Statistical Modeling in the Standardization of Production Systems

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Abstract

This study aims to demonstrate the use of mathematical modeling in the standards of measures to control the quality of production processes and also the tests of metrical measures of control to follow the specific standards of the norms in Brazil for the characteristics and properties of knitted fabrics and the essential standardization of quality in order to ensure the quality of the products.To ensure a system of quality in the enterprise, it is necessary to define standards (material measures or references) which are parameters used to ensure quality in the production system. In this way, they are very important to the system. The establishment of standardized practices of process is necessary to ensure that the norms are followed by all and the tasks are performed in the most efficient and uniform manner. Therefore, we must establish standards to retest the capacity of the process.The research showed that the processes reveal distortion and instability which can cause faults in the process.

Key Words: Quality, tools, standards, measurement, textiles

1. Introduction

To establish a system of quality in the enterprise, it is necessary to define standards (material measures or references) which are parameters used create quality in the production system, and so are very important to the system.

The enterprise combines a series of factors necessary to develop planning: a collection of processes, procedures, indicators of performance and analyses which are developed in order to attain a common objective.

For Taylor, "the organization and the Administration must be studied and treated scientifically and not empirically. Improvisation must give way to planning and empiricism to science: the Science of Administration. Scientific Administration is a combination of Sciences instead of empiricism. Harmony instead of discord. Cooperation and not individualism. Maximum profits instead of reduced production. Development of each man in order to gain greater efficiency and prosperity."(CHIAVENATO, 2000).

In this context, important for the administration of the processes are actions which can avoid waste of the resources used for production and so it is necessary to make comprehension of them simple so as to facilitate the understanding of the actors involved in the production system.

The estimate of capacity supplies the parameters for the production process which are essential for the measure of capacity.

1.1 Objective

The study aims to demonstrate the use of mathematical modeling in the standards of measurement to control the quality of the processed of production, as well as the metrical tests of control to comply with the specific standards of the norms of Brazil, characteristic and proper to the knitter industry; this standardization is essential to the products to establish quality. The tools used to develop the quality controls were based on facts observed and not declared, having as principal characteristic the trial of testing to suggest improvements in standardization.

1.2 Methodology

As the method to develop this study, we opted to use methodologies of control of production and quality. For this purpose, we used testing carried out on raw material, in process of production and produced. By way of the tests carried out we formulated the capacity and the parameter of the standard.

The use of a model to define the performance made it necessary for us to seek measures which could evaluate the capacity of performance, give information about control and with this increase the quality of the processes.
Santis (2012, p. 99 -109) states that: " a case study must relate a series of paradigms and prejudices with the theoretical, checking reactions and actions or unexplored. Therefore it was necessary to find within the textile industry, a company that was willing to give information regarding its performance about their production processes. This company became the object of study contributing significantly to the investigation".

1.3 Justification

To establish a quality system in an enterprise, it has become necessary to make some modifications in the production system, in the processes, in the activities developed and in the human resources.

The use of a model to define performance has made it necessary to find a measure which can evaluate quality, give information on control and thus increase the quality of the process.

One of the propositions of this study is defined as a contribution to the improvement of the quality of production in a small-scale industry. In this way, some of the studies carried out had as principal basis the requirements of the ISO 9000 family, which decide norms for the establishment of a quality system.

The definition of indices for measuring performance has for its aim evaluating the capacity of production, the performance of flow and quality of the products. Since the ISO 9000 family has as one of the requirements for obtaining certification documentation, standardization, specification of processes and production to establish a plan of norms.

Providing greater details of the processes and routines becomes a necessity, even if not to obtain certification.
Parmenter (2007) affirms that "the development of performance-improvement strategies and performance measures becomes an iterative process in time. That is, the direction and context for change progressively become modified and informed as teams are increasingly empowered and develop innovative solutions and ideas."

The material measures by way of the tests can help to correct and prevent faults in the products, processes and activities of production and in this way increase the quality of their products, In this sense, we are using the definitions of the book de Boas Practicas de gestão da qualidade-Portugal (2005) as a basis for practice

Standard:--material measure, instrument of measurement, reference material or system of measurement used to define, carry out, conserve or reproduce a unit or one or more values of sufficient size to serve as a reference.
Track ability--the property of the result of a measurement or of the value of a standard which consists of being able to be related to set references, generally national and international standards, by means of comparisons, all tending towards given uncertainties.

