(REFEREED RESEARCH)

AN APPLICATION OF THE FMEA METHOD TO THE CUTTING DEPARTMENT OF A CLOTHING COMPANY

BİR KONFEKSİYON FİRMASININ KESİMHANE BÖLÜMÜNDE KARŞILAŞILAN HATALARA HATA TÜRÜ VE ETKİLERİ ANALİZİ UYGULAMASI

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ABSTRACT

Emek yoğun yapısını koruyan ve makineleşmenin diğer sektörlere göre daha az olduğu konfeksiyon sektöründe üretim akışının tüm aşamalarında çok sayıda hata ile karşılaşılmaktadır. Üretim sürecinde ortaya çıkan hataların analiz edilmesi, bu hataların nedenlerinin tespit edilmesi kalite ve verimlilik açısından önem taşımaktadır. Bu araştırmada konfeksiyon kesimhane departmanında 1 yıl süre ile inceleme yapılmış ve kesim süreci sırasında karşılaşılan hatalar, hata türü ve etkileri analizi yöntemi (HTEA) ile sınıflandırılarak kaynakları tespit edilmiştir. Araştırma sonucunda kesimhane departmanında tespit edilen 18 farklı hatadan 8 tanesinin risk öncelik sayısı (RÖS) > 100 olarak hesaplanarak çözüm önerilerinde bulunulmuştur.

Keywords: Konfeksiyon sektörü, Hata Türü ve Etkileri, HTEA, Serim ve kesim

ÖZET

There are numerous faults at all stages of the production flow in the clothing sector which protecting the labor intensive disposition. Analyzing all the reasons and the faults themselves are extremely important in terms of quality and productivity. In this research, all the activities during spreading and cutting processes are examined for 1 year and the source of the faults have been identified and classified with the method of Failure Mode and Effect Analysis (FMEA). In the conclusion 18 different faults are obtained during the spreading and cutting processes. 8 of them are determined because of their risk priority number (RPN) over 100, so some suggestions are offered accordingly.

Anahtar Kelimeler: Clothing sector, Failure Mode and Effect Analysis, FMEA, Spreading and cutting

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INTRODUCTION

In this day and time the quality is irreplaceable factor for either service or manufacturing industry. Companies have to aim for not only cheap product or service, at the same time the level of satisfying all the customers' needs and expectations with the products that they produce or service that they serve. The only way of increasing the quality level to the level of satisfying all the customers' expectations is to investigate the reasons of low quality level and make some research on this.

FMEA is a method that to prevent the faults and aim to increase quality level to the top. This method is appropriate for all kind of manufacturing processes. FMEA is an approach to decrease the failures' types and counts. There is a saying by Murphy that "If there is a little failure probability, it absolutely will". The importance of FMEA method can easily be understood from this saying too [1]. In today's economical conditions, the FMEA is a systematic method that to implement zero defect policy correctly for manufacturing and service sector. This method is helpful to,

- To determine the faults swiftly,
- To determine the reasons of the failures,
- To evaluate and assess the effect of possible faults,
- To decrease the frequency of the failures [2].

The FMEA is a frequently preferred method both for manufacturing and service sectors. When the literature is being looked through, with many studies in different sectors can be confronted. The FMEA have been used in some sectors for instance aviation industry [3], information sector [4], food industry [5], automotive industry [6], metal industry [7], manufacturing (organizational basis) [8], logistics [9], petroleum industry [10] to designate the reasons of the failures and get rid of them. There are some implementations of the FMEA method in textile and clothing sector as well. For instance Yücel was made a study in 2007 to minimize the sewing faults in a clothing company. In this study some reductions of the sewing faults have been achieved [11]. In another FMEA study which was held by Yakıt in 2011, a comparison has been made between two different ways to calculate the RPN with the data that gathered from a clothing company [12]. In a study by Özyazgan and Engin in knitting industry, it was determined that all the faults that faced were arisen from the knitting machines. So some precautions have been taken to get rid of these faults [13]. In 2014 Kaewsom and Rojanarowan made a study of spinning machines to find out the reasons of fiber breaks [14]. This study is carried out in the area of cutting department which academicians' attention has been limited. The distinctness of this study is the implementation in cutting department with "The Process FMEA Method".

