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Utilization of Six Sigma Analysis to Evaluate Upcycled Denim towards Sustainability

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Abstract
Six wastes denim fabrics redesign using different decoration technique creating a new trendy wearable accessory, eco fashion, focusing on sustainability and upcycling from point of view and customer satisfaction and problem solving from other point of view. Physico-Mechanical properties of new and waste denim fabrics were evaluated to determine the shelf life of the redesigned products. Function and aesthetic aspect, elements, principles and upcycling properties of the products were examined. The results were evaluated and statistically analyzed using six sigma evaluating tool. The product No. (4) which represents a multipurpose shoulder bag for girls and women is considered the best ranked product as it is the first rank with sigma level (5.74) which it meets customer satisfaction and acceptability.

Keywords
Sustainability, Denim, Recycling, Upcycling, Eco Fashion, 6 sigma

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1. Introduction:
Sustainability is a way of using resources that could continue forever. (1,2) Sustainable fashion is concerned with the usage of fibers from organic, and classified into recycled, repurposed, upcycled materials and zero waste products. (3,4)
Six sigma process: is a methodology for a process improvement and a statistical concept that seeks to define the variation inherent in any process. It focuses on customer satisfaction and problem solving, it is a statistical tool to bring objective knowledge of business problems. (5,6)
The sigma (σ) is the symbol of standard deviation, which is a measurement unit for statistical dispersion and spreading. It is a customer focused improvement strategy methodology to reduce the defects level to 3.4 defect per million in product design, production, delivery, and management processes percentage distribution of six sigma as shown in fig. (1). (7,8)

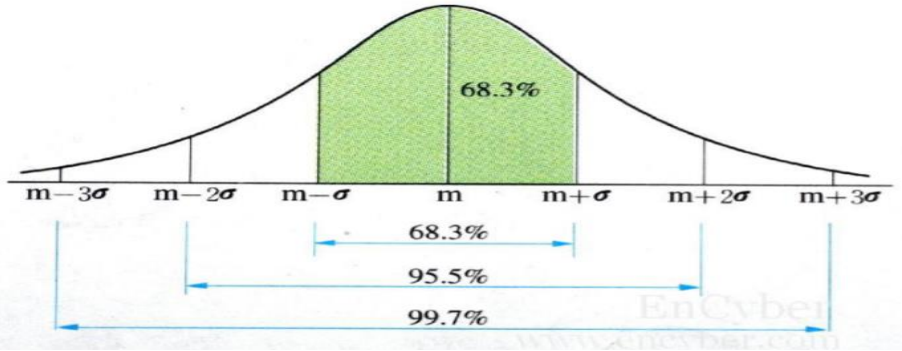

Fig. (1): Percentage distribution of 6 Sigma (6,8)

The statistical representation of Six Sigma describes quantitatively how a process is performing. Its defect is anything outside of customer specifications. (9,10) The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of Six Sigma improvement projects. (10,11)

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The aim of this research is to upcycle wastes denim fabrics via redesign strategies to create a new trendy wearable accessory, evaluated with Six Sigma analysis focusing on customer satisfaction and problem solving.

2- Experimental work:

New fashionable trendy accessories were created via using denim waste (old used child's trouser and a man's short). Six new products were created and decorated using different accessories.

2.1. Materials used: old used denim, sewing threads, trims, zippers, crochet threads, canvas threads, metal rings, wooden beads, and colored beads.

2.2. Techniques: different sewing technique, embroidery, stitching, threads, and hand printing.

2.3. Steps of upcycling:

- Recreate new fashionable trendy accessories via used denim waste (Used trousers).
- Re-construct and re-cut old denim to be suitable for the new end use.
- Decoration by different methods used embroidery, stitching, threads, and hand printing were used as a decorative technique.

2.4. Testing and analysis Methods:

2.4.1. Physico- mechanical measurements:

- The Tensile Strength and Elongation: measured according to ASTM D5035 test method. (12)
- Tearing strength: determined according to ASTM D1424 test method. (13)
- The Fabric Weight: determined according to ASTM D3776-09a2013 test method. (14)
- The Evaluation of Wettability: measured according to ISO 4920. (15)
- Color strength(K/S): Color strength (K/S) of the dyed samples was measured on Mini Scan XE spectrophotometer using Hunter lab universal software. (16)

2.4.2 Fastness Properties:

- Wash fastness: The wash fastness of denim fabric was determined according to ISO105-C06 test method. (17)
- Light fastness determined according to ISO 105-B02 test method color fastness to artificial light Xenon arc fading lamp test. (18)
- Perspiration fastness: determined according AATCC test method 15-2002. (19)

2.5. Products Evaluation:

The products were evaluated via analyzed of questionnaire sheet which designed, judged, evaluated, and analyzed using Six Sigma statistical tool. The designed questionnaire sheet was shown in table (1).

Table (1): Questionnaire sheet for evaluation of redesigned waste denim fabrics.

Dear evaluator/

This questionnaire sheet is a partial fulfillment of the PhD thesis of Home Economics, Textile & Clothing program. The thesis entitled.

"Utilization of Six Sigma analysis to evaluate upcycled denim."

The team of the thesis would like to evaluate the proposed and implemented designs from upcycling points of views.

The terms used are as following:

Upcycling involves the process of converting thrown away objects into a product of higher functionality by reducing waste. The textile waste can be used as the raw material for value-added products. The concept of upcycling design is part of an effort for implementing sustainability practices to enrich the ecosystem. Upcycling is a mixture of upgrading and recycling including both adding value to and reusing products.

Eco-fashion as green fashion, ethical fashion or slow fashion, has become a trending topic today. Where 'Fashion sustainability' is trending as a buzzword to gain attention and credibility; fashion brands are re-thinking about their business models; switching to more sustainable production and operation approaches.

So, please read the questionnaire statements and register your response by marking ( ) what is consistent with your opinion according to the five ranking levels terms {very agree (5), agree (4), agree to some extents (3) do not agree (2), do not agree at all (1)}.

Your response of all items is recommended.

1. Job &Title:
2. Work Media:
3. Date:

Finally, many thanks and appreciation for your cooperation.

Researcher

Wafaa Saeed Mohamed Ahmed

Items	Questions	First design	Second design	Third design	Fourth design	Fifth design	sixth design
The functional aspect	1-The design suitable the women's age from (15-50) Year.						
	2-The applied idea achieved satisfied level in design and application.						
	3- The design is suitable to be a marketable product.						
	4-the overall acceptability of the aspect.						
The aesthetic aspect	1-The design shows aesthetic touches.						
	2- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.						
	3-Design keeps up fashion recent trends.						
	4-Overall acceptability of the aspect.						
Elements and principles of fashion design	1-overall acceptability of fashion design elements (Line- Shape- Color- Texture).						
	2-overall acceptability of fashion design elements (Balance- Proportion- Emphasis- Harmony- Rhythm).						
Upcycling Denim	Upcycling used Jeans to recreate sustainable Accessories fashion designs.						
	The fabric used compatible with the thesis idea to achieve sustainability.						
	The added value achieved an attractive design.						
	4-Designs allowed mobility and movement with different styles of cloth.						
	5-The materials used succeeded in applying long term trendy accessories.						
	6- Design will be preferred for women to purchase in any retail store.						
	7-The colors of the embroidery used are matched with the fabric of the design.						
	8-Overall acceptability of upcycling denim.						

2.6. Six Sigma Analyzing tool:

The DMAIC (Define, Measure, Analyze, Improve, Control) method used in analyzing the results obtained from questionnaire sheet via Q1 Macro 2024 software.

2.7. Upcycled Accessories Designs pattern and layout:

Six upcycled accessories were created from two

waste denim pieces (a child's trouser and a man's short). A full set of accessories and across bag with cuff and a band for hair.

