms of business objectives in textile enterprises where manual processes are intense. For this reason, the defect monitoring system at three different control points in the company's jacket production line has been integrated with a DSS. It is aimed that quality controllers and the senior manager use different interfaces in the system where they can log in with their usernames and passwords. With the proposed system; operators at control points ensure that the types and numbers of errors they encounter in their units are entered into the system on a date basis and kept in a database. The control points mentioned are sleeve preparing, primer and final product. These points are coded as CNT1, CNT2 and CNT3, respectively. At the CNT3 point; the final checks of the jacket, the production of which is completed by going through the sleeve attaching, collar fastening and side pocket preparation processes, are performed. There are a total of 21 critical defect types at the CNT1 point, 19 at the CNT2 point, and 17 at the CNT3 point. Defect types displayed in DSS interface are coded as CNTi-DFj due to company confidentiality.

The classes and weights of defects were determined by a team of production manager, industrial engineer and textile engineer by depending on the definitions on Table 1. The expert group, who assigned the defects at each control point to the classes, benefited from their experience and historical information. For all type of defects that may be encountered in the jacket production process rework rates, rework times and costs are recorded by the company. This information could not be shared with the reader due to company confidentiality. The expert group assigned the defects that could cause serious dissatisfaction to the customer after shipment and cause the rejection of the lot to be class B and weighted it with 50 points. Although it can be detected during production and corrected by rework, defects that increase cost and processing times are assigned to C class and weighted with 10 points. Even if the product is shipped, negligible defects that do not cause dissatisfaction with the customer are included in the D class and 1 weight point is assigned. The di values used to determine the limits of the control chart were also calculated using the relevant weights. In Demerit control charts, very serious defects that may cause harm to people or even death during the use of the product are evaluated in Class A. Since such defects were not encountered in the jacket production process, no assignment to Class A was made. Classes for defect types are shown in Table 2.

Table 2. Classes for defect types

Defects (CNT_1)	Class	Defects (CNT_2)	Class	Defects (CNT_3)	Class
CNT1-DF1	B	CNT2-DF1	B	CNT3-DF1	D
CNT1-DF2	C	CNT2-DF2	B	CNT3-DF2	D
CNT1-DF3	C	CNT2-DF3	B	CNT3-DF3	C
CNT1-DF4	D	CNT2-DF4	C	CNT3-DF4	D
CNT1-DF5	B	CNT2-DF5	D	CNT3-DF5	B
CNT1-DF6	C	CNT2-DF6	D	CNT3-DF6	C
CNT1-DF7	C	CNT2-DF7	D	CNT3-DF7	C
CNT1-DF8	B	CNT2-DF8	B	CNT3-DF8	D
CNT1-DF9	D	CNT2-DF9	C	CNT3-DF9	D
CNT1-DF10	D	CNT2-DF10	C	CNT3-DF10	B
CNT1-DF11	D	CNT2-DF11	D	CNT3-DF11	C
CNT1-DF12	B	CNT2-DF12	B	CNT3-DF12	D
CNT1-DF13	B	CNT2-DF13	C	CNT3-DF13	C
CNT1-DF14	C	CNT2-DF14	C	CNT3-DF14	D
CNT1-DF15	B	CNT2-DF15	D	CNT3-DF15	B
CNT1-DF16	D	CNT2-DF16	D	CNT3-DF16	D
CNT1-DF17	D	CNT2-DF17	D	CNT3-DF17	D
CNT1-DF18	B	CNT2-DF18	B		
CNT1-DF19	C	CNT2-DF19	C		
CNT1-DF20	C				
CNT1-DF21	C				

The controllers at all three control points enter the number of jackets they have examined throughout the day, the defect types and numbers they encounter into the system via an interface (Figure 2). These data kept in the database are used in the forming of Pareto and DCCs. An example of a data set obtained as a result of entries made for 15 days is presented in Appendix A.

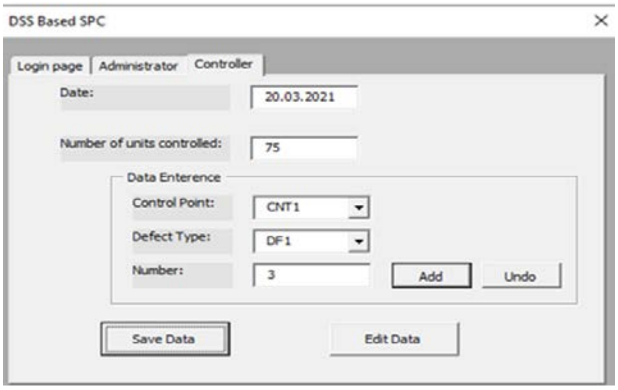

Figure 2. Interface for defect entries

With the interface used by senior managers, pareto charts can be formed for the desired date range and control points. Besides, it can be monitored whether the process is under control with the help of DCC graphics. The interface for managers is displayed in Figure 3.

Pareto charts can be formed for both defect frequencies and weighted defect frequencies via “Pareto Chart button”. Thus, decision makers have the chance to evaluate the defect types corresponding to 80% of the problems by taking into account the weights placed in Table 1 and/or frequencies of defects, with the help of pareto charts. Pareto charts for all control points drawn with data for the last 15 days are displayed in Figure 4. Pareto charts on the ride side (weighted frequencies) were obtained by multiplying the weight value of the class in which the defect took place with the frequency of defects. For example, in CNT1, approximately 80% of the problems causes from DF7, DF3 and DF6 according to the Pareto chart formed by weighted frequencies of defects.