2. MATERIAL and METHOD

2.1. Material

The material of this study is the cutting department of a clothing company which is in Izmir Cigli Atatürk Organized Industrial Zone. The product range of this company is basic t-shirt, polo t-shirt, sweat shirt, leggings, hoody and so on. So the main material is jersey fabric that contains cotton and cotton blend. The cutting department of this company has been followed for 1 year period by the FMEA team which comprise of the authors of this study and two personnel from the company. One of these two personnel from company works in cutting department as a cutting operator for 21 years and the other one follows the spreading and cutting processes under the title of productivity for 7 years.

The spreading and cutting processes are held with semi-automatic spreading machine and automatic cutting machine. All the faults that encountered were recorded during the following period and noted. The faults that determined were analyzed by the FMEA method and some suggestions have been made not to be repeated.

2.2. Method

The FMEA method is an engineering technique that aims to determine, identify and eliminate all the possible faults about design, process, system and service. The FMEA is to distinguish itself from the other risk analysis methods with holding both qualitative and quantitative elements and evaluating the risks with three multipliers. The occurrence (O), severity (S) and detection (D) values are performed for all the faults that identified in the FMEA studies [12]. The FMEA is a method that prioritizes all the types of faults by taking into consideration the faults' level of importance value on the system instead of making improvements for all of them together [13].

The different types of the FMEA method according to where and when to implement are available. The types of this method are system, design, process and service [14]. In this study "The Process FMEA" which is an analytical technique and allows taking care of all the problems to be resolved during the manufacturing of the product is used. The process FMEA type can be applied for the manufacturing processes which are like all the new products/components, modified products/components and new manufacturing technologies used in a product/component [14].

The aim of the study is to determine the weak points of the department and take some precautions to put them away for better product flow. Therefore the Process FMEA type is thought more appropriate according to the aim of this study and all the analysis and calculations have been performed in this direction.

The roadmap to be followed in the FMEA studies is shown as Figure 1 below.

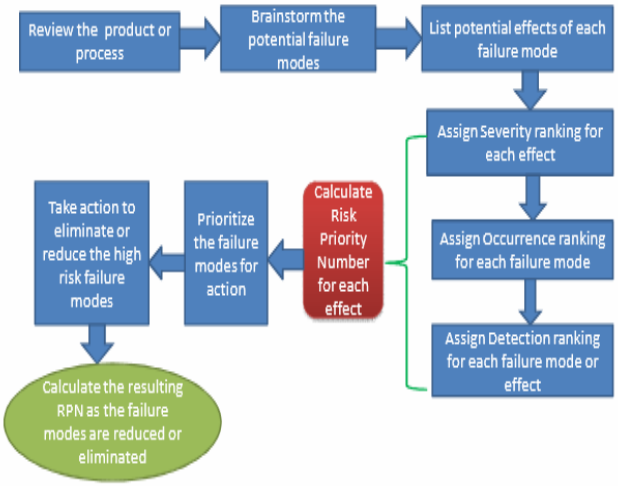

Figure 1. The stages of the FMEA method [19]

Within the scope of this study, all the faults that encountered during cutting and spreading processes have been recorded. All the faults and their effects are shown in Table 4.

The occurrence, severity and detection values of all faults should be determined after the system is analyzed and the faults are determined. So the Risk Priority Number (RPN) should be calculated by using these values accordingly [15].

Some predictions have been conducted according to the characteristics of the faults for the values of occurrence, severity and detection. Because of the reason that this study is carried out in the cutting department of a clothing company, the cutting process is considered as the customer of the fault, if the fault occurred during the process of spreading and labelling and sewing process become the customer of the fault, if the fault occurred during the process of cutting.

➢ ***The Determination of the Severity (S);***

The severity evaluation processes of the determined faults will be done according to severity classifications that shown in Table 1.

➢ ***The Determination of Occurrence(O);***

The occurrence probability level of the faults that have been encountered should be calculated. For this purpose the following table will be used.

➢ ***The calculation of Detection(D);***

The detection table which is Table 3 has been used to assign the detection values of the faults encountered.

➢ **The Calculation of Risk Priority Number (RPN)**

The formula below will be used to calculate the risk priority number of each faults.

Risk Priority Number = Severity x Occurrence x Detection

RÖS = S x O x D

After the calculation of the risk priority numbers, the order of precedence will be generated with taking into account the risk priority numbers of each fault.