2.7.1 Design and pattern No. (1): This figure shows the upcycled design (1) and its pattern.

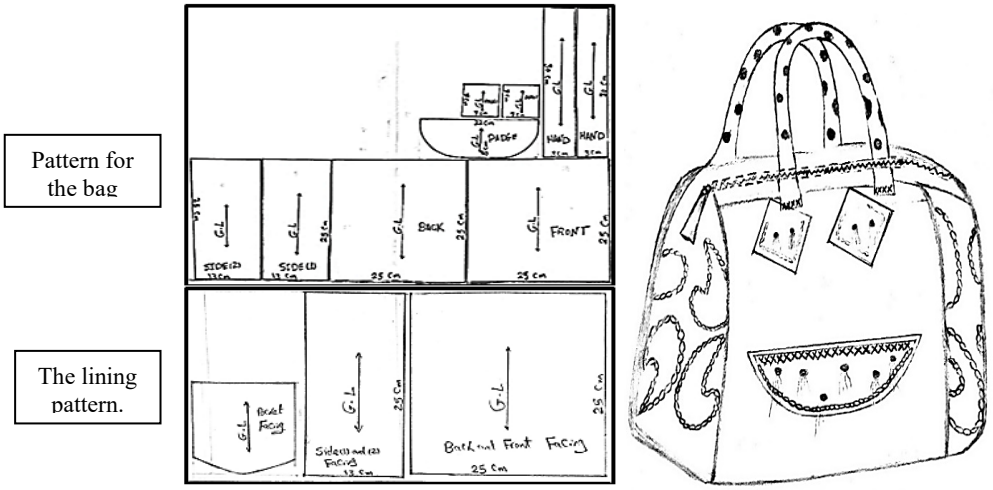

Fig. (2): pattern and upcycled design (No.1).

Materials: cropped trouser of denim, canvas threads, zipper, embroidery threads and {white & pink} pigment colors for hand printing.

Embroidery Stitches: Chain stitch, Running stitch and Herring Bone stitch were used around the hand printing shapes and for fixing the badges**.**

Description: used fabric cut and reconstruct according to the fabric suggested in fig (٣). Then, hand printing was applied using the white and pink pigment colors then the bag was sewn, and the patches were fixed by decorative stitches (Chain stitch, Herring Bone stitch and Running stitch), stitch the zipper and finally the facing for the bag.

2.7.2 Design and pattern No. (2): This figure shows the upcycled design (2) and its pattern.

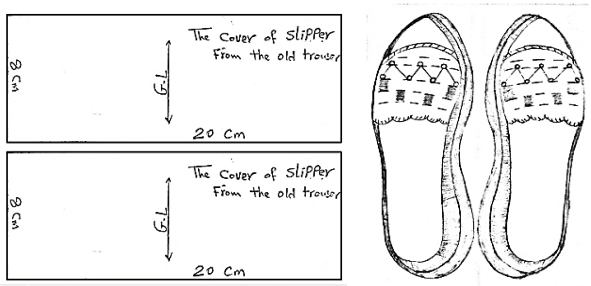

Fig. (3): pattern and upcycled design (No.2).

Materials: cropped trouser of denim, canvas threads, embroidery threads and wooden beads.

Embroidery Stitches: Running stitch, Satin stitch and Herring Bone stitch were used for decoration the face of the slipper.

Description: The remaining piece of the trouser was cut into four rectangle pieces from the remaining part for the face and the insole then some stitches were added to the face of the slipper as Running stitch, Blanket stitch, and Satin stitch, after that wooden beads were added in a zigzag shape for decoration.

2.7.3 Design and pattern No. (3): This figure shows the upcycled design (3) and its pattern.

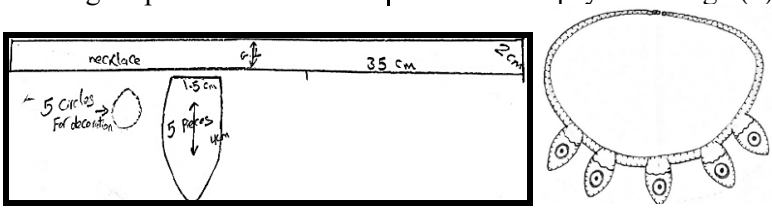

Fig. (4): pattern and upcycled design (No.3).

Materials: the tuck of the trouser leg, canvas threads, embroidery threads, Crystal beads and pink pigment color for hand printing.

Embroidery Stitches: Running stitch was used for fixing oval and circle shapes along the necklace and the blanket stitch was used around the oval shapes and around the necklace. Crystal beads were added over the circles of pigment to add an aesthetic value.

Description: the tuck of the trouser was reconstructed according to the suggested design. And decorated by hand printing and pink pigment

color was used on the circles, and the canvas threads and the blanket stitch were used to fix the shapes.

2.7.4 Design and pattern No. (4): This figure shows the upcycled design (4) and its pattern.

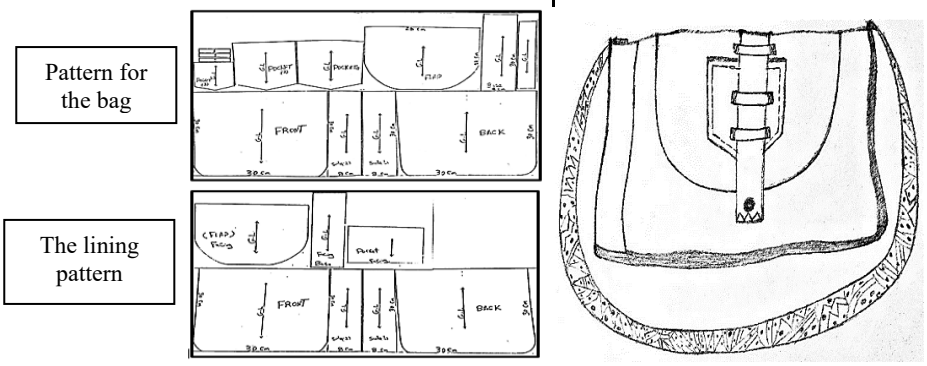

Fig. (5): pattern and upcycled design (No.4).

Materials: Used denim fabric, canvas threads, zipper, embroidery threads, metal button, a printed fabric belt and metal rings for the belt.

Embroidery Stitches: Running stitch and Zigzag stitch were used for fixing loops with an aesthetical shape along the belt that is used as closure to this bag.

Description: The pocket of a trouser was cut and reconstructed to decorate the bag front side and the loops of the old pocket used to construct a new closure for the bag pockets, the hand hangers of the bag was decorated using metal rings and fixed on the sides of the bag.

After that, the remaining parts of the waistband were used for making Two different cuffs, an earring, and a hair band.

2.7.5 Design and pattern No. (5): The following figure showing the upcycled design (5) and its pattern.

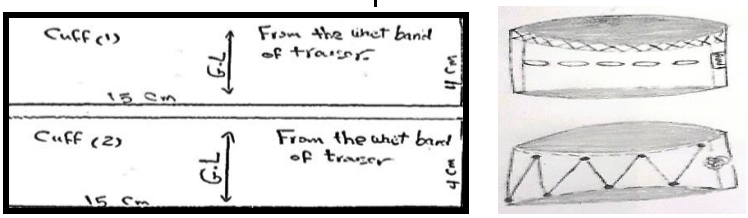

Fig. (6): pattern and upcycled design (No.5).

This design is about two cuffs for girls and women used for several external purposes.

Materials: waistband of the used jeans short, canvas threads, embroidery threads and metal beads.

Embroidery Stitches: Chain stitch, Running stitch and Herring Bone stitch, also wooden beads, colored beads, metal beads and colored threads were added as an aesthetic value.