2. Standards

Mathematical modeling can contribute to the development of standards, translating the events of the system into a symbolical language with greater facility of demonstration. In this way, the standards proposed in the enterprise XYZ will be translated into the language of mathematics. Standardization must contribute to the control and quality in the production and processes.

Measurement can become a valuable source of information for the managerial control of the operations.

In agreement with Parmenter (2007), Kaplan and Morton "brought to management`s attention that performance needed to be measured in a more holistic way. They came up with four perspectives that have been increased to six in this book. Kaplan and Norton´s new work on strategic mapping alludes to the importance of employee satisfaction and the environment/community perspectives."

The processes of the production system must be adequate to the requirements and furnish information necessary to the management of these processes. The standardizations follow the ABNT norms, which are standards for industries, international technical specifications suitable for the knit-ware industry.

In the present study we began the creation of the criteria for standardization: thread, product in course, final article, according to the Table 1.

According to Silva (1999), the quality of the the prime material , as well the conditions of the equipment and resources employed in the fabrication process of the fabric alters the quality of the product.

The determination of the measure of the standard used is influenced by the type of raw material and final product to be produced by the client, and is a form of establishing a process flow which permits the planning of production and furthermore analysis of quality and information about faults.

For Hemdan (2008), "statistical features such as mean, standard deviation, variance, coefficient of variation, moment, skewness and kurtosis are used to characterize the histograms and to distinguish between normal and defective fabrics."

Martins and Laugeni (2005) affirm that for the development of this work in practice, one needs measurement of the time of production, control of the process and sources of variation, or better, the causes of variation in the productive process. Under this heading we selected the items which could in some way interrupt or hinder the process of production, as any fault can generate a loss both to the client and the enterprise. It is therefore important to develop parameters which can ensure prediction of faults and continued improvement in the process. Furthermore, verification of defects or faults in finished products can also be measured, since they affect the client directly.

After numerous visits to the enterprise in question, in conversations with the managers, we collected the following information:

2.1 Prime Materials

In the enterprise, to identify the possible faults in the articles of knit-ware it became necessary to define various activities which could contribute an improvement in quality. In this way, the checking of the prime material (thread) received and the criteria adopted for inspection will be carried out by an assistant manager who is responsible for the loading and unloading of the materials.

ISO 9000 presupposes the documentation and internal conformity of the processes and operations in accord with the requirements adopted.

In thread, because we are dealing with a prime material furnished by the client, there are requirements for reception. The packaging, transport and warehousing are important to guarantee the quality of the product. The description of this activity must be described in a manual which serves as part of the details of the processes.

In the reception of polyester thread and/or natural cotton thread, the criteria for the processes are defined by critical visual inspection:

1. Conditions of packaging--check if the box is sealed;
2. Conditions of the cone--open the box and check that the cones are not crushed or humid;
3. Integrity of the piece--check that there are no loose or broken threads.

When the raw material has been received, it will be transferred to the stock or to production according to the formula indicated.

The knit-ware factory which served as the object of this study works with circular looms (machines with mono-front) and produces wool stockings by weight in kilogram measure. The knit-ware is produced by interlacing the threads;this is called knitting because it uses needles or various needles for the confection as in Figure 1.

In the process of knitting, the type of thread used depends on the product to be produced.

The type is the quantity of microfilaments existing in the thread. The threads employed in the production of knit-ware all possess the same twist. The principal characteristics required in knit-ware thread are : uniformity, flexibility and resistance.

Uniformity--irregularity in the diameter of the thread causes defects like holes and transparency of the cloth.
Flexibility-- for the knitware article it is very important, in case the thread is twisted or texturized, it stabilizes the filaments, helping the production.

Elasticity--if it is an article modeled to the body , this characteristic helps the knitting: after the tension stops, the thread goes back to its original length.

Resistance--influences the resistance of the article, giving greater durability.
In consideration of the relation of the types of thread used for the production of the articles of stocking stitch, the enterprise uses the descriptions furnished by the supplier, according to the technical documents of the polyester threads sent by the client and which possess the characteristics which are displayed in a technical file, in which the item being received is described.

In the knit-ware factory, the thread used is texturized, which means that it is mechanically altered, and so lengthened. The quantity of threads used for the knitting can be measured by the thread count (Figure 1, shows the thread seen by the thread count machine, which is used to calculate the length of the thread).