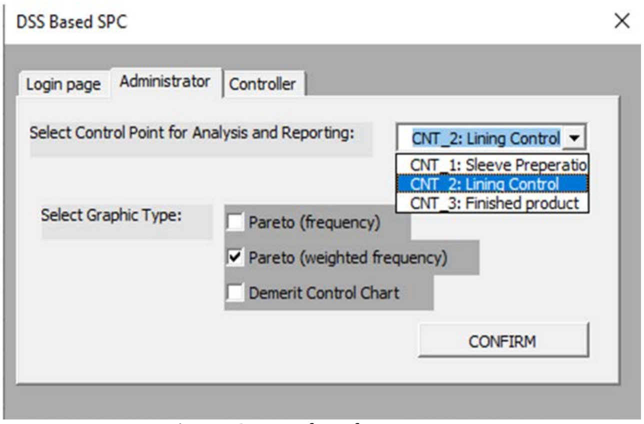

Figure 3. Interface for managers

Control limits, control charts and information messages about graphic interpretation regarding DCC can be viewed by the managers via “DCC button”.

When demerit control chart option is selected in Figure 3, admin is allowed to enter a date range shown in Figure 5. In this step, weight selections are made with the administrator authority. The defect types for the selected control points are displayed and the admistrator is expected to choose the class corresponding to these defects. Also, in this step, the weights corresponding to the class type are displayed in parentheses. Demerit control chart is drawn based on the weight parameters entered for the selected control point.