Description: the waist band of the old trouser was cut and reused to create design No. (5) which is about two cuffs. one of them was decorated using Herring Bone stitch and colored wooden beads fixed on equal distances and a wooden button used as a lock for the cuff, the other cuff of the old trouser was decorated by Chain stitch and Running stitch also, metal beads were fixed via zigzag shapes, and four metal beads were used as a locker for the cuff, as shown in fig. (7).

2.7.6 Design and pattern No. (6):

The following figure showing the upcycled design (6) and its pattern. This design is about an earring and a hair band for girls and women used for outdoor.

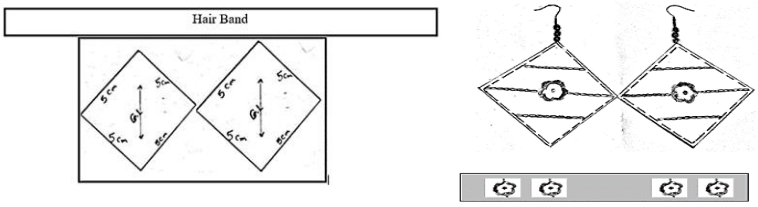

Fig. (7): pattern and upcycled design (No.6).

Materials: the remaining waste fabric of these part of the used denim fabric, pink pigment color for hand printing., canvas threads, embroidery threads and crystal beads.

Embroidery Stitches: Chain stitch, Running stitch and Branch Stitch, also crystal beads, and colored threads were added as an aesthetic value.

Description: used fabric cut and reconstruct according to the fabric suggested design fig**.** (8). Then, the remaining waste fabrics of the used jeans short were cut into four squares (5*5) cm for making earring and fixed in a rhombus shape with

its rings and decorated with Branch stitch, Chain stitch and Running stitch and pink circles were printed by hand and crystal beads were added to give an aesthetic aspect. To construct the hair band, the two rectangles (2*35) cm were cut and decorated with four rose shapes (from embroidery threads) and fixed on the hair band, crystal beads were added to give an aesthetic aspect to the design, as shown in fig. (8).

3- Results and Discussion:

3.1. Physico mechanical measurements and fastness properties:

Table No. (2) shows the results of the physico mechanical properties of the used fabric before and after four years' usage.

Table (2): The physico mechanical properties of denim fabric

No.	Test Type	Raw Material	Used Denim
1	Tensile Strength (kg)	96.12	73.08
2	Elongation at Break (%)	26.36	23.65
3	Tear resistance kg/m2	4382.5	3275.5
4	Fabric weight(g/m2)	357	344
5	Wettability(sec).	7	5
6	Color Strength(k/S)	12.67	9.88

The tensile strength of the fabric after four years were decreased by 24%, The deterioration rate of the fabric is 6% per year. The fabrics before recycled were used in apparel clothes and the new products are fashion accessories the usage of the fabric expected to be less than its usage in the apparel. The deterioration is less than 6% per year. As the tensile strength decreased, the other physico-Mechanical will also have decreased such as elongation at break decreased by 10%, also The tear strength resistance decreased by 25% and fabric weight (g/m2) decreased by 3.6% per four years may be due to the fabric dye faded and decrease in the tensile strength of the fabric. The wettability and Color Strength of the fabric also decreased by (28.5% and 22%) respectively because of the dye fading as a result of daily usage and washing and other factors which affect clothes wear.

Table No. (3) shows the results of the fastness properties of the used fabric before and after four years' usage.

Table (3): The fastness properties of denim fabric

No.	Test type	Standard	Raw Material	Used Denim
1	Wash fastness	ISO105-C06	5	4-5
2	Light fastness	ISO 105-B02	5	4-5
3	Fastness to perspiration (Acid)	AATCC test method 15-2002.	5	4-5
4	Fastness to perspiration (Alkali)	AATCC test method 15-2002.	5	4-5

All the fastness properties of the fabrics were slightly decreased due to the fading and decrease in K/S of the fabric. The wash fastness decreased because of the rupture of the covalent bond between the dye and the fabric and using the laundry detergent in the wash cycle, also the light fastness decreased due to the effect of the environment and light condition on the color fastness of the fabric. The acid and alkali perspiration fastness also decreased as the fabric doesn't withstand the acid and alkali effect. All the fastness slightly decreased after four years. This is a good sign in the life time of the fabric.

3.2. The final created accessories:

A six new upcycled products were created from an old trouser for a child and an old man short taking into consideration the elements and principles of fashion design, these products were decorated to give an added value and aesthetic appearance via embroidery stitches, printing, and beads. the products were evaluated via specialists in the textile and clothing fields according to the previously mentioned questionnaire sheet.

3.2.1. Product No. {1}

Fig. (8): Upcycled product No. (1).

Used fabric: 100% woven cotton denim fabric. Textile construction: Twill (3/1), diagonal twill pattern.

Fig. (8): represents a tote bag used for college, club, job, and other external purposes.

The tote bag patches decorated with colored stitches such as (Chain stitch, Herring Bone stitch and Running stitch) white and pink pigment colors were used to give a harmony and attract the eye.

For the ease of opening the bag was decorated with a zipper. A patch pocket was added to the facing to be used for mobile or as a pocket money, finally two hands of the bag that make it easy to hold in the hand or hang it on the shoulder.

3.2.2. Product No. {2}

Fig. (9): Upcycled product No. (2).

The product in fig. (9) represents a slipper for women used in (college, club, …. etc.). the face of the slipper is decorated by some stitches such as Running stitch, Blanket stitch, and Satin stitch, wooden beads added in zigzag lines and decorative embroidery to give an attraction and good transition to the design. This slipper's style is appropriate for summer because the insole is wrapped with denim fabric to keep the foot dry.

3.2.3. Product No. {3}

Fig. (10): Upcycled product No. (3).

Product No. (3) represents a necklace suitable for most trendy clothes. The necklace is decorated by Running stitch in fixing the oval and circle shapes, Blanket stitch around the oval shapes, Crystal beads on the center of the circles, all these decoration techniques give a radial effect, attract the eye, and gives high aesthetic trendy look.

3.2.4. Product No. {4}

Fig. (11): Upcycled product No. (4).

The Product in fig. (11) represents a shoulder bag for girls and women used for schools, jobs, clubs, colleges. The bag is constructed of three pockets (two pockets in the back, and one pocket in the front), also there is one pocket in the facing of the bag gives a functional and aesthetic effect, also a long handle for the bag which facilitate wearing the bag in different positions. The bag is wide enough to carry many things as (books, purposes for baby and picnic items). Running stitch and Zigzag stitch were used for fixing the loops and at the end of the locker belt and the printed belt with obvious contrast mixed colors gives pleasant look. The bag was decorated by some stitches such as Running stitch and Zigzag stitch in the loops, the belt is decorated by printing with contrasted colors which gives a harmony effect to the design also emphasis the movement of the eye up and down through the design, in this design we achieved the principles of the design (harmony- proportion -balance- emphasis - rhythm), and the elements of design (line -shape -texture -color).

3.2.5. Product No. {5}

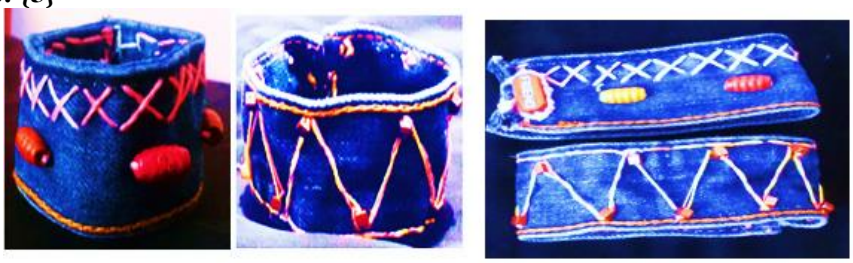

Fig. (12): Upcycled product No. (5).