Another important element is the needles (Figure 2). The needle used in making knit-ware is measured in inches: in the enterprise, they use needles of 22 to 34 inches depending on the article to be produced. The thicker the thread, the shorter the needle.

According to the client`s request, it is known what type of equipment must be used, the approximate quantity and type and size of needle to be used in the production of the article.

The needles interlace the threads forming the knitting. The state of the needles is very important for the article to be of quality and a broken needle causes a defect in the final article.

2.2 Gage

The cage used in the circular loom is lateral: it is the place where the cone of threads is placed. The weight of the cone varies between 1.8 kilos and 2 kilos.

Feeders: Their purpose is to feed the loom at each revolution of the machine feeding thread to the needles.

2.3 Circular loom

The circular looms are machines which carry out the interlacing of the threads by means of needles. There are two categories: large and small diameter. They are thus categorized by the size of the cylinder: the machines of the enterprise are large diameter employed for the production of stocking stitch and tubular knit-ware.

According to Boynton, (2002), to interpret capacity it is necessary to have information, convergences, critical and strategic planning and knowledge of the internal control system. In this way, one can observe all the operations; only after knowing the process and its specifics was it possible to carry out the research and collection of data.
In the process of the study we used probability which according to Oliveira (1999) "signifies a body of rules by means of which one calculates the number of cases which must occur for a certain fact or phenomenon."
For the development of the tests of this study we carried out a check of the looms for an aleatory sample of seven looms showing the following characteristics of production:

From Table 3 we selected the Shinta Knitting machine to select finished pieces as sample for the tests. For the tests we used various equipments which will be demonstrated during each test.

3. Discussion

The test of the length of the stitch is carried out with an equipment called thread counter and a metrical tape-measure. This test consist of counting the length of the point. The method used consisted of a 30x30 cm sample taken from the piece;we marked with a pen a line along a column situated 5 cm from the margin of the knit, we counted 100 columns (excluding the two marked at the beginning and the end). We removed the piece and the tension and measured the thread. This test was carried out on 30 samples and we obtained Chart 1The data of length of stitch were obtained by way of calculations.

For this as a means of work we used the thread-count machine (Figure 5), metrical tape-measure and a pincer to remove the sample. After removing the sample, the thread was measured with the tape. This method was used to calculate the consumption of threads each turn of the circular loom, this being important as quality control. To obtain the calculation we also used the arithmetical mean of the values obtained in the test to obtain a measure of stability for the calculation of the stitch, and median to calculate central tendency For the calculations, the following formulas:

To understand the data we used descriptive statistics to explain the frequency of variations is still used graphics.

Another test of importance is the gramme-weight of the fabric, the mass per surface unit of a fabric. The gramme-weight can be obtained in two ways, dividing the weight per area of sample or or by way of graduated scales measuring g/m2.The sample must be removed by a cutting mold and immediately weighed obtaining the gramme/weight. To calculate the gramme-weight, use the formula: Gramme/weight (g/m2)= P (weight of sample)/A(area of sample). In the test carried out, we used the scales for g/m2 and the cutting mold as in Figure 6.

The chart (Chart 2) shows the results obtained for the samples in the study carried out on a piece of tubular polyester knitware 1.03 cm wide and weighing with 30 samples taken from pieces of polyester 14.250 cm wide. The data obtained were grouped in chart form to give a basis for calculations compatible with the needs of the tool. The data were laid out so as to monitor clearly the variations of the measurements, and to do this, we used the arithmetical measures, such as, for example, average, median, standard deviation, variance etc. So we described the variations obtained with software minitab, which helps a lot in making graphics.

The table (Table 7) demonstrates the formulas used for calculations obtained by software minitab.

The measurement of performance is to evaluate the conditions of the process.. The metrical measures are to measure efficiency which in this case is used to evaluate the threads for the process of production and the finished product. The measurements were made by means of the tests and from them we obtained parameters of calculations to observe the processes and the product.

To measure the efficiency of the product, we used the gramme-weight and calculated with basis of the formulas, which were used by the minitab software. We chose to use an appropriate tool to reduce the chances of errors in the calculations or the graphics.

