The use of 3D printers in fashion design for different models and sizes

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Abstract

Purpose

In this research, it is aimed to make modular skirt designs gaining a new model by letting out-taking in the dress size. Moreover, it is also aimed to draw attention to the diverse use of new technologies in fashion design in terms of 3D printer technology that is used in production, alteration and assembly of modules, and in terms of the opinions that are elaborated on this subject.

Design/methodology/approach

In this study, skirt, whose 3D modules obtained from 3D printer, has been chosen as the type of clothing for the experiments to design clothes that can be altered according to different body shapes and models. The experimental development method has been used in designing of skirt models.

Findings

The overall objective of the research is to create modular skirt designs whose modules can be produced with 3D printer technology and whose sizes and models can change according to different body shapes. In that direction, this study embraced a modular design approach which is one of the mass customization methods. Moreover, model features that are compatible to change has been tried and determined, patterns have been prepared accordingly and design and application tests conducted aiming to find out the material and the method to montage modules with clothings.

Originality/value

This study includes an innovative approach for users during the period of using the clothing. This approach enables users to renew only certain modules of their clothing using 3D printers in accordance with trends as well as design and dimensioning features they would prefer. The study not only includes sample skirt designs consisting of modules with changeable sizes and models but also focuses on the possible features of these modules by virtue of today's 3D printer's equipment and texture technologies.

Keywords

Modular design, mass customization, sustainability, fashion design, 3D printers

Article Classification

Research Paper

ISBN: 978-989-20-7053-7

INTRODUCTION

The Earth has been damaged considerably by unfortunate factors such as rapidly developing industrial capacity, unbalanced population growth, senseless consumption of natural resources, environmental pollution and adverse effects of global warming. It is not hard to see the big picture when the first photograph of the Earth taken from the space in 1966 and its current image is compared. In the last three decades one third of the natural resources is consumed, 80% of the forests are destroyed, therefore, average seasonal temperatures have been increasing rapidly (Turhan, 2011). Thus, environmentally-friendly raw materials and green production methods are gaining importance in the ecological production process (İşmal and Yıldırım, 2012). Subject to continuous change and focusing on fast moving products, fashion and textile industry is one of the leading industries in terms of its harm to the environment in manufacturing operations. More than 20,000 liters of water is used for one kilogram of cotton which is used to produce one t-shirt or a jean, while approximately 8,000 chemicals are used to turn raw materials into textile products including the processes such as finishing (FashionRevolutionTurkey, 2015). New concepts and methods focusing on the reduction of the harm to the environment resulting from the operations of the fashion industry were developed as it was the case for other industries especially in the last quarter of the 20th century. “Sustainability”, “Ethical Fashion”, “Green Fashion”, “Eco-Fashion”, and “Organic Fashion” are among the examples of these concepts. On the other hand, different methods must be used in order to be able to adopt these concepts. Although, new consumer-oriented manufacturing methods may seem as a factor increasing the sales volume, they also contribute to the sustainability in terms of improved product lifecycle, therefore, protection of the environment. So, the concept of mass customization, a customer-oriented approach, comes forth as one of the ecology-oriented approaches for the fashion design field.

The concept of mass customization was first used in the book “Future Perfect” by Stan Davis published in 1987 and was described as “mass production where a number of similar products are manufactured and individual production where each product is customized for the consumer” (Pine and Gilmore, 2011). Piller, on the other hand, describes mass customization as “alterations in the product or service features in accordance with the demands and needs of the customer” (Piller, 2007). Developed based on the demands and expectations of the customers, the mass customization method offers competitive advantage in the global market while reinforcing the customer’s perception of value chain about the customized product. Within the mass customization approach, consumers are considered not only as a group of people with purchasing power but also a mechanism which has a say in processes from product development to its production and even its recycling. Thus, an inherent bond is built between the consumers and the products they consume or use. Research showed that consumers regard products customized in accordance with their demand as more special and valuable products (Franke and Piller, 2004). This kind of a customer perception leads to improved product life cycle and reduced need for purchasing a new product. Particularly based on consumer perception, the fashion industry places importance on this result due to the challenges available in raw material provision, although any effort to eliminate the need to purchase a new product is contrary to the nature of fashion industry. Nevertheless, Franke & Piller (2004) reported that consumers agree to pay more for individualized products. This is an indicator of both nature and manufacturer benefit from mass customization.