Product No. (5) represents two cuffs which used as a decoration for the arm, the two cuffs were cut in a symmetrical way and simple locker to facilitate wearing and taking off. The cuffs were decorated with some stitches such as Herring Bone stitch, Chain stitch and Running stitch, also wooden beads and buttons distributed in an equal distance, metal beads in Zigzag lines, the overall colors of the designs give balancing and emphasis effect.

3.2.6. Product No. {6}:

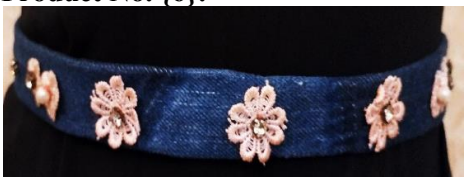

Fig. (13): Upcycled product No. (6).

Product No. (6) represents an earring and a hair band for girls and women. The circle pin used for

installing the earring in the ear is very easy to put and take it off and the hair band is long enough to tie or remove it with ease. The earring was fixed as a rhombus shape with its pin Branch stitch, Chain stitch and Running stitch were applied and pink colors in a circular shape was printed by hand and crystal beads were also added, all that give eye balancing and emphasize design unity. The hair band constructed of four rose shapes made from embroidery threads and fixed on the hair band, also crystal beads were added.

Fig (14): Suggested looks for the performed items.

3.3. Evaluations of the questionnaire and analyzing the results also calculating Six Sigma.

The products were evaluated according to the specialist's opinions and the questionnaire results were analyzed using Q1 Macro 2024 software programs. As the Sigma level increase the Defects that would make a customer reject a product or service decrease. Upper Specification Limit (USL) and Lower Specification Limit (LSL). Specification Limits derived from the customer requirements, and they specify the minimum and maximum acceptable limits of a process. Any data point above the USL and below LSL is termed as defect.

3.3.1. The following table shows the result of the functional, aesthetical, elements, principles, and the upcycling properties of the product No. (1):

Table (4): The aspects values of product (1) according to the questionnaire sheet.

Items	Questions	Percentage
The functional aspect	1-The design suitable the women's age from (15-50) Year.	95
	2-The applied idea achieved satisfied level in design and application.	90
	3- The design is suitable to be a marketable product.	92
	4-the overall acceptability of the aspect.	95
The aesthetic aspect	5-The design shows aesthetic touches.	95
	6- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.	99
	7-Design keeps up fashion recent trends.	96
	8-Overall acceptability of the aspect.	95
Elements and principles of fashion design	9-products fulfill elements and principles of fashion design.	95
Upcycling properties	10-Upcycling used Jeans to recreate sustainable Accessories fashion designs.	92
	11-The fabric used compatible with the thesis idea to achieve sustainability.	94
	12- The added value achieved an attractive design.	95
	13-Designs allowed mobility and movement with different styles of cloth.	95
	14-The materials used succeeded in applying long term trendy accessories.	94
	15- The sustainable fashion was achieved to a certain extent by using available materials.	97
	16- Design will be preferred for women to purchase in any retail store.	93
	17-The colors of the embroidery used are matched with the fabric of the design.	94
	18-Overall acceptability of upcycling denim.	96

According to the specialists the overall acceptability of the functional aspect of product No. (1) recorded a high percent (95%), as the product contains functional tools such as zippers (used for opening and closing the bag), hands (which facilitate the hanging of the bag on shoulder or on the hands), and the pockets (which used as a pocket money), also the bag is suitable for a lot of women ages.The aesthetic aspects overall acceptability recorded 95%which considered a high percent this is due to the suitability of the chosen decorative colored stitches (Chain stitch, Herring Bone stitch and Running stitch), hand printing colors (white and pink colors to the design which gives a harmony, attractiveness, and trendy look to the aesthetic aspect. The elements and principles of fashion design was fulfilled with 95% in the product, also product is following the upcycling concept by 96% and the recreated bag considered a sustainable fashion design with (92%), so the used fabric compatible with the aim of the research.

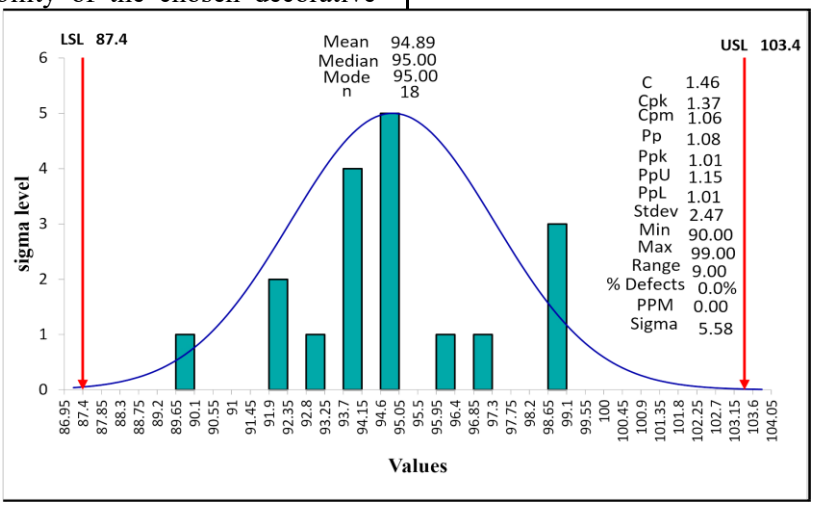

Fig. (15): Histogram of product (1) for calculating Six Sigma.

The above figure shows the statistical analysis of questionnaire sheet of product No. (1). These data were obtained from Q1Macro 2024 Software Program. The Mean, Median, Mode values recorded 94.89 ,95 and 95 which considered a high record.

The difference between the Maximum and Minimum value of the data is 9, this means that all the data of the product No. (1) is in the acceptable range. The Standard deviation recorded 2.47 this means that the data variation is low and product No. (1) achieved the research aim. And the product is suitable to be upcycling product. The two processes capability analysis CP (process capability) and CPK (Process Capability Index) represents how product No. (1) meets the customer expectation and quality standards as all the data are within the range of USL (Upper Specification Limit) (103.4) and LSL (Lower Specification Limit) (87.4). The CP value (1.46), the histogram is in bell curve and the data are meeting the specification limits exactly, no margin for variability or unexpected shifts. The number of defects is low which means this product meets the customer specification.

The CPK value is (1.37). There are shifts with 1.37towards the LSL the minimum acceptable. Value from the customer point of view. CP value is 1.46 while CPK 1.37. The CP measure only the spread of the process while CPK measure both the spread and the cantering of the process mean. The high CP and low CPK indicates that the process is on target and not well centered enough and may lead to some issues in the futures but the process in general is performing well and is not likely to produce any defects unless the elements and principles of the design changed. To improve the process, we need to adjust the process mean and reducing variability CP and CPK should be considered to ensuring the process stability. CP and CPK >1 so, the process is more capable and higher the number the more capable the process is, and the lower the risk of the process drifting and producing defects. The CP and CPK values mean that all the data of the questionnaire lies within the specification limits and centered around the main target of the upcycling and meeting customer expectation and the average output is at the desired level. PPL=1.01which is considered as the distance from the process mean 94.89 to the lower specification limit 87.4. PPU (Process Performance, Upper) =1.15 is the difference between the upper specification limit 103.4 and the process mean 94.89 divided by 3σ. PPK is the smallest value of

PPL and PPU, so it equals 1.01 as PPL. But according to PP (Process Performance) = 1.08, which is like the CP but on the long term.