The CP and Cpk to test the potential ability of a process. Note that the Cpk> 1.33 is desirable.

$$Cp = \frac{(USL - LSL)}{6\hat{\sigma}}$$

$$CpU = \frac{(USL - \bar{X})}{3\hat{\sigma}}$$

$$CpL = \frac{(\bar{X} - LSL)}{3\hat{\sigma}}$$

$$Cpk = Min(CpU, CpL)$$

The Pp is used when the total population and is testing the performance of a system to meet customer needs. Pp, Ppk using standard deviation. Note that PPK> 1.33 is desirable.

$$Pp = \frac{(USL - LSL)}{6\sigma}$$

$$PpU = \frac{(USL - \bar{X})}{3\sigma}$$

$$PpL = \frac{(\bar{X} - LSL)}{3\sigma}$$

$$Ppk = Min(PpU, PpL)$$

4. Results Presented

By way of the calculation we obtained the average length of the stitch and Graphic 1 demonstrates that even with the variations obtained the knitware article tends to have a variation depending on the place where you take the sample. The graphic for thread control used to monitor the prime material presents a standard deviation that may be a defect shown in the article. The variation may have occurred in the thread production and caused damage to the article.

The next graphic analyses the probability of obtaining the same measures again. Analysis can perceive that the greater probability of occurrence is between 0.25 cm and 0.26 cmm, if we use threads of similar standards.
In Graphic 2.

We verify the probability of the occurrence of distortion in the thread, observe that 86.7% of the frequency is between 0. 26 cm and 0.25cm, indicating that the probability of repetition of the analyzing the graphic, the distortion can occur is between 25 and 26 , which shows a problem of processes. The Pareto Chart is used to index variations presented, the degree of occurrence of problems.

From the histogram we can see that the gramme-weight follows a distribution that is concentrated between the nearby measures halfway between 0.97 g/m2 and 0.99 g/m2, which is within the standards required by ISO 3891/1.

4.1 Calculations of Capacity

The graphics of the control of capacity (Graphics 4,5, 6) were used to determine the degree of stability in the production process. The estimate of capacity furnishes the parameters. Note that the data obtained presents an estimate, a test for measurement and adequacy for parametrization.

In Graphic 4, observe that 69.6% of the frequency is between 0.97 and 0.99, indicating that the probability of repetition of the gramme-weight is between these limits.

In Graphic 5, the measurements are compared by the distance of the sample: analyzing the occurrence, we determine that between 0.97 and 0.99 are found the most frequent items which occurred at varied distances.
The graphic analyses the capacity of the process, explores the normality of the occurrences and calculates the capacity. The indices of lower and upper limits were calculated based on ISO 3801/1 on the average obtained by the data, which are respectively LIE=0.9310 and LSE=1.0290.

In the graphic of stability of the process, we can verify that the individual values present a point of standard deviation, which indicates variation in the process. But as one can observe in the graphic of mobile amplitude, the values are within the control limits. The graphic of observation confirms that that the process possesses great variation in twelve of the measurements carries out. However, the histogram of capacity shows us that the process is within the limits, yet the process is not under control. But considering that the indices shown of CP=1.23 and CPK=1.22, are within the limits of specification, and the value of the index is greater than 1.0,we consider the system unstable and to get trustworthy results it will be necessary to stabilize the system and recalculate the measurements.

5. Final Considerations

The study showed that the processes possess distortion and the instability causes faults in the process. Although approximately 80% fulfill the requirements of the international norms, instability hints at a problem. It is necessary to establish standardized practices of process which will ensure that the norms are followed by all and that tasks are performed in the most efficient and uniform manner. Therefore, we need to establish standards to test the capacity of the process again.

By reformulating the procedures and creating standardized norms for the operations or transactions that are to be carried out we can succeed in guaranteeing a correct and uniform manner of production.

Thus it becomes necessary, after implanting standardization, to have new tests of capacity which are fundamental to the setting up of a quality system. Having as parameter the test carried out in our study, we can compare with tests after the implementation of the norms and verify if there is an alteration in the conduct of the process, using as a basis the length of the thread and the gramme-weight, important factors for the quality of knitware.