Looking into the recent efforts done in terms of mass customization in manufacturing industry, successful examples of mass customization practices are available in industries such as housing, shoemaking, printed products, convenience food and fresh food and especially IT and textiles (Yuluğkural, 2009). Currently, there are several strategies for mass customization practices. Yuluğkural (2009) sorts and explains the mass customization strategies available in the literature, as follows:

1) Lampel & Mintzberg Model: This study addresses manufacturing methods under two categories, namely, customization and standardization, which are further grouped under 5 categories, namely, “pure standardization”, “fragmented standardization”, “individualized standardization”, “tailored customization” and “pure customization” according to the combined or separate use of these two methods.

2) Gilmore & Pine Model: Gilmore & Pine suggests four approaches for customization, namely, “collaborative”, “adaptive”, “aesthetic”, and “transparent”. Collaborative customization involves the highest level of customization while transparent customization involves the lowest level of customization.

3) Amaro Model: Amaro et al. developed a model in order to categorize firms operating without keeping stocks and to explore the role of customization in creating competitive advantage. This study grouped customization for firms operating without keeping stocks under “assembly upon order”, “production upon order”, and “engineering upon order”.

4) Duray Model: Duray et al. categorized mass customization in terms of consumer inclusivity and modularity. This categorization suggests that it is not possible to achieve the “mass” feature of mass customization without modularity. This study involves four groups, namely, “fabricators”, “involvers”, “modularizers”, and “assemblers”.

5) Alford Model: The Mass Customization Practice Strategy suggested by Alford et al. addresses customization in three categories, namely, “form customization”, “optional customization” and “core customization” according to customization’s involvement in the value chain in design, production and distribution stages.

All the above-mentioned strategies suggested different categories for customization, however, modularity comes forth as an important customization method (Soyuer, 2005). It was emphasized that the use of modules is a convenient solution for customized product manufacturing as it makes it possible to mass-produce customized products, to shorten manufacturing process, to reduce manufacturing costs and to increase the diversity. Yuluğkural (2009) stated that modularity is the most important feature of mass customization which makes the term ‘mass’ meaningful and that modularly manufactured components meets the demands and expectations. Sievanen (2002) claims that modularity is the key feature for advantages involved in volume such as low costs and that modularity is the most commonly used customization method. Bardakçı (2004) describes modularity as “a method which allows for assembly of the product at the point of sales according to the demands and needs of the consumer which also offers the opportunity to address the changing demands and needs of the consumer with its replaceable modules”. Having addressed modularity from a customer-oriented perspective, Blecker et al. (2005) claims that modularity reduces the need for different products as it allows customers to customize, maintain, repair and upgrade the product.

Pine (1993) offers six methods to modularize a product. These are "component sharing modularity", " component swapping modularity", "cut-to-fit modularity", "bus modularity", "sectional modularity" and "mix modularity" Modular systems available in Pine’s categorization are described and illustrated, as follows;

Component Sharing Modularity: This is the production type in which the same component can be used in more than one products. Different products are designed with the same shape and volume necessary to accommodate the shared component. Example: Battery, cassette, CD-ROM, Disc, etc.

Designed by Italian designer Eugenia Morpurgo, AnOtherShoe (Figure 1) is a product complying with the component sharing principles being equipped with a feature which allows for the foot-bed to be changed, as necessary.

Figure 1: Eugenia Morpurgo, AnOtherShoe

Component Swapping Modularity: In this method, components are assembled in order to complete a product. The number of different products which can be made is as much as the number of components being used. Selling children’s books, Create-A-Book stores the books sold on electronic environment and restructures the story in the book with the customer’s info (name, surname, date of birth, etc.) and then prints and binds the customized copy and delivers it to the customer. Here, the variable component is the personal information of the customer.

Designed by Italian designer Flavia La Rocca (Figure 2) and making it possible for users to change the model of their cloths in the course of the day using modules, the collection is a remarkable example of the component sharing modularity concept in fashion design.

Figure 2: Flavia La Rocca

Cut-to-Fit Modularity: This method is based on the idea of styling the component with the desired size before its assembly to the other component. It allows for minimal processing before the use of the product according to varying needs. Example: customized eyeglass temples, etc.

Customized (Made to Masure) textile products are one of the essentials of the cut-to-fit modularity concept. Especially the LOT NO.1 by Levi’s allows for different models with 20 different color, 12 leather patch, and 7 button options while making it possible to customize the size of the product (Figure 3).

Figure 3: Levi's LOT NO.1

Bus Modularity: This is a modular structure which involves a fixed base and modular components to be installed to this base in combinations. Stage lighting equipment which allow for different number and type of luminaires to be mounted on are among the examples of this system.

Developed by ThreadLab, the men's shirt series is a suitable example for the bus modularity concept (Figure 4). Allowing for its users to attach collars, cuffs, and pockets on the shirt base without the need for seams, this design is also the first DIY clothing design for men.