PPM (part per million): quantifies the defect rate or number of flawed units in service process. No. of defects equal zero so, PPM equals zero also. CPM (Critical Path Management) is the process capability measured against performance to a target. The CPM capability index compares the width of the specification to the spread of the process output plus an error term for how far the center of the distribution is from the target. The value of CPM = 1.08, which is >0 so the process output is normally distributed. Product No. (1) attained Six Sigma at 5.58

sigma. At Six Sigma, this is a good value.

3.3.2. The following table shows the functional, aesthetical, elements, principles, and the upcycling properties of the product No. (2):

Table (5): The aspects values of product (2) according to the questionnaire sheet.

Items	Questions	percentage
The functional aspect	1-The design suitable the women's age from (15-50) Year.	93
	2-The applied idea achieved satisfied level in design and application.	92
	3- The design is suitable to be a marketable product.	92
	4-the overall acceptability of the aspect.	92
The aesthetic aspect	5-The design shows aesthetic touches.	93
	6- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.	93
	7-Design keeps up fashion recent trends.	95
	8-Overall acceptability of the aspect.	95
Elements and principles of fashion design	9-products fulfill elements and principles of fashion design.	93
Upcycling Denim	10-Upcycling used Jeans to recreate sustainable Accessories fashion designs.	90
	11- The fabric used compatible with the thesis idea to achieve sustainability.	89
	12- The added value achieved an attractive design.	94
	13-Designs allowed mobility and movement with different styles of cloth.	92
	14-The materials used succeeded in applying long term trendy accessories.	92
	15- The sustainable fashion was achieved to a certain extent by using available materials.	96
	16- Design will be preferred for women to purchase in any retail store.	93
	17-The colors of the embroidery used are matched with the fabric of the design.	93
	18-Overall acceptability of upcycling denim.	93

According to the specialists the aesthetical aspect ratios recorded 95% and play an important

role in the total overall acceptability of the product. Different stitches were added to the face of the slipper such as Running stitch, Blanket stitch, and Satin stitch, and wooden beads are added in zigzag lines, which giving interest and attracting eyes to whole design and also decorative colored threads used for embroidery over the slipper. According to the functional aspect, this slipper can be worn for women in college, club, and other external purposes. The insole of this slipper was covered with denim fabric to protect the foot from perspiration, so it is recommended to be worn in summer days, all of this help to increase the functional aspect to 92%. As the principles of design (harmony- proportion -balance), also the elements of design (line – shape – color) were achieved in this product with 93% with respect to upcycling technique which showed 93%. And the overall acceptability of this performed product showed 93.25%.

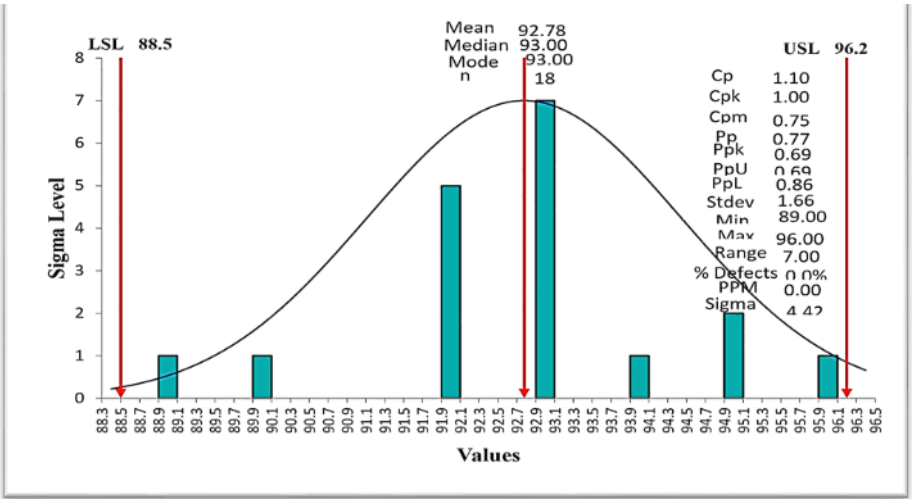

Fig. (16): Histogram of product (2) for calculating Six Sigma.

Fig. (16) represents the statistical analysis of product No. (2), which shows that The mean is 92.78, The median 93 and the value which appear a lot in the result (mode) is 93. Also, the data range is 7 which is the difference between maximum value (96) and minimum value (89). All these results represent a high value which mean that product No. (2) achieved the main aim of this research. The standard deviation recorded 1.66 as the variation amount of the values is so low which mean that all the data are in high value and linked to each other in harmony which will affects the results of all the statistical analysis.

The two processes capability analysis CP (process capability) and CPK affected by the standard deviation and hence the standard deviation is in a high value so, all the data fall within the USL (Upper Specification Limit) (96.2) and LSL (88.5) which means that product No. (2), meet the customer expectation. CPK (Process Capability Index) value is 1.00, there is a shift towards the LSL (Lower Specification Limit) from the customer point of view, The CP is1.10 that mean the data isn't sufficiently centered. To solve the problem of not centering the data we recommend to alter the design components and also lowering the variability to improve the process. To guarantee process stability, The CP should be higher than 1 and CPK value equal 1 as the higher the value, the less possibility of the process drifting and creating faults.

PP (Process Performance) and PPK (Process Performance Index) values measure how close the process is running to its specification limit they are the same as CP and CPK but in long term.

The PPL value is 0.86 the higher value of PPL is considered a good sign that all the customer expectation is achieved in Product No. (2). CPM (Critical Path Management) value is 0.75 which considered less than CPK =1.00 so, there is some drifts and we recommend the design alternation. The overall acceptability and sigma level of Product No. (2) is 4.42and the defects % is zero.

3.3.3. The following table shows the functional, aesthetical, elements, principles, and the upcycling properties of the product No. (3):

Table (6): The aspects values of product (3) according to the questionnaire sheet.

Items	Questions	percentage
The functional aspect	1-The design suitable the women's age from (15-50) Year.	90
	2-The applied idea achieved satisfied level in design and application.	92
	3- The design is suitable to be a marketable product.	94
	4-the overall acceptability of the aspect.	89
The aesthetic aspect	5-The design shows aesthetic touches.	92
	6- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.	94
	7-Design keeps up fashion recent trends.	93
	8-Overall acceptability of the aspect.	94
Elements and principles of fashion design	9-products fulfill elements and principles of fashion design.	93

Items	Questions	percentage
Upcycling Denim	10-Upcycling used Jeans to recreate sustainable Accessories fashion designs.	92
	11- The fabric used compatible with the thesis idea to achieve sustainability.	91
	12- The added value achieved an attractive design.	93
	13-Designs allowed mobility and movement with different styles of cloth.	93
	14-The materials used succeeded in applying long term trendy accessories.	93
	15- The sustainable fashion was achieved to a certain extent by using available materials.	95
	16- Design will be preferred for women to purchase in any retail store.	92
	17-The colors of the embroidery used are matched with the fabric of the design.	96
	18-Overall acceptability of upcycling denim.	93

For the specialist's point of view, the aesthetical aspect recorded 94%. Which gives a high percent to the total overall acceptability of product no (3) because of the usage of different stitches like Running stitch which was used for fixing oval and circle shapes along the necklace and the Blanket stitch around the oval shapes and around the necklace. Crystal beads were added over the circles of pigment all that give central and radial spirit of interest and nice attraction giving high aesthetic aspect leads to reach trendy look. According to the functional aspect, this necklace has a lock that make it easy to wear and take it off, the oval shapes of it help to wrap around the neck easily. which help to increase the functional aspect to 89%. The elements and principles of fashion design were achieved in this product and showed 93% respect to upcycling product which showed 93%. And the overall acceptability of this performed product showed 92.25%.