3. FINDINGS

Before all the calculation of the severity, occurrence and detection values, the effects of all the faults have been given in table 4 which shown below.

➢ **The Effects of the faults;**

The determination of the occurrence values the rate of incidence of each faults have been taken into account. So the occurrence values are shown in Table 5.

Table 1. Severity Classifications [15]

Classification	Example	Code
Hazardous without warning	Very High ranking affecting safe operation	**10**
Hazardous with warning	Regulatory non compliance	**9**
Very High	Product become inoperable with loss of function, Customer very much dissatisfied	**8**
High	Product remain operable but loss of performance, customer dissatisfied	**7**
Moderate	Product remain operable but loss of comfort/convenience	**6**
Low	Product remain operable but loss of convenience and customer slightly dissatisfied	**5**
Very low	Non-conformance noticed	**4**
Minor	Non-conformance by certain-Noticed	**3**
Very Minor	Non-conformance bycertain item- Noticed	**2**
None	No effect	**1**

Table 2. Occurence Table [15]

Fault probability	Ratios		Code
Very High: Inevitable Failure	in 2 ≥ 1	0,5 and more	10
	1 in 3	b/w 0,33-0,5	9
High: Repeated Failures	1 in 8	b/w 0,125-0,33	8
	1 in 20	b/w 0,05-0,125	7
Moderate: Occasional Failures	1 in 80	b/w 0,0125-0,05	6
	1 in 400	b/w 0,0025-0,0125	5
	1 in 2,000	b/w 0,0005-00025	4
Low: Few Failures	1 in 15,000	b/w 0,0000667-0,0005	3
	1 in 150,000	b/w 0,00000667-0,0000667	2
Remote: Failure Unlikely	1 in 1,500,000	b/w 0,00000067 - 0,00000667	1

Table 3. The Detection Table [15]

Detection	Criterion	Probability of Reaching Customers (%)	Rank
Extremely unlikely	No design techniques available/control	%82- %100	10
Very very low likelihood	Unproven, Unreliable design/poor chance of detection	%72 - %82	9
Very low likelihood	Design chance of detection	%62 -% 72	8
Low Likelihood	Design controls are likely to miss the problem	%52 - %62	7
Medium likelihood	Design controls may miss the problem	%42 - %52	6
Likelihood	Design controls can miss the problem	%32 -%42	5
Moderately	Design controls are moderately effective	% 22 - %32	4
High Likelihood	Likely to be corrected/high probability of detection	%12 - %22	3
Very High likelihood	Can be corrected prior to design release/very high probability of detection	%2 -%12	2
Extremely Likely	Can be corrected prior to prototype/ Controls will almost certainly detect	%0 - %2	1

Table 4. The faults and their effects

FAULTS	EXPLANATION	EFFECTS
Wastage(length)	The length difference of the fabric layers that are spread	- If there is some length difference means loss of productivity, waste of fabric, rise of costs and rework
Wastage(width)	The width difference of the fabric layers that are spread	- If there is some width difference means loss of productivity, waste of fabric, rise of costs and rework
Less-More Layer	Less or more fabric layer(s) when the spreading process is completed	- If there are surplus layers means loss of productivity, waste of fabric, rise of costs and rework - If there is layer deficiency means rework
Reverse Layer Spreading	Reverse spreading of the fabric layer(s)	Rework of the spreading and cutting processes
Bending of the Spread Layer	Bending of some fabric layer(s) during spreading	Rework of the spreading and cutting processes
Dimension Difference	The dimension difference between the cut pieces	Rework of the spreading and cutting processes
Notch Mistakes	Marking the cut pieces untruly	Rework of the notch processes
Incorrect Settlement to Vehicle	The wrong settlements of the fabric rolls to the spreading vehicles	Rework of the spreading processes
Insufficient Piece	A piece that increases the length of marker plan during placement	Loss of productivity, waste of fabric, rise of costs and rework
Incorrect Settlement to Shelves	Incorrect placement of the pieces to the shelves	Rework as a result of the mismatch of order and related fabric
Cutter – Cutting Mistake	The incorrect cutting of the pieces by cutter	Rework of the spreading and cutting processes
Edge Adhesion of Fabrics	Sticking the edge of the fabric due to heating the cutter's knife up	Rework of the spreading and cutting processes according to the damaging volume of the pieces
Writing Wrong Lot Number to Report	Having different lot numbers of the fabric used in the sample and the bulk production	Rework of the sample production, sample approval, spreading and cutting processes
Edge Fraying	Creating the fringes at the edges of the fabric pieces because of the cutter	Rework of the spreading and cutting processes
Material Mistake (Interfacing)	The material mistakes made in the progress of spreading or cutting processes	Rework of all the processes about the material
Spreading Wall Mistake	Creating incorrect wall during spreading processes	Rework of the spreading processes
Wrong Spreading Plan	Using incorrect spreading plan	Rework of the spreading and cutting processes
Manuel Cutting Mistake	A faulty cutting operation performed by manually cutting machines	Rework of the spreading and cutting processes