Figure 4: TreadLab Shirt

Sectional Modularity: This system provides products for different purposes with combinations of similar or the same components. Example: Lego® products, picket fences and sectional sofas, etc.

Developed by Eunsuk Hur and formed with the use of similar modules in line with the user’s preferences, Transformative Design project is one of the examples of textile design with sectional modularity (Figure 5).

Figure 5: Eunsuk Hur, Transformative Design

Mix Modularity: Allows for a mixture of different modules. The products takes the shape of the final product attached and all the attachments may lose their form. Decorative paints which allows the consumer to find the right color blending a number of colors are good examples of this approach.

Mass customization efforts are gradually increasing in the clothing industry. Global brands such as Nike ID, Adidas, Levi's, Brook Brothers, Burberry, Longchamp, Converse, Vans, etc. are now offering the opportunity to their customers to create the product they need in stores or through their websites. Bain&Company (2013), one of the world’s leading market research company, in its research on the consumer’s tendencies to use mass customization for fashion products and their perception of the concept, show that 10% of the consumers already use customized products while another 30% is willing to use such products. Data obtained from this study reveals the potential for mass customization practices to be recognized by the consumers.

Pine (1993) stated that customization in clothing industry will make a difference and offered the fact that body sizes change irregularly among individuals as a reason for this. It was underlined that customization practices in the clothing products are based on the cut-to-fit modularity principle and that companies which are able to apply a quick response system will obtain the competitive advantage. As noted by Pine, difference in individuals' body size is an important factor for customization in clothing design. Size changes depending on the body structure. The research results showing that designs manufactured with standard body sizes are not efficiently serving for the masses increases the importance of and reveals the need for designing modular cloths which can be altered according to different body sizes.

Today, brands and designers are developing innovative strategies and products along with mass customization practices in order to obtain competitive advantage. Among these practices, additive production technologies have been gaining ground in the recent years. Started with the textile industry in the UK in the 18th century, the 1st Industrial Revolution transformed into the 2nd Industrial Revolution with the moving assembly line developed by Henry Ford in the early 20th century. Today, we are talking about a 3rd industrial revolution with the introduction of digital production (3D production, additive production) (The Economist, 2013). However, this method is not yet a competitor to the subtractive manufacturing which is dominant in the industry, additive or additive manufacturing is gaining new areas use in several industries every other day. Additive manufacturing adopts the 3D printing method in order to turn a number of materials into fully functional and durable objects using engineering files. As soon as a layer is attached to the previous one using heat or chemicals, another layer is added and the process is repeated. Involving attachment of each layer together to produce the geometrical shape defined with a 3D CAD model perfectly, this technology makes it possible to manufacture highly complex components without the use of any cutting device or fixtures and without producing waste materials (Kara, 2013).

Many innovations are made in additive production since the very first study conducted by Chuck Hull in 1984. 3D printers have been used commonly in fields such as health, dentistry, automotive, architecture, etc., especially since the beginning of the 21st century. Due to its rather high cost and insufficient material options, 3D printers are commonly used by designers and engineers to manufacture prototypes and gained attention for end product manufacturing when plastics and metal materials started to be used as input materials.

New developments are abound in 3D printer, a.k.a. additive manufacturing technology. Research by Terry Wohlers shows that the preference of 3D printers in the end product manufacturing will hike up to 50% by 2020 from a reference point of 20% in 2011 (The Economist, 2011). Barnatt (2013) conducted studies on estimations for the future of the 3D printing adaptation and its usage and suggested that the technology will account for 20% of the individual manufacturing by 2040 (Figure 6). This translates into consumers will manufacture their own products which will lead to reduced need for manufacturers.

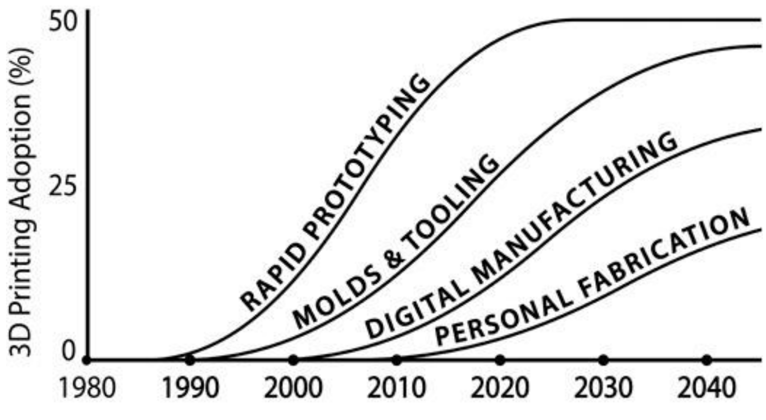


Figure 6: 3D Printing Market Segments Adoption Curves by Barnatt

Berman’s (2012) predictions in his study, “3-D printing: The new Industrial Revolution” for the future of this technology are as follows;

"A major advantage of 3-D printing is the separation of product design from manufacturing capabilities. Since design and manufacturing can be easily outsourced in 3-D printing, designers can contract with firms such as Shapeways to produce, ship, and collect proceeds for goods based on their designs. Alternatively, a consumer can download a CAD software design for a replacement part online—–as easily as he/she would download digital music and then download and print the part on his/her 3-D printer."