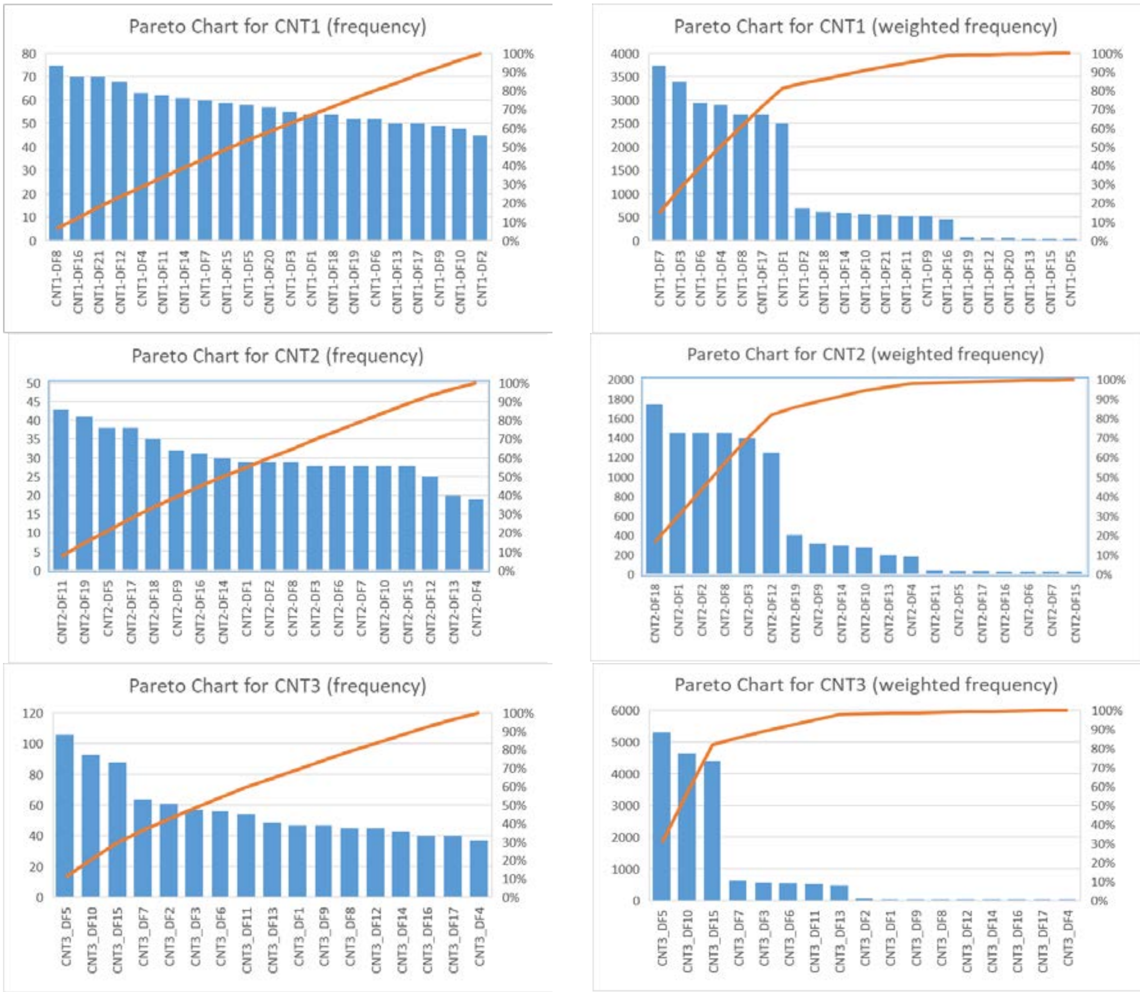

Figure 4. Pareto charts for all control points

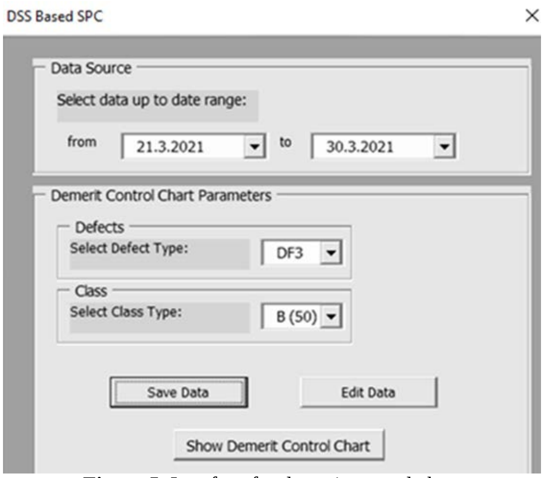

Figure 5. Interface for demerit control chart

For three control points, the DCC control limits obtained with the last 15 days' data are shown in Table 3. Control limits were calculated by the help of DCC formulations mentioned in equations (1-6) before.

Table 3. Control limits for DCC

	Σ	*UCL*	*CL*	*LCL*
CNT1	3.595	33.685	22.900	12.114
CNT2	2.322	16.461	9.497	2.532
CNT3	2.082	14.733	8.485	2.238

Control charts are drawn for all control points based on the 15-day observation values and the control limits in Table 3. When the control charts in Figure 6 were examined, the process is under control for the last 15 days' data. In the next stages, with the help of DSS-based analysis and graphics, the situation of whether the process is under control or not will be dynamically monitored. In out of control situations, it will be possible to intervene in the process in a timely manner.

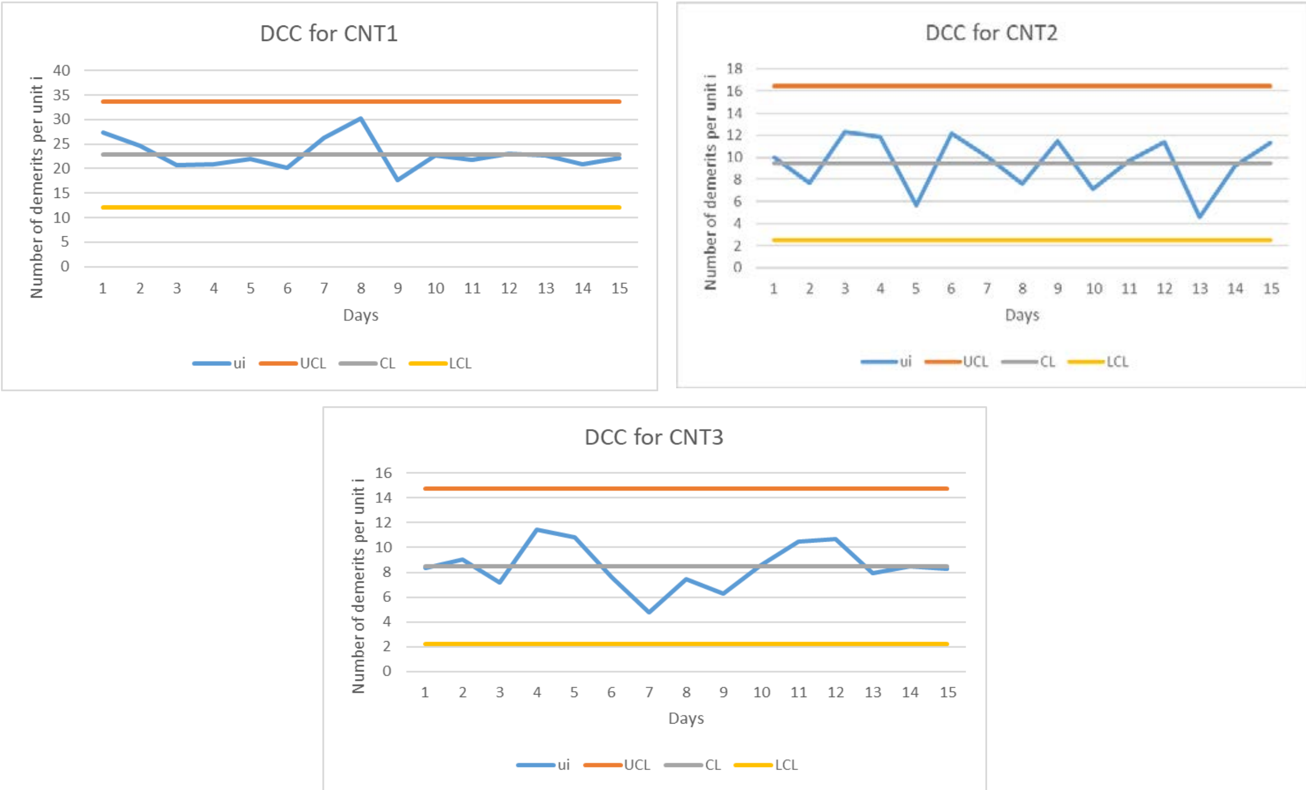

Figure 6. Demerit control charts for tle last 15 days

3.1.2 DSS-based process FMEA

For FMEA application, basic T-shirt was chosen as one of the most frequently ordered and produced product types.