The severity and the detection values of the faults have been designated with taking into account the faults' types and characteristics relying on the experience of the working team. The risk priority numbers which are obtained with mathematically multiplying the severity, occurrence and detection values of all the faults are screened on Table 6.

The risk priority numbers that was calculated within the FMEA method should be taken into account at the improvement in the department of cutting processes. As the scope of FMEA method if the risk priority number of a fault is equal to or greater than 100 (RPN $\geq$ 100), the improvements should begin with these faults in question [15]. All faults' risk priority number values are shown in the figure 2.

Table 5. The amounts of the occurrence values of each fault during 1 year

FAULTS	Occurrence Amounts	Occurrence Ratios	Occurrence Values
Wastage(length)	570	0,289	8
Wastage(width)	163	0,083	7
Less-More Layer	149	0,076	7
Reverse Layer Spreading	27	0,014	6
Bending of the Spread Layer	214	0,109	6
Dimension Difference	62	0,031	6
Notch Mistakes	460	0,233	8
Incorrect Settlement to Vehicle	3	0,002	5
Insufficient Piece	44	0,022	7
Incorrect Settlement to Shelves	68	0,035	7
Cutter – Cutting Mistake	139	0,071	7
Edge Adhesion of Fabrics	12	0,006	5
Writing Wrong Lot Number to Report	3	0,002	5
Edge Fraying	16	0,008	5
Material Mistake (Interfacing)	12	0,006	5
Spreading Wall Mistake	4	0,002	5
Wrong Spreading Plan	8	0,004	5
Manuel Cutting Mistake	6	0,003	5

Table 6. Calculation the Risk Priority Number

FAULTS	SEVERITY	OCCURRENCE	DETECTION	RPN
Wastage(length)	4	8	4	128
Wastage(width)	4	7	3	84
Less-More Layer	4	7	3	84
Reverse Layer Spreading	4	6	3	72
Bending of the Spread Layer	7	6	2	84
Dimension Difference	5	6	3	90
Notch Mistakes	4	8	7	224
Incorrect Settlement to Vehicle	3	5	5	75
Insufficient Piece	2	7	5	70
Incorrect Settlement to Shelves	5	7	5	175
Cutter – Cutting Mistake	4	7	3	84
Edge Adhesion of Fabrics	6	5	5	150
Writing Wrong Lot Number to Report	8	5	5	200
Edge Fraying	6	5	4	120
Material Mistake (Interfacing)	5	5	3	75
Spreading Wall Mistake	6	5	4	120
Wrong Spreading Plan	8	5	4	160
Manuel Cutting Mistake	7	5	2	70