The number of fashion products manufactured using 3D printers has also been increasing in the recent years. Designs manufactured using 3D printers are now commonly available in the collections of designers and brands which participate world’s leading fashion weeks such as Paris, London, New York, and Milano fashion week. Pioneered by famous designers such as Iris van Herpen, Janne Kyttanen, Danit Peleg, Michael Smith, and Francis Bitonti, this technology-based approach will certainly gain ground every other day. Nevertheless, the “3D Fashion Show” held as part of the “3D Print Week” in New York reveals the position of 3D printers in the fashion industry.

Today, cloths and accessories manufactured using 3D printers are most commonly dysfunctional and aim to attract attention. These designs are not addressing the needs of urban population which lives a dynamic life and makes clothing decisions accordingly, and they offer a minimum level of wearability and purchasability being unsuitable for their lifestyle and norms. This is not complying with the nature of fashion design which is built on motivation for consumption, however, it is associated with the concept of design based on problem solving. Furthermore, disadvantages such as time required for production and costs limits the possibility for mass production of designs to be manufactured using 3D printers. Therefore, designs in question are more often couture dresses.

Figure 7: Design by Iris Van Herpen

Figure 8: Design by Alexis Walsh

Whether the idea of desktop devices turning into daily textile product manufacturing stations may sound a bit science fiction, there are promising studies conducted recently. However, it was not yet possible to manufacture surfaces with fabric features using only 3D printers, it does not seem to take that long to achieve this goal. Almost every day a new development is published regarding the field-specific material technologies and considerable investments are made to this end.

Although, it is not possible to manufacture fabrics suitable for sewing using 3D printers today, the recent achievements in printing with textile products are important developments to close this gap. Having been studying on surfaces combining 3D printer technology and the materials used with textile products, Laura McPherson and Mark Beecroft are taking considerable steps to manufacture cloths we can wear in our daily life. Having used woven fabrics and 3D printers in combination, researchers stated that their aim is to bring about new approaches with the use of old and new technologies together (Figure 9).

Figure 9: Design by Laura McPherson & Mark Beecroft

Another example of the combined use of textiles and 3D printed texts is the Fabricate project developed by Cube. In this project fabric is used as a base surface and 3D printer prints the output on this surface. After this process the fabric is used in a cloth or used as an accessory (Figure 10).

Figure 10: Design by Cube

Based in Israel, Danit Peleg is another researcher who works towards adapting the 3D printer technology to regular wear. Having designed a collection of 5 pieces manufactured using a specialized material called FilaFflex, the artists created dresses looking like lacework manually attaching each output of A4 paper size together. The most remarkable feature of these designs is that the dress gives the impression of fabric with the movements of the user (Figure 11).

Figure 11 : Design by Danit Peleg

Despite the advantages it has to offer, manufacturers most commonly use 3D printers as a device to manufacture prototypes instead of using it for the end-product. Yılmaz et al. (2014) suggests the present reasons behind it, as follows;

a) Slow operation when compared to mass production,

b) Undependable quality and lack of standardization,

c) Difficulties in manufacturing specific complex structures.

Above all, the process is even slower when it comes to products with many details. For example, manufacturing a product with the size of a baseball and with smooth lines may take between 6 to 8 hours. Naturally, manufacturing thousands of this product will take years. However, the technology advances very fast and remarkably. Ability to manufacture tens of products simultaneously using the same device, superior product quality available in 3D printing (better than casting and similar to forging) and other reasons reinforce the 3D printing option for the end-product (Yılmaz et al., 2014).

The usage of modularity was also explored for this field following the research into the feasibility of 3D printing in fashion design. Literature review shows that studies on modular clothing so far focused on multi-functionality. As reported by Halaçeli (2013), examples of modular clothing may include transformation of a skirt into a blouse; and a hat, manufactured by Chinese fashion house JNBY (Figure 12) to a bag. Although modules are altered structurally and functionally in the aforementioned designs, these are fully suitable for the modularity definition suggested by Pine.