Production Process

The production process is managed in accordance with some orders designed by foreign customers, and the schedules can even be updated daily/hourly. A production plan is usually prepared according to planned orders. Monthly, weekly and daily goals are determined within this plan. There is a checkpoint throughout the enterprise almost after each processing step. Although the company pays great attention to controls, there are no error-preventing activities. Instead of preventing error before, cutting is done well above the number of orders by taking into account high error rates. This leads to a high percentage of resource waste, and in order to change this point of view, it is aimed to take corrective and preventive actions by descending to the root causes of errors with the help of process FMEA.

It is summarized as follows the basic process steps for the basic T-shirt product:

Fabric Control: The dimensions of fabrics are measured and recorded. Fabric cleaning, waste and defect controls are performed. In the laboratory, many properties such as fabric durability, paint quality, color and homogeneity are checked. Properties that must be checked according to the selected fabric also vary.

Steaming: All unprocessed fabrics are washed and cleaned first and then processed in a large steam machine. Thus, the shrinkage that may be encountered after washing is minimized. The steaming machine, thanks to its high steam power, allows the fabric to pull as much as possible and reach its final size, improving the quality of the fabric.

Cutting: Afterwards, the selected fabric is cut according to the pattern, and the cutting process takes approximately three hours. At the cutting stage, machines are selected according to the fabric type. If the fabric is a delicate fabric such as satin, a laser cutting machine is chosen, otherwise one of the cutter machines is chosen. The fabric of the product examined in the study is processed in cutter. According to the fabric type, laser cutting, knife cutting or manual cutting can be done. A large number of parts can be cut at the same time with the appropriate machine.

Classification: It is the stage in which the cut semi-finished products are counted and the parts are checked in detail. After the number of parts and measurement checks, the parts are distributed to the processing points on the production line. It is very important to do this application before the sewing phase. In this way, possible errors are minimized.

Sewing: This is the stage of sewing the parts according to the model. It consists of different sub-stages according to each model. The model is analyzed and the sub-work steps are determined. Operator-job matching is performed according to the job steps.

Control: The control stage after sewing requires a lot of attention. In cases of detected errors, necessary repairs are made and precautions are taken.

Logo Seam: It can be printed with a pressed machine or the logo can be sewn manually. According to customer's request; metal logo, plastic logo, printing logo or other kinds of logo can be used.

Ironing and Packaging: After appropriate ironing, quality control is carried out according to customer standards and the products are packed according to customer requirements and the labeled products are made ready for shipment.

DSS-based process FMEA for the basic T-shirt production process

The textile production process is one of the processes in which errors and wastes are observed intensively due to its labor-intensive structure. Increasing waste rates due to high production speed cause inefficiency, and the pressure created by daily targets together with the fatigue caused by the complex structure in the processes leads to more errors. All defects that may be encountered during the production phase are shown in Figure 7 with a process type cause-effect diagram according to the process steps.

The most common types of defects are stain, bad fabric smell, looseness and shrinkage, regional defects, deviation in seam, logo seam and measurement defects. In addition, incorrectly applied work studies and incorrect determination of production times, incorrect planning and human factors also lead to high scrap rates and even bottlenecks with inefficiency and loss of speed.