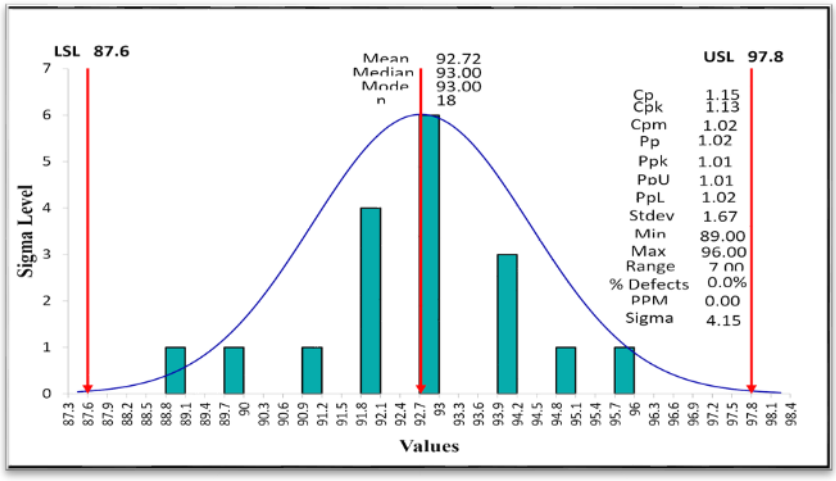

Fig. (17): Histogram of product (3) for calculating Six Sigma.

Fig. (17) shows the statistical analysis of product No. (3). All the data of the mean (92.72), median (93) and mode (93) are in a high frequency. The data range is 7 which is the difference between maximum value (96) and minimum value (89) which means that the design principles and elements and functionality are achieved in design (3). The data standard deviation is 1.67 there is no significant variation in the values. The CP (process capability) and CPK (Process Capability Index), which represent the customer expectation are in a good value, the customer expectation is met by 1.15 in the short term and on the long run CPK of customer expectation is met by 1.13. All the data lies between the USL (Upper Specification Limit) (97.8) and LSL (Lower Specification Limit) (87.6). There is a little shift of the data towards the LSL. The high CP and low CPK mean that the design target isn't sufficiently centered. So, some alternation of the design may be recommended to improve and ensure the process stability. All the data of PPL=1.02 and PPU (Process Performance,

Upper) = 1.01. PPK (Process Performance Index) = 1.01 show that the product No. (3) is capable of achieving the research goal of upcycling. The CPM (Critical Path Management) = (1.02) is considered the same as PPL index. It takes into consideration the variation between the process average and the quantify the success of Six Sigma .The Sigma level is 4.15. The Product No. (3) overall statistical analysis shows good values that meet the customer expectation and if applied in the industrial field. The number of defects in the product will be zero.

3.3.4. The following table shows the functional, aesthetic, elements& principles, and the upcycling properties of the product No. (4):

Table (7): The aspects values of product (4) according to the questionnaire sheet.

Items	Questions	percent age
The functional aspect	1-The design suitable the women's age from (15-50) Year.	96
	2-The applied idea achieved satisfied level in design and application.	95
	3- The design is suitable to be a marketable product.	96
	4-the overall acceptability of the aspect.	97
The aesthetic aspect	5-The design shows aesthetic touches.	95
	6- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.	94
	7-Design keeps up fashion recent trends.	93
	8-Overall acceptability of the aspect.	97
Elements and principles of fashion design	9-products fulfill elements and principles of fashion design.	95
Upcycling Denim	10- Upcycling used Jeans to recreate sustainable Accessories fashion designs.	96
	11- The fabric used compatible with the thesis idea to achieve sustainability.	94
	12- The added value achieved an attractive design.	96
	13-Designs allowed mobility and movement with different styles of cloth.	95
	14-The materials used succeeded in applying long term trendy accessories.	94
	15-The sustainable fashion was achieved to a certain extent by using available materials.	95
	16- Design will be preferred for women to purchase in any retail store.	94
	17-The colors of the embroidery used are matched with the fabric of the design.	97
	18-Overall acceptability of upcycling denim.	97

According to the evaluations of specialists to this product the functional, aesthetical and upcycling aspects recorded 97% which helped this product to be the best one of all products, for the functional aspect, there are four pockets, three in the front and back of bag and one in the facing, all of them can be used as a pocket money or other purposes. It can be used as across bag through the long belt of it, also it is wide enough to carry many things as (books, purposes for baby and picnic items), so the functional aspect showed 97% as mentioned above.

In view of the aesthetical aspect, Running and Zigzag stitches were used for fixing the loops and at the end of the locker belt and the printed belt with obvious contrast mixed colors gives pleasant look. Matching between colored threads of embroidery and colors of printed belt emphasize with eyes move up and down to reach trendy look which give aesthetical aspect with 97 %.

As for the elements (line -shape -texture -color) and principles (harmony- proportion -balance- emphasis - rhythm), of the design were achieved for the product performed with 95% respect to upcycling technique which showed 97%. And the overall acceptability of this performed product showed 96.5%.

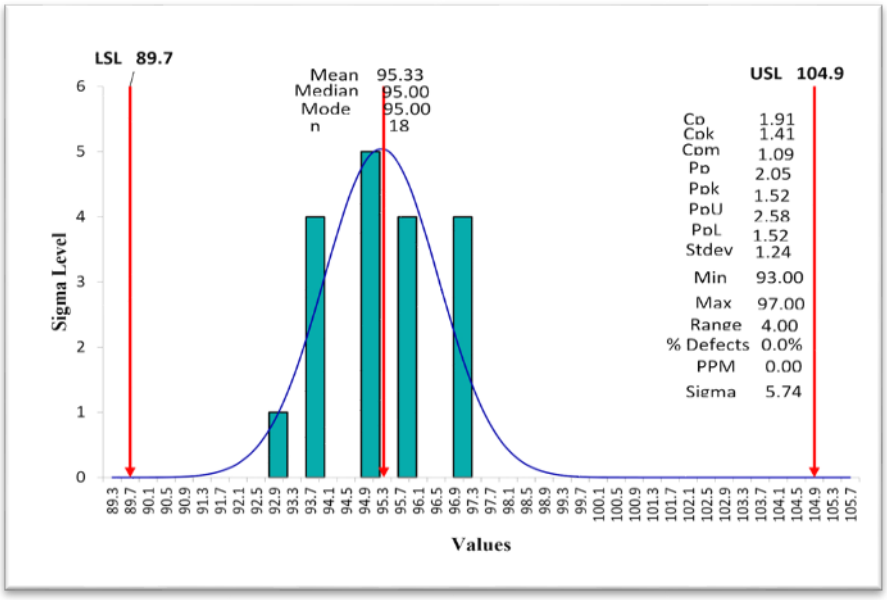

Fig. (18): Histogram of product (4) for calculating Six Sigma.

Fig. (18) represents the questionnaire values of the product No. (4). And the values show that arithmetic average of the data is 95.33, the middle value of the data is 95.00 and the highest frequency of the values (mode) is 95.00. All the mean, median and mode values show high values according to the specialist opinion. There are no notable differences in the data range which recorded 4, all the properties of the data are in a good range as the maximum data

Value 97 and the minimum data value 93. The lower number of standard deviation between the process average and the acceptable process limits is 1.24 which indicates that the product met the goal of the research and cause little defect as the percentage of defects is zero so, the design no. (4) is a perfect choice to be upcycled product.