Figure 12: Transformative apparel design by JNBY

Figure 13 : Design by Belassus

Based on addition or reduction of a module, cloths such as the one designed by Belassus (Figure 13) most commonly focus on the change in model. It was also found that studies on module change which allows for increased or decreased size are considerably limited and far from being aesthetical. Maybe the best example of these studies is the "Suit Your Self" by Kathleen Michelle Dombek-Keith (Figure 14) In this study, the size change is made possible with zippers and button available on the waist line rather than modules. Modularity, on the other hand, only makes it possible for model change. Literature review did not give any results for a study on size or model change with the addition or reduction of a module which was printed using 3D printer.

Figure 14 : "Suit Your Self" by Kathleen Michelle Dombek-Keith

We are observing that integral aspects of life, economic structure and therefore the social structure, are going through a process of change due to the substantial impact of globalization. From lifestyle to values; from behaviors to individual roles, many social aspects are being reshaped in the postmodern society. As similar interests, desires and preferences are greatest and most prominent components of interaction, the role consumers play in this new setting has also changed significantly. In this process, passive consumer profile is leaving its place to an active consumer profile which has the desire and power to dominate the market. The change in the consumer profile and consumer expectations gave rise to a challenging competitive environment. According to Porter (1985), long-term success depends on the sustainable competitive advantage and low costs, product differentiation, and focus are the keys of success. However, it is not possible to apply these three strategies and to achieve success at the same time. The reason behind this is the additional costs resulting from product differentiation. Furthermore, focusing or entering the niche market also increase the costs. Pine & Gilmore (2011) suggest that it is possible to achieve mass customization and the targets of product differentiation and low cost at the same time. With this information in mind, one can say that success is possible through mass customization in this competitive environment.

The purpose of mass customization is to maintain an efficiency close to mass production thanks to the scale economy while delivering for different consumer needs. Mass customization has a favorable impact on the consumer behaviors and preferences. Nevertheless, Merle, et al. (2010), Franke, et al. (2010) and Bharadwaj, et al. (2009) found that the use of customized products increases the confidence of consumers in their personal preferences (Forgliatto, et al. 2012).The positive approach observed in consumers towards mass customization was one of the reasons behind the selection of this research topic.

Pine (1993) defined the existence of a parameter for clothing products which is varied depending on the body size along with components such as color and form which are also available in other industries as a distinctive feature. In this context, customization in clothing industry will provide an important competitive advantage. The term, “tailored”, is used in customization terminology and is also a common term for the clothing industry. However, in clothing industry, this term may define “made-to-measure (M-T-M)” cloths which are manufactured according to the customer preferences such as fabric color, fabric properties, accessories, etc. along with customer’s body size and customer’s demands. In mass customization, on the other hand, customer is asked to participate in the process and it has a wider perspective which involves product diversity, custom-made products, processes and services and the use of technological innovations and industrial possibilities (Vuruşkan, 2010).

When customized production and ready to wear production is compared, it can be seen that many consumers have problems with the right fit for their body. Yeşilpınar & Bulgun (2007) explored the clothing types and cloth sections which proved most problematic for Turkish women of ages between 25 and 55, and reported that only 9.2% of the participants did not experiencing size/fit problems while the remaining majority of 90.8% did. It is believed that customization efforts in clothing focusing on body size will help eliminate the size/fit problems consumer experiences. In this context, this study identified the properties of modular designs which will allow for changes in the cloth size and communicated designs meeting these qualities. Nevertheless, modules aim to make it possible for size change along with model change.

Mass customization involves production of a unique product or service for each customer. For this purpose, it is required to identify and record personal preferences and demands of each customer for the duration of the manufacturing process. Otherwise, the customization process will add up to insignificant gravity. Nevertheless, consumer's readiness for customization is another aspect to be taken heed of. Therefore, this study considered the results reported in "A Study on the Responsivity of the Consumers to the Customized Ready-Made Clothing Products" by Atrek & Bayramoğlu (2008). The aforementioned research showed that gender plays an important role in responsivity and that women have a higher responsivity to customized ready-made clothing products when compared to men. The findings led to the conclusion that addressing the women's wear is more important and the research was conducted accordingly. The same research reported that the most commonly expected features from a ready-made clothing product are "size" and "color" and their consistency with customer demands and needs. In this context, it is believed that designing modular cloths allowing not only size change but also for model and color change will considerably meet the consumer expectations. The study conducted by Dombek Keith (2008), "Re-Fashioning the Future Eco-Friendly Apparel Design", offers another indicator of the validity of these results as "Suit Your Self", a project which involves clothing products offering users the chance to change the size and the model, was the selection of the participants among the five projects conducted in order to protect the environment.