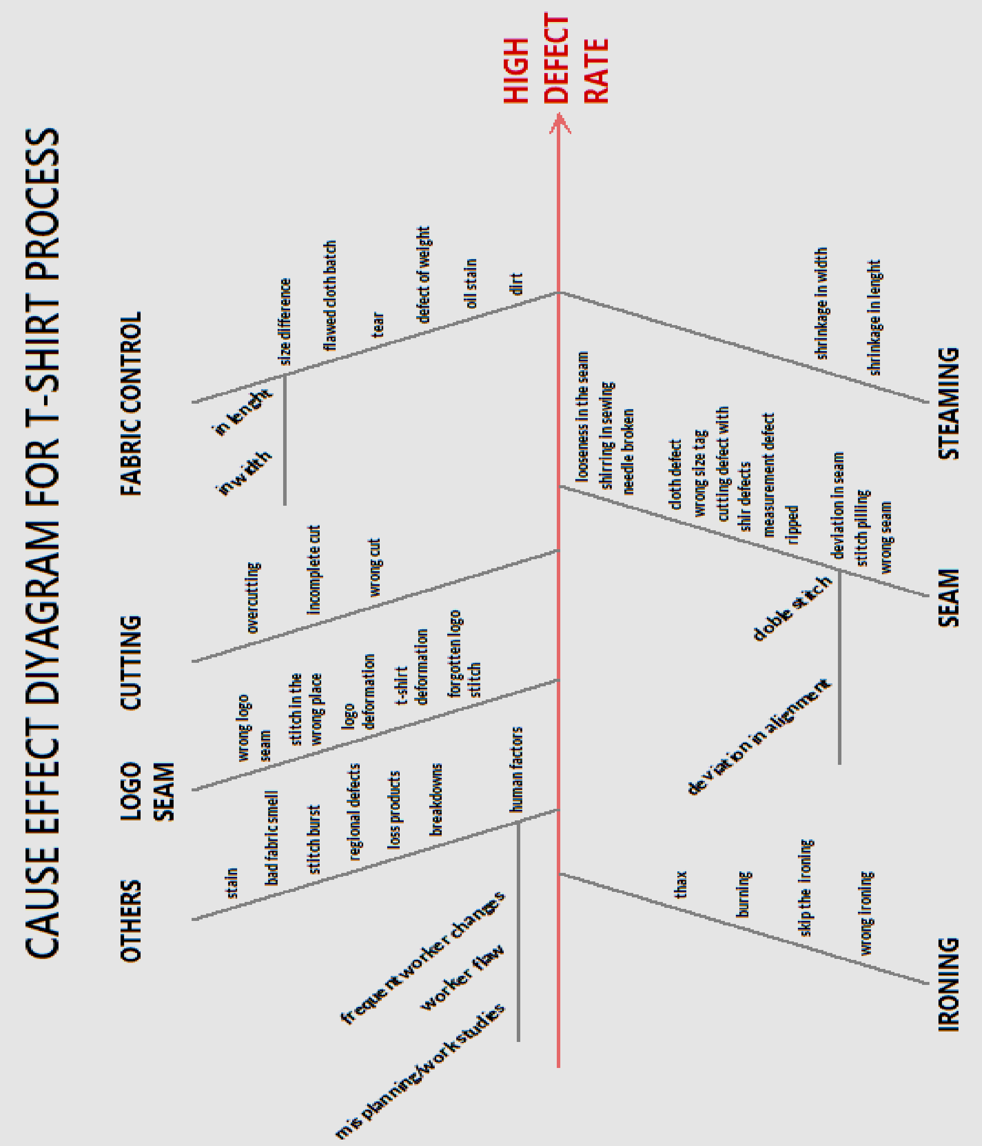

Figure 7. Cause-Effect diyagram for basic t-shirt process

At the next stage, the aim is to report DSS-based FMEA results by identifying the possible causes and effects of current and potential failures with the FMEA team. If the reasons for the failures are understood and expressed correctly, optimal results can be obtained. A large number of reliable and accurate data is required for the effective FMEA studies. With the help of the observations and collected data, the frequency of the failures, the results it caused, the probability of detecting the error and the RPN values were determined.

Between arch September 2020, about 53000 products from the basic T-shirt model produced in the enterprise were checked and the error numbers are shown in Figure 8 with pareto according to the error types.

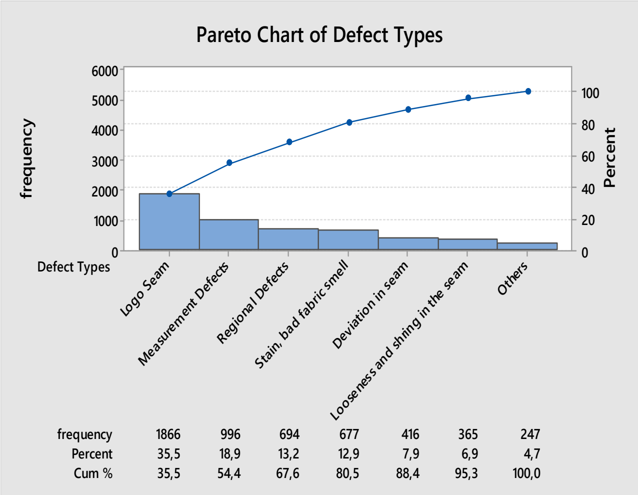

Figure 8. Pareto chart for defect types in basic t-shirt process

The most frequently observed failures in pareto constitute the scope of DSS-based FMEA. When calculating PRN, risk factors were valued between 1-10 in the DSS interface (Figure 9) by the employees in the FMEA team. Relative frequencies were used to determine the values related to the occurrence factor.

As a result of the calculations, the RPN values given in Figure 10 were obtained. The RPN represents the entire risk for the system user and serves as a decision tool for the actions. The larger the RPN is, the greater the priority that the risk is lowered with the help of design and quality assuring actions; individual values for S, O, and D that are greater than 8 should be more closely observed; the product of O and D gives information concerning the probability that undetected parts with defects will reach the hands of the customer [27].