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Table 1 -Abnt

Density	ISO 7211/2	Warp (knitting columns) Standard Article ± 5.0% Trama (knitting careers) Standard Article ± 5.0% The area Standard Article ± 3.0%
WEIGHT	ISO 3801/1	General Standard Article ± 5.0% For patterned Standard Article - 5.0% +15.0% Standard drawing ± 5.0%

Table 2 - Criteria for Control

Proposed standard	Item Inspection	Test	Expected Return
Thread	Title Twist and direction of twist / twisting regularity imperfections hairinessResistance to breakage Moisture content Coefficient of friction Visual appearance Conformity color	Jardeira + balance Torcimetro Regularímetro or mirror wire Regularímetro Regularímetro Dynamometer hygrometer Friction Meter __________ Light camera	Identify suppliers that offer product with low quality, reduce the impact of errors in the process and return the product
Start of Production Process	Feeding the yarn tension Output voltage loop Opening the reamer atmospheric conditions	Tensiometer visual tape device register	Increase product quality, avoid waste and rework
During the production process	Atmospheric conditions	Device register	Check the production
Article late start inspection	Loop length weight g/m2 Defects in the mesh loom defects	Malhimetro Gram*mage* (weight) - ratio of the weight in grams per square meter (ABNT NBR 10591) visual Machine review	Providing quality articles and prepare a process control
During the production of the final article	Defects in the mesh loom Loop length	Visual	Aesthetic appearance quality
	width lengthWeight per rollweight g/m2	Tape Account metro Balance Sample cuts	Grammage (weight) - ratio of the weight in grams per square meter (ABNT NBR 10591)
Control of process parameters	Product traceability	Visual inspectio*n of the* product, part number marking and designation of the client	Quality in processes and services

Source: Boas Practicas de gestão da qualidade-Portugal (2005)

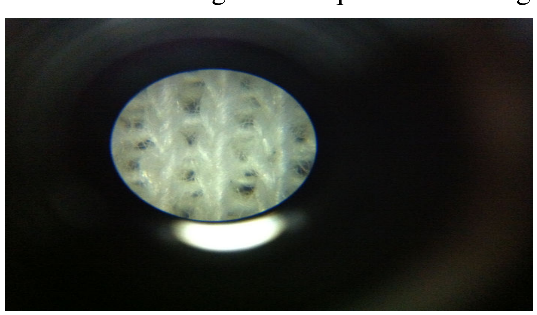


Figure 1- Woolen Knit Seen in Thread Count
Source: Author (2012) - Seen Through the Mesh Wire Account

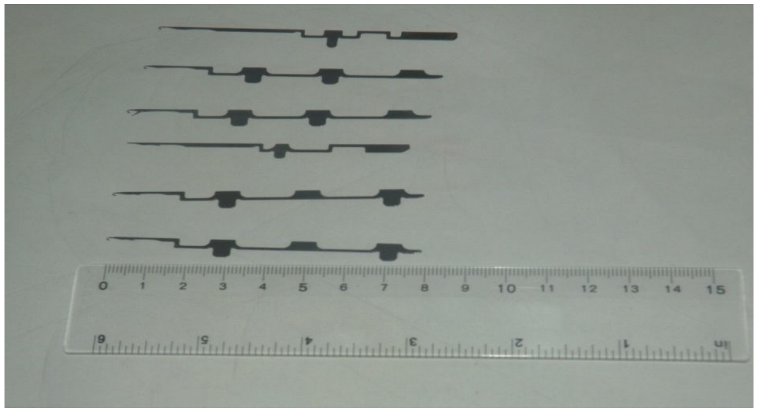


Figure 2. Circular Loom Needles
Source: Author (2012)

Figure 3. Cage And Feeders
Sources: Author (2012)

Figure 4 Circular Loom
Source: Author (2012)

Table 3. Relation of Loom to Production

Yarn	Machine	Number of laps Program	Title-dtex	needles	RPM	No. of coil	LFA cm	Wire length per point	Needle fineness
PES	Marchisio	3170	100/36	5280	24	84	14	31,0	30
PES	Kuan yu Machinery	2940	100/96	5593	24	72	16	29,7	28
PES	Kuan yu Machinery	1850	150/44	5597	22	72	16	33,0	22
PES	7Jumberca	4800	75/72	2940x2	24	84	18	33,0	24
PES	9 Shinta Knitting	1850	75/36	2232	22	116	18	25,87	28
PA	Kuan yu Machinery	2940	70/24	5597	22	72	18	27,5	28
PES	Marchisio	3170	75/36	5280	24	84	14	32,0	32