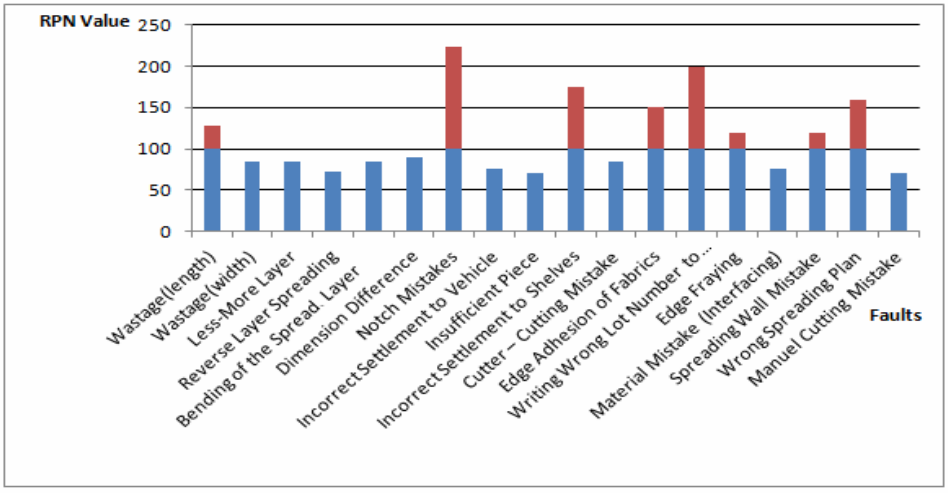

Figure 2. The RPN Values of Each Fault that Encountered in Cutting Department

So in this study the faults whose risk priority numbers are equal to or greater than 100. These faults can also be seen in figure 2.

- ***Wastage(length) (RPN=128)***

In the company inspected, the spreading processes are made with semi-automatic spreading machine and cutting processes are with automatic cutting machines. During the spreading processes the person who is responsible with the cutting processes leads the spreading machines. For this reason, the occurrence of the height difference fully up to this person's experience and education. The importance of this fault should be explained with numerical values to this person in order to prevent this fault as soon as possible.

- ***Notch Mistakes (RPN=224)***

The pieces of a garment should be marked with notches on specific places to provide easy sewing processes. Putting notch marks requires little cutting on the pieces. This work needs highly importance and sensibility. Otherwise it is possible to meet some situation like while some pieces are cut more than needed and on some pieces there is even no cut. Cutting these pieces more than required (for instance more than seam allowance) means wasting them at all. Similarly, cutting the pieces less than needed means to miss them and sew unrestrainedly.

While this fault can be derived from irregular spreading processes, the knife of the cutting machine may be a reason as well. The pieces should be controlled carefully after every spreading and cutting processes by thinking the notch marking to avoid this fault. At the same time fabrics should be spread smoothly (not even a camber) and all the parts of the cutting machines have to be maintained systematically.

- ***Incorrect Settlement to Shelves (RPN=175)***

The pieces after spreading and cutting processes need to be waiting until the existing manufacturing processes complete. So the cut pieces should be put in the shelves according to their category. If the pieces that cut recently put in the wrong category (to the wrong shelf), the manufacturing order will be intermingled in consequence of the wrong material settlement to shelves. So at the end different products will be manufactured in different time and production line. Such a small settlement faults will confuse the manufacturing department entirely. For that reason this is an important and worth-stressing problem. To solve this problem, the cutting process, the cut pieces, the bundle that comprise of the cut pieces and even the shelves need to be designated numerically. After each cutting process, the pieces and bundles should be placed to the related shelves according to their numbers. Also, if possible, the settlement of the cut pieces to the shelves and giving the numbers to the bundles should be performed by the same person. In addition, the use of techniques such as 5S and so on which helped working environment to be organized clearly should be implemented to prevent confusion and provide these applications with continuity.

- ***Edge Adhesion of Fabrics (RPN=150)***

Heat occurs because of the reason of friction during passing the knife through the fabric. Overheating of the knife causes the fabric edge curl and dissolution if the fabric has thermoplastic fibers. The forced opening of the adherent fabric edges result in edge fraying. The fraying edges also discomfort during wear. So to avoid this situation,

- To control the knife after every cutting processes,
- To change the knife if it complete its usage time,
- To use anti-fusion paper during cutting,
- To decrease cutting speed (if needed),
- To decrease the spread fabric high.

- ***Writing Wrong Lot Number to Report (RPN=200)***

If a dying process of the different roll of same type of fabrics is done in different dyeing machines, the tone difference (even for the same colors) occurs between these rolls. After the dying process, each rolls get lot number. The same rolls which are dyed in same machines get same number as usual. These numbers call lot number. Writing the wrong lot number to the report causes using the rolls of fabric that have different lot numbers. This leads to tone differences between the pieces of same product and this is an undesired situation for everyone.

In order to avoid this situation, samples from the fabric rolls that will be spread should be taken and the shade differences should be considered. Writing the wrong lot number, RPN value as 200, is amongst the top three failures considering the other failure types. Therefore, various investments may be conducted to avoid this failure type. For instance, if the fabric rolls enter the company with a RFID barcode, than because of the reason that laying process will require the same barcode, the wrong roll will not be used due to this situation, even though the lot number is reported with another number in the report. Thus, the fabric with a different lot number will not be utilized and also the failure exist in the report may be distinguished.