All the data of the questionnaire falls between the USL (Upper Specification Limit)(104.9) and LSL (Lower Specification Limit)(89.7), and the ratio of the spread between the process specification and the six times process standard deviation in short terms is 1.41, which measure the customer requirements, according to the CP (process capability) value the customer requirements are fulfilled in product (4) and the CPK (Process Capability Index) which consider the centering of the process is 1.41 also confirm that the product meet the customer specification. The CP and CPK values which represent the process capability indices shows that product No. (4) capable to produce the required output within the specific limits. The over able capability of the process is 2.05 (PP), the values of PP (Process Performance) indicate the process are more capable. It is similar to CP, but it uses long term standard deviation. The PP and PPK (Process Performance Index) are the process performance and capability over long period of time. The difference between CPK (1.41) and PPK (1.52) shows a little value (0.11) which mean the process is stable and PPK >1.41 which mean that there is no shifts or drifts over time. The PPL value (1.52) and PPU (Process Performance, Upper) value (2.58) which measure the overall capability of the process the high value of PPL and PPU indicates that the process is capable to meet customer specification. The process capability index (CPM) 1.09 of the design No. (4) is less than CPK which considered as a shift from the target value.so, the design need more improvement but in general the design meet the customer specification and sigma level is 5.74. Product No. (4) achieve the goal of 6 sigma concept, and meet the customer specification.

3.3.5. The following table shows the functional, aesthetic, elements& principles, and the upcycling properties of the product No. (5):

Table (8): The aspects values of product (5) according to the questionnaire sheet

Items	Questions	percentage
The functional aspect	1-The design suitable the women's age from (15-50) Year.	92
	2-The applied idea achieved satisfied level in design and application.	93
	3- The design is suitable to be a marketable product.	94
	4-the overall acceptability of the aspect.	94
The aesthetic aspect	5-The design shows aesthetic touches.	96
	6- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.	95

Items	Questions	percentage
	7-Design keeps up fashion recent trends.	93
	8-Overall acceptability of the aspect.	95
Elements and principles of fashion design	9-products fulfill elements and principles of fashion design.	94
Upcycling Denim	10- Upcycling used Jeans to recreate sustainable Accessories fashion designs.	90
	11- The fabric used compatible with the thesis idea to achieve sustainability.	94
	12- The added value achieved an attractive design.	89
	13-Designs allowed mobility and movement with different styles of cloth.	92
	14-The materials used succeeded in applying long term trendy accessories.	93
	15- The sustainable fashion was achieved to a certain extent by using available materials.	92
	16- Design will be preferred for women to purchase in any retail store.	92
	17-The colors of the embroidery used are matched with the fabric of the design.	87
	18-Overall acceptability of upcycling denim.	93

Table (8) shows the result of questionnaire evaluation of design (5), the aesthetical aspect ratios recorded 95% which played an important role in the total overall acceptability of product no (5) because of the usage of Herring Bone stitch and colored wooden beads that were added on equal distances and a wooden button was used as a lock for the first cuff. And for the second cuff two embroidery stitches were added (Chain stitch and Running stitch), After that metal beads were added with zigzag shape along the second cuff, all these colors give eye balancing and emphasize design unity.

While the functional aspect of this product recorded 94%, in which the two cuffs were designed with symmetrical simple cuts and simple lock for each cuff to be easy to wear and take off.

All the elements of design such as (line – shape- color- texture) and the principles of design such as (harmony- emphasis- rhythm- proportion- balance) recorded 94% respect to upcycling technique which showed 93% And the overall acceptability of this performed product showed 94%.

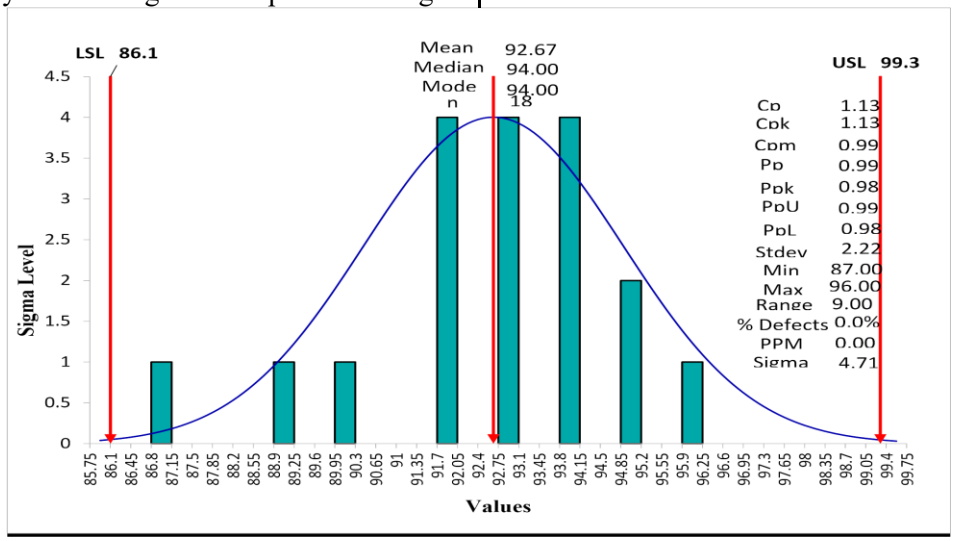

Fig. (19): Histogram of product (5) for calculating Six Sigma.

Fig. (19) shows the result of questionnaire sheet of product No. (5). The Mean, Median, Mode values are 92.67 ,94.00 and 94.00 respectively shows high value as the mode of the value is 94.00 which is the highest frequency data.

The data range is (9) all the data in acceptable range as the maximum value is 96 and the minimum value is 87 which mean there is no significant difference on the data range.

The standard deviation is (2.22), the variation

between the data is so little as the product meet the research aim of being suitable to be upcycling product.

All the data falls between the USL (Upper Specification Limit) (99.3) and LSL (Lower Specification Limit) (86.1), and the CP (process capability) and CPK (Process Capability Index) are equally 1.13, so the product No. (5) meet customer expectation and quality standards in short term.

Also, in long term the values PP (Process Performance) and PPK (Process Performance Index) are 0.99 and 0.98 equally to some extent this mean that product No. (5) will meet the customer expectation over long period.

The CPK is 1.13 this means that all the data are cantering between the USL and LSL.

The PPU (Process Performance, Upper), PP and CPM are equally 0.99, while PPL and PPK are equally 0.98. All these values mean that product No. (5) meet customer satisfaction and expectation and will continue over a period of time. The number of defective units PPM (part per million) is zero. This means that design No. (5) meets the target performance and the sigma level of product No. (5) is 4.71in an acceptable value.

3.3.6. The following table shows the functional, aesthetic, elements& principles, and the upcycling properties of the product No. (6):

Table (9): The aspects values of product (6) according to the questionnaire sheet.

Items	Questions	percentage
The functional aspect	1-The design suitable the women's age from (15-50) Year.	92
	2-The applied idea achieved satisfied level in design and application.	93
	3- The design is suitable to be a marketable product.	93
	4-the overall acceptability of the aspect.	93
The aesthetic aspect	5-The design shows aesthetic touches.	93
	6- The chosen technical (trimming-loops-embroidery stitches- colored threads) added an aesthetic dimension helped to produce trendy design.	95
	7-Design keeps up fashion recent trends.	92
	8-Overall acceptability of the aspect.	95
Elements and principles of fashion design	9-products fulfill elements and principles of fashion design.	91
Upcycling Denim	10-Upcycling used Jeans to recreate sustainable Accessories fashion designs.	91
	11-The fabric used compatible with the thesis idea to achieve sustainability.	94
	12- The added value achieved an attractive design.	90
	13-Designs allowed mobility and movement with different styles of cloth.	94
	14-The materials used succeeded in applying long term trendy accessories.	87
	15- The sustainable fashion was achieved to a certain extent by using available materials.	93
	16- Design will be preferred for women to purchase in any retail store.	92
	17-The colors of the embroidery used are matched with the fabric of the design.	94
	18-Overall acceptability of upcycling denim.	92

According to the evaluations of specialists to this product, the aesthetical aspect recorded 95%that raised the overall acceptability of that product, as the earring was fixed as a rhombus shape with its pin Branch stitch, Chain stitch and Running stitch were applied and pink colors in a circular shape was printed by hand and crystal beads were also added, all that give eye balancing and emphasize design unity. And the functional aspect recorded 93%, because of using circle pins for wearing the earring that make it very easy to put and take off also the hair band is long enough to tie or remove it with ease.