Source: Equipment

NOTE:PA=polyamide , PES=polyester, LFA--length of thread absorbed

Table 4 - Stitch Length

Sample No.	Distance in (50) cm^2	Stitch Length cm^2	Sample No.	Distance in (50) cm^2	Stitch Length cm^2	Sample No.	Distance in (50) cm^2	Stitch Length cm^2
1	0	0,25	11	2,50	0,25	21	5,00	0,25
2	0	0,25	12	2,50	0,25	22	5,00	0,25
3	0,50	0,26	13	3,00	0,26	23	5,50	0,25
4	0,50	0,26	14	3,00	0,26	24	5,50	0,25
5	1,00	0,26	15	3,50	0,26	25	6,00	0,25
6	1,00	0,26	16	3,50	0,26	26	6,00	0,25
7	1,50	0,25	17	4,00	0,26	27	6,50	0,28
8	1,50	0,25	18	4,00	0,26	28	6,50	0,28
9	2,00	0,25	19	4,50	0,26	29	7,00	0,28
10	2,00	0,25	20	4,50	0,26	30	7,00	0,28

Table 5 – Formulas

Average	Median	Variance	Standard Deviation	CoefVar
X =$_{(i\to n)}$ x_i]□ n	$\frac{(n+1)}{2}$	$\operatorname{var}(X)=\operatorname{E}\left((X-\mu)^2\right).$	$s=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2}$	$c_v = \frac{\sigma}{\mu}.$
*0,25800	0,26000	0,00010	0,00997	3,86

for C * Variable Q1 Median Q3 Maximum Mode fashion Stitch Length cm2 0.25000 0.26000 0.26000 0.28000 0.25 14

Figure 5 Thread-counter
Source: Author (2012)

Figure 6 Equipment: Scale and cutting mold

Table 6 – Gramme-Weight by Weight

Sample No.	Distance in m2	Value Weight	Sample No.	Distance in m2	Value Weight	Sample No.	Distance in m2	Value Weight
1	0,5	0,98	11	3,0	0,98	21	5,5	1,00
2	0,5	0,99	12	3,0	0,98	22	5,5	0,99
3	1,0	0,97	13	3,5	0,98	23	6,0	0,98
4	1,0	0,97	14	3,5	1,01	24	6,0	0,99
5	1,5	0,96	15	4,0	1,02	25	6,5	0,97
6	1,5	0,98	16	4,0	1,01	26	6,5	0,98
7	2,0	0,97	17	4,5	1,01	27	7,0	0,98
8	2,0	0,97	18	4,5	1,00	28	7,0	0,97
9	2,5	0,99	19	5,0	0,99	29	7,5	0,99
10	2,5	0,97	20	5,0	0,99	30	7,5	0,97

Table 7 Average Variation

Average	Median	Variance	Standard Deviation	CoefVar
$X = {}_{(i\to n)} x_i]/ n$	$\frac{(n+1)}{2}$	$var(X) = E((X-\mu)^2).$	$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$	$c_v = \frac{\sigma}{\mu}.$
*0,98467	*0,98000	*0,00022	*0,01479	*1,50

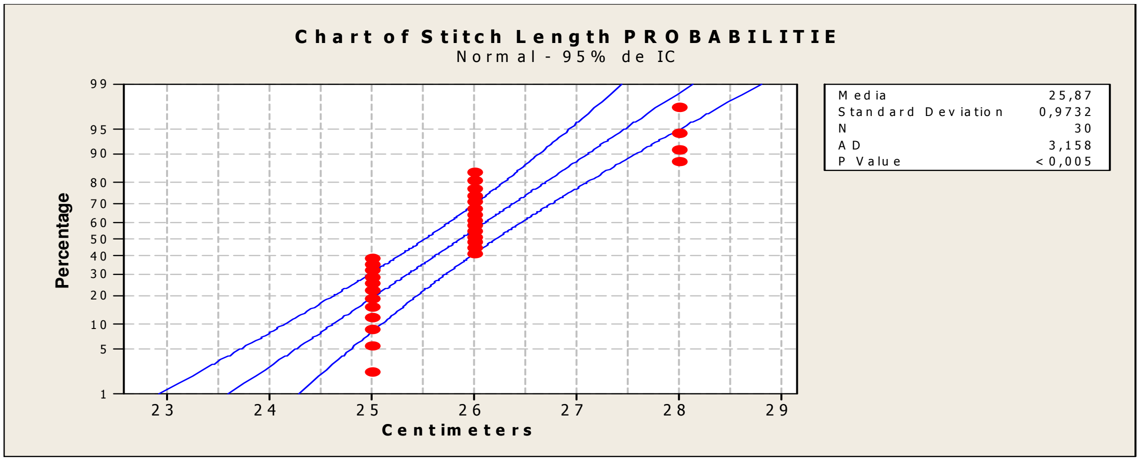
* Descriptive statistics: Weight Media Variation