One of the most important factors for increased competitive advantage defined by Porter (1985), the "differentiation" principle follows a developmental trend which parallels with innovation and inventiveness. Investigating the potential of the clothing industry for product and technology development is important in order to be able to understand the advancements in innovation and inventiveness (Som, 2010).

For a designer to be succeed, he or she ought not only to respond to users' expectations, but also to keep up with the latest developments in technology as well, and to apply successfully those novelties within the bounds of possibility. One of the most important results of the rapid changes in technology that occurred, especially in the last quarter of the century is 3D printer. Application of 3D printer, which is called the third industrial revolution, is becoming widespread in the fashion industry along with many other industries. In the fashion runways held in the world's leading fashion weeks, it is now quite likely to encounter with garments produced by 3D printer.

In this research, it is aimed to make modular skirt designs gaining a new model by letting out-taking in the dress size. Thanks to their user-oriented structure, improved designs are considered within the scope of the mass customization that has been occurring in the field of design. Moreover, it is also aimed to draw attention to the diverse use of new technologies in fashion design in terms of 3D printer technology that is used in production, alteration and assembly of modules, and in terms of the opinions that are elaborated on this subject. It is also expected to contribute to the development of further researches on design proposals for clothing design with 3D printer that can adapt to changes in personal measurements.

OBJECTIVE

The overall objective of the research is to create modular skirt designs whose modules can be produced with 3D printer technology and whose sizes and models can change according to different body shapes. In that direction, this study embraced a modular design approach which is one of the mass customization methods. Moreover, model features that are compatible to change has been tried and determined, patterns have been prepared accordingly and design and application tests conducted aiming to find out the material and the method to montage modules with clothings.

The answers of the questions below have been sought in the tests:

1. What are the technical requirements of the modules that allow size and model change?

2. How should be the reflections of varying degrees of differences in size and body shape in the module?

3. What methods should be used to change the modules that allow model and size changes in clothings?

METHOD

In this study, skirt, whose 3D modules obtained from 3D printer, has been chosen as the type of clothing for the experiments to design clothes that can be altered according to different body shapes and models. The experimental development method has been used in designing of skirt models. In "Frascati Manual in the Light of R & D" titled report published by TUBITAK (2005), the experimental development method is described as follows: benefiting from available information obtained from research and / or practical experience, to produce new materials, new products or devices; to establish new processes, new systems and services, or the systematic study to significantly enhance the already established or produced ones.

In this direction, this research has been conducted to determine the ratio of differences in measurement primarily for the change in size and in designing the clothes whose size and model can be altered in line with different body shapes. Besides, features of the module have been determined. Due to aesthetic considerations in size change, the change amounts that can both fit well with the lower and the upper size were adopted. Skirt models were designed considering the study results and technical analyses were performed on each model. Three designs have been selected for the purposes of research among other skirt designs. At the end of the experiment, the most appropriate technique to use in the next step in the change of the module, method and materials were determined, and a zipper with 3 + 1 properties was developed. 3 + 1 zipper design was decided to be used in all the models. Later, technical and detail drawings along with the model descriptions were reported to create the model patterns.

When it was decided upon the final version of the design along with the patterns were prepared, new theories were developed for the modules to be produced with 3D printer. It was shed light on the future researches pertaining to size form, features of the developing designs and material and methods suitable for modularity

FINDINGS

Since in the study, the size changes will be operated through modules, the British Standards Institution's data that has been published under the code number of EN 13402-3 in 2004 titled "Size Designation of Clothes-Part 3: Measurements and Intervals " has taken into account (Figure 16). In this table, which shows the difference between the standard size differences among 15 sizes, it seems that in the first eight sizes, the differences of change in measurement are equal and with the nineth size differences of change in measurement start to vary.

Size		32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
Bust	(inches)	30	31.5	33	34.75	36.25	37.75	39.5	41	43.5	45.75	48	50.5	52.75	55.25	57.5
	(cm)	76	80	84	88	92	96	100	104	110	116	122	128	134	140	146
Waist	(inches)	23	24.5	26	27.75	29.25	30.75	32.5	34	36.25	38.75	41	43.5	45.75	48	50.5
	(cm)	58	62	66	70	74	78	82	86	92	98	104	110	116	122	128
Hip	(inches)	32.5	34.75	35.5	37	38.75	40.25	41.75	43.5	45.75	48	50.5	52.5	55.25	57.5	60
	(cm)	82	86	90	94	98	102	106	110	116	122	128	134	140	146	152

Figure 15: BIS (2004): Size Designation of Clothes-Part 3: Measurements and Intervals

It has been decided that the study to be realized in the first eight sizes in accordance with the above data. The measurement between these sizes is four centimeters. After determining the differences in measurements, skirt patterns of the company DesignCutandWear were benefited to identify where and in what proportion differences in measures were (Figure 16).