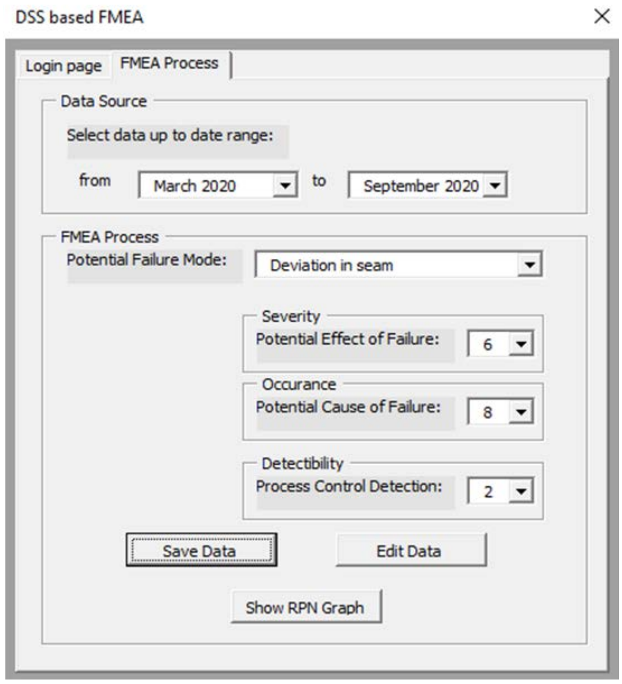

Figure 9. Interface for FMEA process

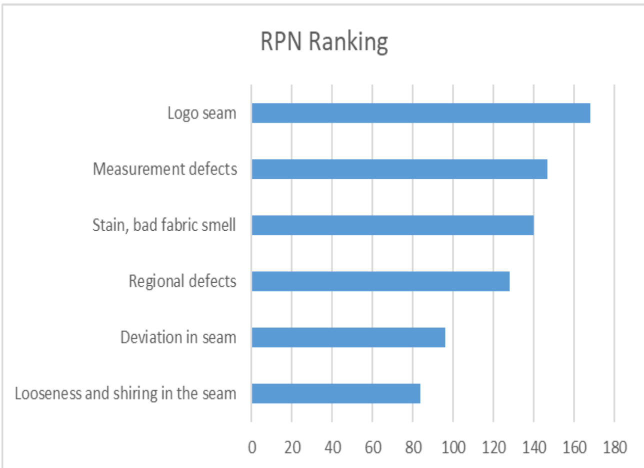

Figure 10. Ranking according to RPN values

According to RPN values in Figure 8, potential failure modes related to the failure effects and failure causes are summarized in Table 4:

Table 4. Failure modes and effects, causes of failures

Potential failure mode	Potential failure effects	Potential causes of failures	Current process control detection
Logo sewing	Mistakes in sewing metal or plastic logos indicating the brand.	• Logo sewing in the wrong place, • Wrong rope use, • Logo defects such as cuts and tears, • Influence of human factors	• In process inspection by monitoring the appereance of logo in logo seam step
Measurement defects	The final product does not have equal dimensions with the original.	• Wrong seam allowance, • Hurry due to bottleneck, • Incorrect work studies	• Post process inspection by checking the measure of product for every 20 samples manually
Regional defects	Tears, cuts, dents, scuff marks etc. on the product.	• Defect originating from logo sewing, • Transport-related defect, • Defects caused by machining, • Contract manufacturing defect, • Influence of human factors, • Incorrect work studies/standard time	• In process visual inspection by monitoring defects of the product
Stain, bad fabric smell	Occurrence of undesirable events such as permanent or temporary stains, dirt, odors in the product.	• Negligence of periodic machine cleaning, • Transport-related contamination, • Hygiene neglect in contract manufacturing, • Influence of human factors	• In process visual inspection by monitoring defects of the product
Deviation in seam	Stitch not aligned correctly, double stitching.	• Frequent machine downtime, • Misalignment in the machine, • Hurry due to bottleneck, • Influence of human factors, • Incorrect work studies/standard time	• Post process inspection by checking the alignment of seam by a gauge
Loseness and shiring in the seam	Problems caused by the fabric being too stretched or released while sewing.	• Hurry due to bottleneck, • Influence of human factors, • Incorrect work studies/standard time	• Post process visual inspection by checking on product appereance by a gauge

3.2 Improvement Proposals

An effective incoming quality control system should be established for the logos and fabric outsourced, and acceptance sampling techniques should be used. It has been suggested to detect and warn the subcontractors that send the faultiest products.

Standard times should be re-arranged by time studies. Employees working in the processes of fabric cutting, sewing and logo sewing should also act as controllers, and material-related defects should be prevented before errors occur. Especially experienced workers should be selected for these processes, the circulation of workers should be reduced and sustainability should be ensured with an effective performance system. In order to control the performance evaluation system fairly, color identity application can be proposed. With this implementation, it is possible to define a color code for each worker and use this small set of colored adhesive paper to easily determine which product is sewn by which worker. Thus, employees who work meticulously and do their job well can be identified and wage incentives can be provided for error-free work.

The lack of motivation of employees due to situations such as intense pace, insufficient breaks, pressure, stress, lack of communication and unwilling work that result in a decrease in productivity are remarkable. Rearranging shifts is important for employees to be fit, motivated and focused. In addition, workers' rest and break time adjustments will contribute to minimizing fatigue and reducing errors. The processes that cause the bottleneck should be analyzed, and the disruption of production due to factors such as loss, waste, stolen should be prevented. For this, it has been proposed to integrate additional control points for more frequent counting and control effort. Intensive manual labor and reducing the amount of sub-contraction is another issue that needs to be considered.

To reduce machine-related failures and contamination, preventive maintenance, machine cleaning and replacement of old machine parts and equipments can be error-reducing solutions. During the production phase, human and machine based factors have the potential to cause undesirable faults such as dirt, oil, odor, and permanent or temporary stains and odors. The cost of damages such as time, labor, energy loss encountered as a result of errors is enormous. If it is not noticed during production and reaches the consumer, it may cause prestige and customer loss. If a permanent stain occurs on a large amount of products, the production plan may be disrupted. With 5 S applications in the T-shirt production process, the confusion in the process can be reduced, and defects caused by contamination and odor can be greatly reduced. It is important to regularly clean the containers in which the products are transported.

Rough and non-transparent sacks used in storage cause lint in the product, and the fabric or thread getting stuck in the sack and rupture causes damage to the product. To remedy this, using smooth and transparent sacks are proposed. Thus, it will now be less likely to cause damage to the product, as it is more reliable and easier to visual control.

In addition, it can be a good precaution to warn employees about cleanliness and order, and to hang noteworthy announcements on the entrance panels of sewing sections where problems are common.