Variation	N	N*	Media	Standard	Standard Deviation	Minimum	Q1	Median	Q3	Maximum
Weight	30	0	0,9846	0,00270	0,01479	0,96	0,97	0,98	0,99	1,02
Meters	30	0	7,000	0,802	4,394	0,000	3,0	7,0	11,0	14,0

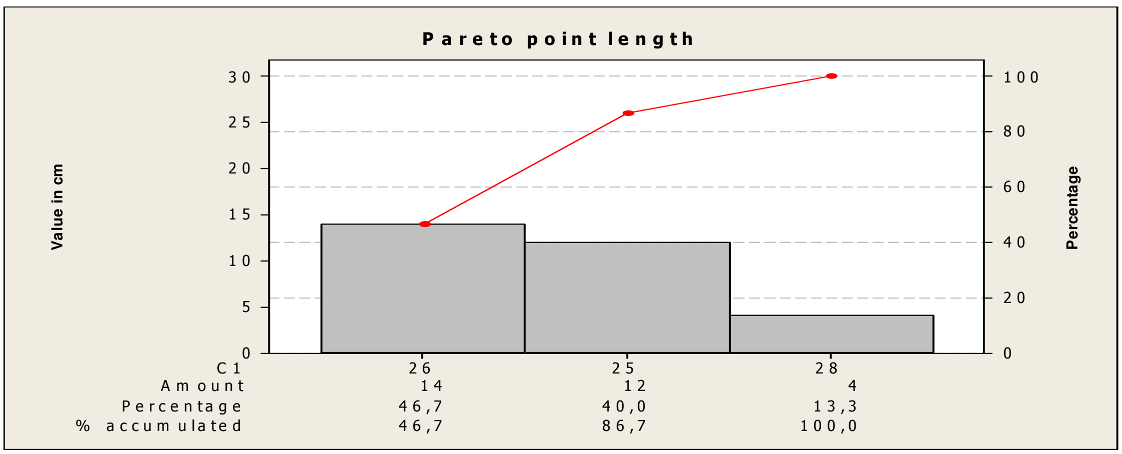
Descriptive statistics: Weight

Variation	N	Media	Standard	Standard Deviation	Minimum	CoefVar	Variance	Median	Q3	maximum
Weight	30	0,9846	0,00270	0,01479	0,96	1,50	0,00022	0,98	0,99	1,02

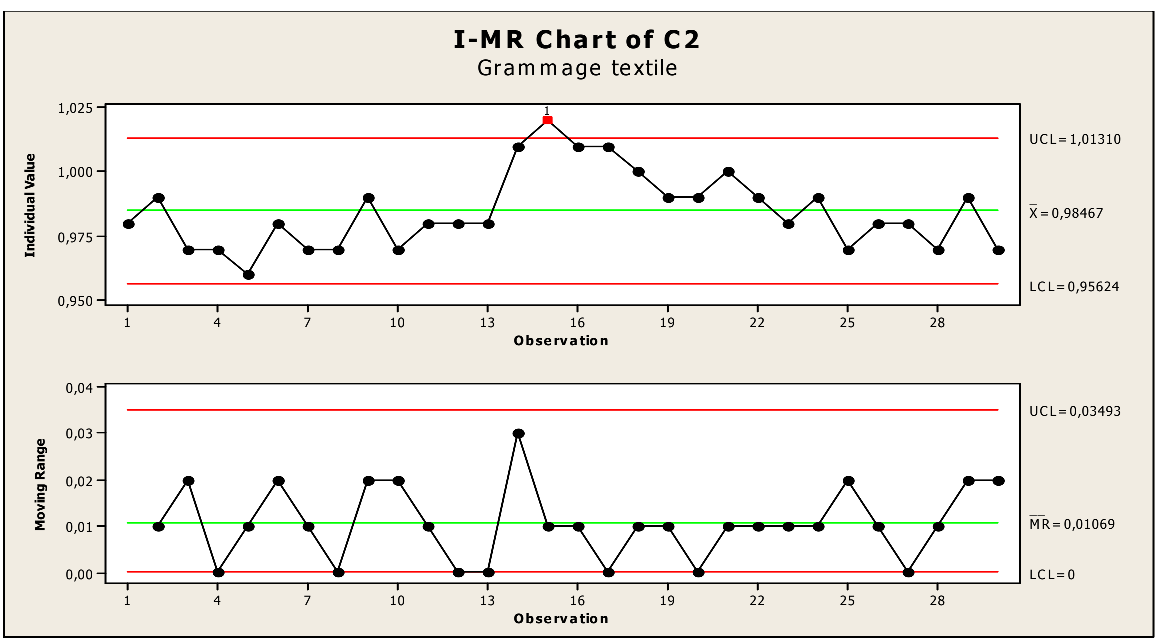
Graphic 1. Variation of the Length of the Stitch