As for the elements (color- line -shape-texture) and principles (proportion – rhythm-balance-emphasis) of the fashion design were achieved and recorded 91% respect to upcycling technique which showed 92%. And the overall acceptability of this performed product showed 92.75%.

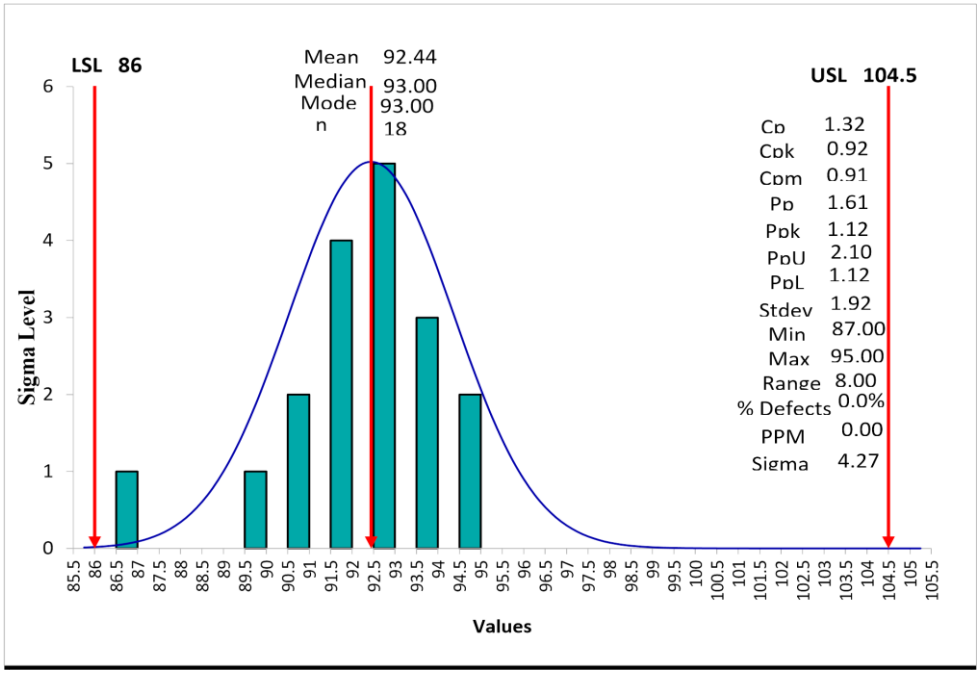

Fig. (20): Histogram of product (6) for calculating Six sigma.

Fig. (20) shows the histogram results of the questionnaire sheet after the Q1 Macro 2024 analysis. The mean (92.44), median (93) and mode (93) these data recorded relatively high result. The data analysis show that the data minimum value 87 and maximum data 95with 8 range difference. The standard deviation recorded 1.92. The variation amount between the data is considered very low and this is a good sign of the agreement of the specialist opinions. All the data fall between the LSL (Lower Specification Limit) (86) and USL (Upper Specification Limit) (104.5). All the data are concentrated from 86 to 99 in the histogram. The CP (process capability) and CPK (Process Capability Index) shows the customer satisfaction and their expectation on the product quality. The CP value is 1.32 and CPK value 0.92. The low value indicates that there is low shift in the process capability and the product No. (6) meet the customer satisfaction.

The CPK value measure the spread and centering of the data process mean. While CP measure the spread only. There is a little shift towards the LSL value. This slight shift causes the shifting of the bell shape of the figure to overcome the problem of shifting we suggested to modify the process mean and lower variability of the design. In spite this shift the data of the questionnaire is meeting the customer satisfaction and focused on the goal of upcycling.

The PPL, PPU (Process Performance, Upper) and PP (Process Performance) recorded 1.12 ,2.10, and 1.61. It indicates that all these data on the long run will also meet the customer satisfaction.

The PPM (part per million) measure the Number of defective which recorded zero. The CPM (Critical Path Management) capability index is considered as the distance between the target and the center of the distributions recorded 0.92. It means that the process output is regularly distributed.

The product No. (6) recorded in sigma level 4.27. It is a very good sigma level and meet customer satisfactions.

Table (10): The Overall Acceptability of the products

	Product 1	Product 2	Product 3	Product 4	Product 5	Product6
CP	1.46	1.1	1.15	1.91	1.13	1.32
CPK	1.37	1	1.13	1.41	1.13	0.92
CPM	1.06	0.75	1.02	1.09	0.99	0.91
PP	1.08	0.77	1.02	2.05	0.99	1.61
PPK	1.01	0.69	1.01	1.52	0.98	1.12
PPU	1.15	0.69	1.01	2.58	0.99	2.1
Standard Deviation	2.47	1.66	1.67	1.24	2.22	1.92
Sigma Level	5.58	4.42	4.15	5.74	4.71	4.27

The product No. (4) ranked the best product as it recorded 1.91 in the CP (process capability) (on the short life term), that means the process is capable and meets the customer satisfaction. And the CPK (Process Capability Index) recorded 1.41 which consider the process is well centered, and that value confirm that the product meets the customer specification. The PP (Process Performance) value

is 2.05 which consider a high value, and that indicates a more capable process. The PPK (Process Performance Index) which is an index for process capability and used for long-term variation recorded 1.52.

CPK < PPK and that means the process is stable and is running to its specification limits. PPU (Process Performance, Upper) value (2.58) which measure the overall capability of the process. This value is high, which indicates that the process is capable to meet customer specification. The CPM (Critical Path Management) recorded 1.09which means the design meets the customer specification.

The lower number of standard deviation between the process average and the acceptable process limits is 1.24 which indicates that the product met the goal of the research and cause little defect as the percentage of defects is zero and sigma level is 5.74. so Product No. (4) is a perfect choice to be upcycled product, achieved the goal of 6 sigma concept, and meet the customer specification.

Conclusion:

The aim of this research is to upcycle wastes denim fabrics via redesign strategies to create a new trendy wearable accessory, evaluated with Six Sigma analysis focusing on customer satisfaction and problem solving. Six designs were created from an old jeans' trousers and short. The six new redesigned products were evaluated via questionnaire sheet according to the opinion of specialists in textile and clothing field, also the data obtained was analyzed via Q1Macro 2024 software. All the six products achieved the aim of this research from the point of view of Visual Appearance, Manufacturability and Sustainability. The product No. (4) which represents a multipurpose shoulder bag for girls and women is considered the best ranked product as it is the first rank with sigma level (5.74) which meets customer satisfaction and acceptability, Product No. (1) comes in the second rank and also meets the customer satisfaction with sigma level 5.58. Product No. (5) recorded 4.71sigma level in the third rank. Product No. (2) recorded 4.42 ranking in the fourth level, while product No. (6) with sigma level 4.27 and product No. (3) recorded 4.15 in the fifth and sixth ranking position respectively. Overall, all the six products having good ranking meet the customer satisfaction acceptability, i.e. all the products fulfill the goal of the work with different ranks of Six Sigma.

It is recommended to apply the upcycling technique of waste products as it is more valuable than getting rid of these wastes, which is considered a feasible, an ecological, economically and money saving way.

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