With regular start-up trainings and DSS-based error tracking system similar to the previous application, the negative impact of human factors can be largely eliminated by determining the sources of errors. For example, with the recruitment of new workers, production disruption occurred frequently, and a questionnaire was recommended to prevent this. Until a decrease was achieved in the number of resignations, it was considered to conduct an “Employee Satisfaction Survey”. With this questionnaire, it was aimed to determine the reasons for leaving the job and to get suggestions to improve the general working conditions. Among the recommendations are giving incentives or awards to employees with few mistakes, providing training on the use of simple quality tools by creating quality circles, encouraging the suggestion system working with applications such as before-after kaizen and 5 S. Thus, reducing the workforce circulation as much as possible, and ensuring that each employee specializes in two jobs are intended.

Human-induced errors such as inexperience workers, contract labor and labor circulation were noticed in almost every process. In particular, it has been observed that measurement errors occurring during sewing operations are caused by reasons such as being hasty to meet daily targets, keeping the seam allowance more or less, taking wrongly measured pieces to the production line, distraction of the worker, lack of motivation, adjustment problems in the machine. The reason for the measurement defects during cutting is that the number of fabrics put on top of each other is above the machine cutting capacity. Other reasons can be stated as the negligence of the process follow-up during cutting and the insufficiency of the controls performed during the classification.

Preventive actions have been proposed to reduce these identified causes. It is not possible to apply a different preventive action for faults that occur during cutting because the only action is to stack the fabrics and put them in the machine. The fact that the fabrics are not damaged during cutting generally depends on the fabric structure. However, in some cases, when the required number of pieces is high, the workers keep the number of fabrics too much in order for the process to be completed quickly, and this situation causes the cutting capacity of the machine to be exceeded and the related cutting errors lead to measurement distortion. For this reason, it was recommended to warn and inform the machine supervisor about the cutting numbers before the operation. One of the precautions taken to reduce the size defects that occur during sewing may be to leave one sample model in the working area of each operator. It is important to note that the measurements are exactly accurate according to the main model. The observations made showed that the production lines were created arbitrarily. Instead, the same work step can be given to each operator, enabling workers to specialize in their work.

4. CONCLUSION

This study consists of two different DSS-based applications in jacket and basic T-shirt production processes of the firms in the textile field.

In the first application, manual control and data entry operations at control points in the jacket production process were integrated with a DSS. Thus, correct data usage has become possible in SPC and a dynamic structure has been given to SPC studies. In addition, an interactive bridge has been created between the worker, controller and manager. With the new system, it is predicted that the communication between the employee and the manager will be faster and more secure.

Based on the data recorded in the database, the decision maker can draw Pareto charts by taking into account both frequencies and weighted frequencies for the desired date range, and can determine the defect types that cause 80% of the problems. It can test whether the process is under control or not by means of DCC graphs whose limits are calculated using defect weights and numbers. If an out-of-control situation is observed, it has the chance to intervene on time.

In the second application, a DSS has been designed where FMEA analysis can be performed during the basic T-shirt production process. In this way, it will be possible to make the necessary improvements by analysing failure modes and effects on the customer before shipment. With the developed DSS, first of all, potential failure modes, which were obtained from the records of the previous period and were inscribed as priority errors in the pareto diagram, were obtained. RPN values obtained based on probability, severity and detectability values are presented to the user with graphical visualization. For failure modes with high RPN values, preventive actions regarding failures have been developed by the FMEA team. The proposed DSS analyzed the previous period data, directed them to areas where precautions could be taken primarily, and the existence of such a system created FMEA awareness among employees. The proposed DSS facilitates the calculation of RPN scores in FMEA process. This study is also useful in terms of easily calculating post-improvement RPN scores in future studies and seeing the effects and benefits of the measures taken for improvement

Thanks to the DSS-based FMEA and SPC applications designed to be used in different textile processes, it has become easier for senior managers to interpret, analyze and make certain decisions. With the proposed system, an increase in the production quality and income of the company is expected in the long term.

Jacket is a product with a high share in turnover. Therefore, serious defects can lead to high costs. The people in the position of decision maker in the company, want to monitor the process variability with the help of an appropriate tool after the defects in the jacket production process are classified. Demerit control charts are SPC tools developed specifically for this reason. Despite the developing automation systems, the textile industry maintains its labor-intensive structure. For this reason, many human-induced errors occur. Especially in the T-shirt production process, errors vary according to the model. The more details, fabric sensitivity and processing there are in the ordered product, the more various types of errors occur for the product. FMEA is a useful analytical tool that aims to identify and eliminate known or potential losses/errors in the system during the design or process phase. In further studies, both SPC and FMEA studies can be maintained for many processes in the enterprise. In this article, only one of the DSS-based methods (FMEA/SPC) is exemplified for each process. At the same time, an effective failure tracking system should be established for production processes in textile enterprises with intensive human factors. With a DSS that works in integration with other rapidly developing artificial intelligence techniques, an effective error prevention, error diagnosis and debugging system can be developed, and systems can be created to reduce losses and prevent inefficiency.