- ***Fraying Problem (RPN=120)***

The fraying problem is mostly derived from the shear property of the knife. Sometimes the spreading height of the spread fabric layers causes the fraying problem as well, if this height exceeds the maximum level that cutting machine allows. If some deformation or wear occurs on the sharp side of the knife, it may not be able to work correctly and will not be able to cut the pieces in the right way anymore. Thus, uncut threads will be placed between the garment pieces which will be used in manufacturing. So these uncut threads cause fraying on the edges of the pieces. While the fraying may effect the dimensions of the pieces, it may also distort the image of them. In order to prevent from this fault, the usage lifetime should be considered and the cutting limits and the maximum fabric layer should not be exceeded. Moreover, the proper knife and the cutting speed should be selected according to the material and the knives need to be prepared before every cutting process.

- ***Wall placement fault (RPN=120)***

During the spreading process, one of the edges should be constant and the other layers need to be aligned according to this edge. This operation is called as "creating the wall". This operation is conducted due to the possible fabric

dimension differences. Therefore, the spreading plan is aligned and fixed on the constant edge, after the fabric spreading. Spreading process is fulfilled through semi-automatic spreading machine by the company observed in the study. This mentioned wall faults may be prevented via one of the specific features of the semi-automatic spreading machines, namely the edge regularity controlling system. Because of the 120-RPN value, one can say that this fault may stem from the problems of the machine or the operator. Various training series for the operator(s) work in the spreading process and regular maintenance of the machine may be effective in avoiding this fault type.

- ***Wrong Spreading Plan (RPN=160)***

The situation that using the wrong spreading plan and making cutting processes accordingly causes the wasting of all the fabrics and consuming the spreading plan which belongs to another order. The spreading plans need to be prepared just with getting the acceptance of the order and many times before the spreading and cutting processes naturally. The procedure of the spreading and cutting processes is the responsible person who deals with these processes, takes the spreading plan from the related shelves and spread it on the fabrics which are spread and start cutting directly.

The suggestions to get rid of this problem are carrying the spreading plan's shelves to the spreading plan preparing room. After carrying these shelves, the person that is responsible with spreading and cutting must go to the spreading plan preparing room to take the plan. While taking the plans from the shelves, cutting personnel must give her/his signature to the person who prepares these plans. Also cutting personnel must show the related sample to the planner person before the signature. So this means, the person who prepares the spreading plan will be the only responsible person with preparing the plan and also giving permission to start cutting. Also the procedure must be after the acceptance of the order, the plotting of the spreading plan will be just before the cutting processes. This will obviate this confusion in question.

4. THE REVIEW AND CONCLUSION

This study aimed to determine all type of the faults and the amount of them in a clothing company's cutting department and make suggestions to decrease the faults or get rid of them. At the end of this study the RPN values of 18 different faults have been calculated and the 8 of these faults have RPNs more than 100 level. After the meetings and brain storms which were done with the company managers, the actions to be taken to decrease and wipe out these faults have been classified like, education, correct information flow, machines and equipments maintenance and following modern techniques and manufacturing systems.

In the scope of this research, the reason of dealing with the faults which RPN values are more than 100 primarily is the improvements about them will increase the belief of the company to the RFEA and similar methods. The education that needs to be give to personnel plays a very big role to annihilate these faults. The reasons of the faults like waste (length), notch mistakes, writing wrong lot number to report, wall placement fault and wrong spreading fault cause mostly lack of education and paying no mind on them. Also the systematic maintenance of the machines and equipments help to stop encountering with these faults. The faults which are non-considered but the RPN values are more than 100 like notch mistakes, edge adhesion of fabrics, wall placement fault arise mostly from the maintenance and repairs processes which are not on time of the machines. The insufficient communication between employees causes big troubles and faults like writing wrong lot number, wrong settlement to the shelves and using wrong spreading plans in the sectors which are labour intensive like textile and clothing.

In modern day market conditions providing continuity of the high quality and customer satisfaction effect the competitiveness of all the companies obviously. The method of FMEA is one of the important tools to increase companies' skills like quality, customer satisfaction, manufacturing agility, reducing the costs and so on. It is thought that this study will be an example of the application of the FMEA method to the other studies and also the textile and clothing companies.

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