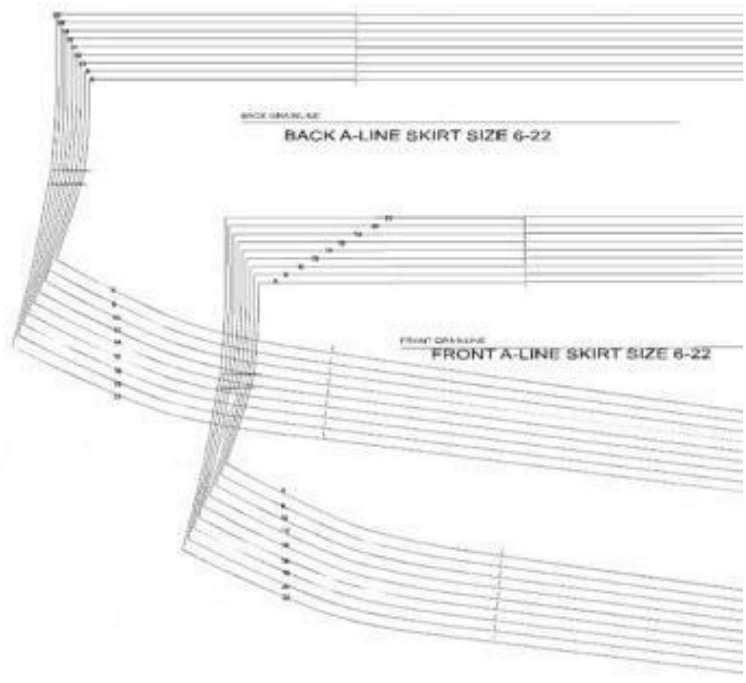


Figure 16: Skirt Pattern Grading

Skirt model series, as seen in the picture, are made on the basis of differences between waist and hip measurements of each size. The differences of measurement between the waist and hip size for consecutive sizes are made via distribution to the back and the front skirt in a systematic way. In this study, it has been determined that since size change can only be realized with module replacement, design features, as well, can solely be made with blocks covering both waist and hip sizes. Therefore it has been used blocks passing in different directions and curves through waist and hips in designs and the sections left between blocks have been identified as modular area of designs.

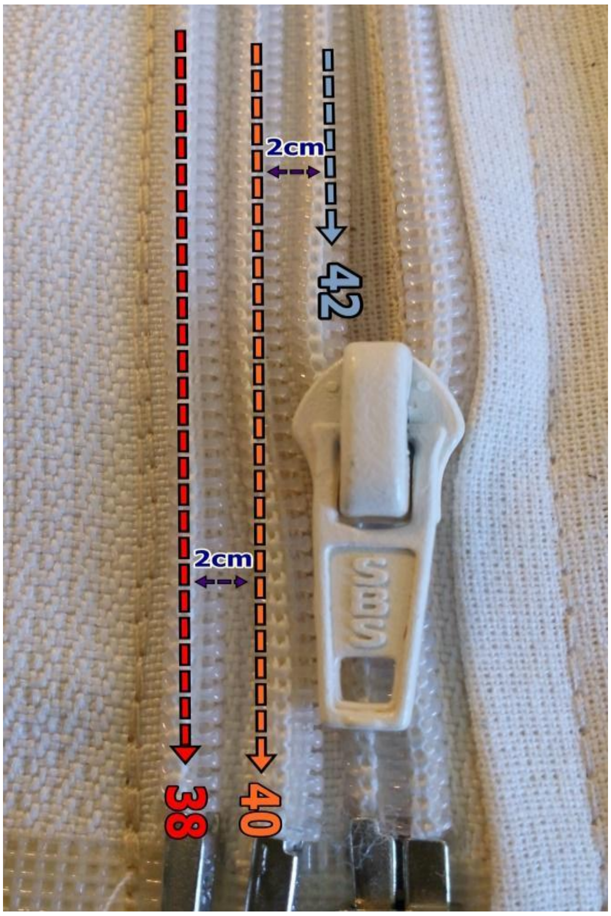
After determining the differences of measurement and identification of the areas where these alterations will be made, it has been begun to model designs. Design criterias were focused on the characteristics of the module assembly that allow change of size and model according to different body types. Study results have shown that in every clothing, it should be used one module, and it has been made a prototype of 3 + 1 zipper for which it has been made a usability test as well.