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Appendix.A Defect types and numbers (data for the last 15 days)

DEFECT TYPE	**w**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CNT1-DF1	50	3	5	1	6	3	5	6	8	3	2	3	2	3	2	2
CNT1-DF2	10	1	4	2	7	2	2	3	0	4	2	5	4	1	3	5
CNT1-DF3	10	4	3	1	3	1	5	2	3	5	2	6	9	6	3	2
CNT1-DF4	1	4	8	5	1	4	2	5	3	3	3	4	5	6	4	6
CNT1-DF5	50	7	3	2	1	2	5	6	7	0	4	5	4	4	2	6
CNT1-DF6	10	6	4	6	3	4	1	2	1	2	8	2	3	4	4	2
CNT1-DF7	10	6	2	3	4	2	3	7	1	4	5	3	6	0	6	8
CNT1-DF8	50	6	9	4	5	4	4	6	7	0	4	6	3	5	7	5
CNT1-DF9	1	6	1	3	4	5	4	3	4	2	5	1	2	3	2	4
CNT1-DF10	1	8	4	5	2	3	4	3	4	5	0	1	3	2	1	3
CNT1-DF11	1	5	6	5	5	4	5	3	4	3	5	3	4	4	3	3
CNT1-DF12	50	3	6	5	2	5	8	6	4	6	2	3	5	7	1	5
CNT1-DF13	50	5	3	3	3	3	0	3	4	4	3	3	5	4	5	2
CNT1-DF14	10	6	4	3	7	1	3	5	2	3	7	4	3	2	2	9
CNT1-DF15	50	7	3	4	4	5	4	2	7	6	4	1	4	2	4	2
CNT1-DF16	1	1	2	8	5	9	7	1	4	5	2	6	5	0	6	9
CNT1-DF17	1	3	2	2	4	2	3	2	4	5	7	3	4	3	4	2
CNT1-DF18	50	3	2	6	3	5	0	4	5	1	7	4	3	3	4	4
CNT1-DF19	10	2	2	5	5	5	1	4	1	7	2	5	2	5	4	2
CNT1-DF20	10	4	7	2	3	5	3	2	5	1	4	6	4	5	4	2
CNT1-DF21	10	3	2	6	3	7	1	6	2	4	8	6	9	6	4	3
CNT2-DF1	50	1	1	1	4	0	3	2	2	4	1	2	3	1	1	3
CNT2-DF2	50	1	2	2	2	0	5	3	0	2	1	3	1	2	2	3
CNT2-DF3	50	3	0	2	1	2	3	2	1	3	4	1	2	0	1	3
CNT2-DF4	10	1	3	1	3	1	2	1	0	2	0	0	0	0	1	4
CNT2-DF5	1	5	1	4	3	2	2	0	3	2	0	5	2	5	3	1
CNT2-DF6	1	1	3	1	3	1	2	2	1	2	1	4	2	3	1	1
CNT2-DF7	1	2	2	1	2	5	2	1	0	1	4	0	1	1	3	3
CNT2-DF8	50	1	3	3	2	1	2	2	2	1	0	3	3	1	3	2
CNT2-DF9	10	1	1	1	5	3	4	4	0	2	0	2	4	2	2	1
CNT2-DF10	10	2	3	1	5	2	2	1	1	2	0	3	4	0	1	1
CNT2-DF11	1	2	4	5	6	2	2	6	2	2	3	1	2	1	2	3
CNT2-DF12	50	1	1	4	2	1	2	0	2	0	1	1	3	0	3	4
CNT2-DF13	10	2	0	2	1	1	1	0	3	0	4	1	0	2	2	1
CNT2-DF14	10	1	1	2	4	3	0	0	0	5	1	4	1	2	4	2
CNT2-DF15	1	3	3	2	1	3	2	0	2	2	3	3	3	1	0	0

CNT2-DF16	1	3	2	2	1	3	3	3	1	0	4	4	1	0	1	3
CNT2-DF17	1	5	3	0	6	0	3	2	1	2	3	2	3	6	2	0
CNT2-DF18	50	6	2	4	2	2	1	4	3	3	2	2	2	1	1	0
CNT2-DF19	10	1	3	4	4	1	1	3	2	9	2	1	5	2	3	0
CNT3_DF1	1	4	1	4	6	3	0	4	5	1	3	2	3	5	3	2
CNT3_DF2	1	4	4	3	5	3	4	4	3	5	6	2	5	4	6	2
CNT3_DF3	10	1	3	7	5	5	3	0	2	3	4	1	2	5	2	4
CNT3_DF4	1	3	2	1	3	0	4	5	2	1	4	1	1	7	1	1
CNT3_DF5	50	4	7	1	5	6	3	2	3	1	3	5	8	3	4	1
CNT3_DF6	10	3	8	0	4	3	4	2	4	3	4	1	3	2	2	3
CNT3_DF7	10	4	1	5	3	3	5	8	4	2	2	4	5	4	2	2
CNT3_DF8	1	5	1	3	5	1	6	2	5	4	2	3	2	1	1	3
CNT3_DF9	1	3	3	5	2	6	1	1	2	1	5	6	2	4	4	1
CNT3_DF10	50	3	2	2	6	2	4	1	0	3	2	4	3	5	3	3
CNT3_DF11	10	4	2	6	5	2	2	2	6	2	3	2	2	2	3	1
CNT3_DF12	1	1	1	4	0	1	1	4	3	0	4	2	3	8	3	9
CNT3_DF13	10	3	2	3	1	6	5	1	2	0	3	3	1	3	2	4
CNT3_DF14	1	1	2	4	2	4	2	2	4	3	2	3	3	4	2	4
CNT3_DF15	50	2	1	3	2	4	0	1	4	3	4	4	2	0	3	5
CNT3_DF16	1	0	0	1	5	1	4	2	3	3	4	4	3	2	3	4
CNT3_DF17	1	7	2	1	1	3	5	5	2	4	1	2	1	1	1	3