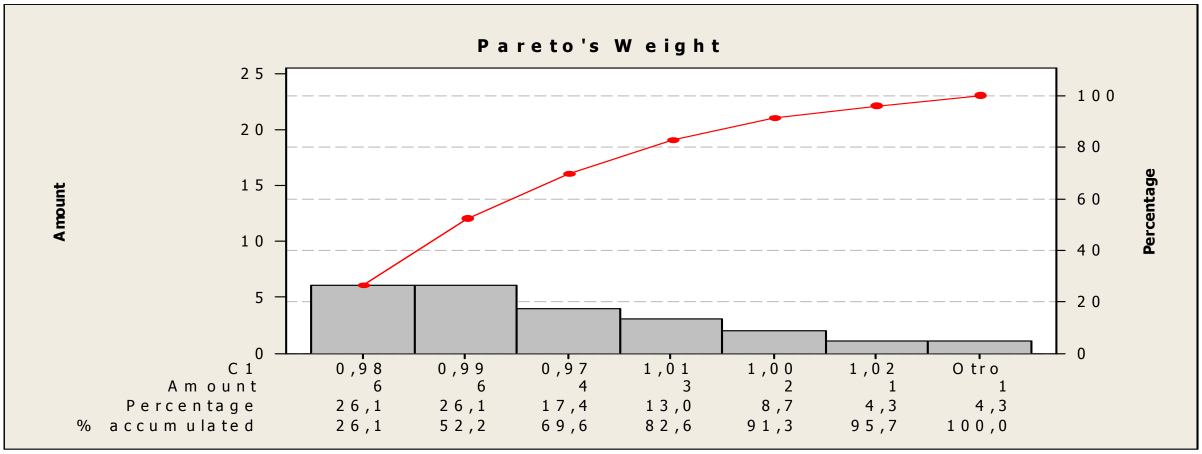
Graphic 2. Length of Stitch



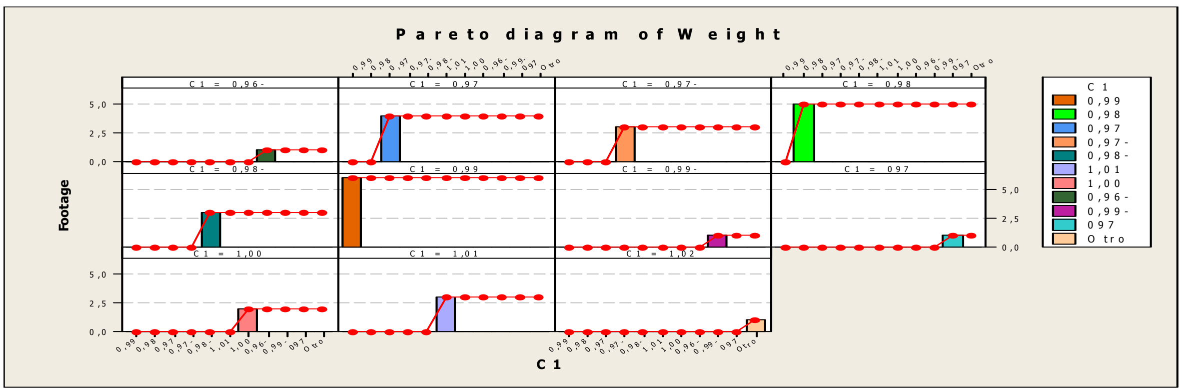
Graphic 3. The Gramme-Weight



Graphic 4. Diagram of Pareto



Graphic 5. Diagram of Pareto By Distance



GRAPHIC 6.Capacity of the Process