The most important feature of 3 + 1 zipper is to contain the differences of series between consecutive sizes in itself as well as it is able to produce in different ranges according to differences of series. The design, where each zipper teeth is located according to the differences of measurements between each size, is operating with standard open-ended zipper principle. While there are three zipper teeth without sliders located on module that allow size and module change, there are one zipper slider on the part corresponding to the module. Each teeth located on module corresponds to a different body size. The teeth located the most inner side allows model to change into a lower size while the teeth located in the most outer allows the conversion to the upper size.

In addition, it has also been considered to add a distinctive feature to this developed 3 + 1 zipper to eliminate size fitting problems of the users who have different body types. This feature has been designed based on the principles of changes of direction of rail lines, allows sliders to help to make the transition between zipper teeth. Thus, users who have not the same waist and hip sizes can fix the module according to their own body features.

It has been developed 3 + 1 zipper allowing the module assembly and have been developed skirt designs according to the design criteria. For trials, it was determined 3 models with different module settlements and styles that are deemed to have technical and aesthetic integrity. With these selections, it is aimed to show how the size changes can be implemented to skirts with different model features through module.

Open version of zipper design



Implementation of the size 42

Implementation of the size 40

Implementation of the size 38

It is also created for each and every skirt model identification forms, was made technical drawings on computer and drafted skirt patterns, and it was also introduced model descriptions and technical details. In addition, general properties that each model should have are listed as follows,

*Single module will be used in models in order to provide cost and production advantages.

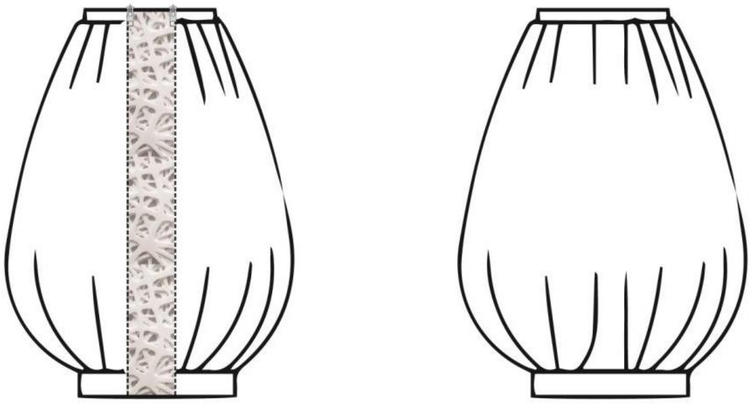
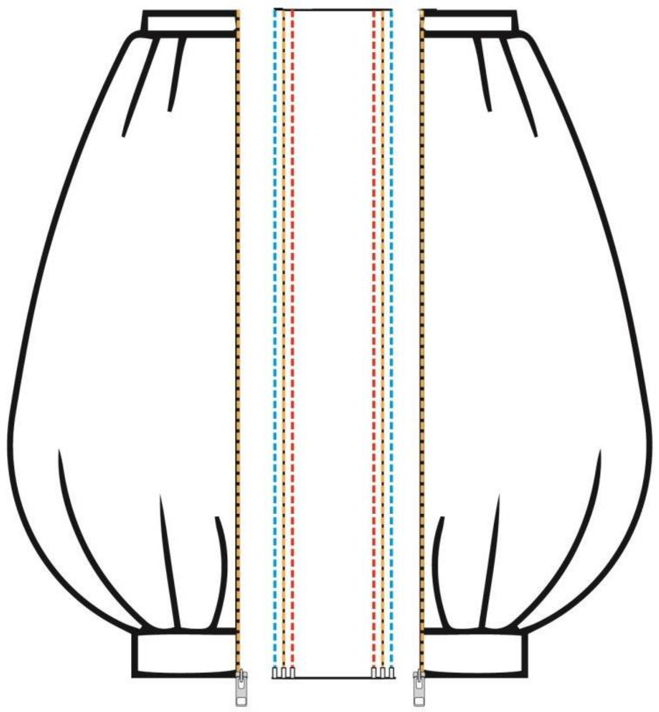
* Module will be placed on the outskirt in a way that includes waist and hip area to reflect the differences of measurements between sizes.

*Models will be worked on size 40 size pattern, and the measurement differences required for the transition to the lower and upper body will be distributed evenly to both left and right of the modules.

*Module assembly will be realized with 3 + 1 zipper system, the three teeth section will locate on the module, one teeth pul tab section will overlap with where module is.

*The modules will be produced in 3D printer along with zipper teeth on them.

MODEL DEVELOPMENTS:

TABLE 1: MODEL 1	MODEL DEVELOPMENT:
 	In this design, it has been identified module changing features in a model which has a belt and a band on the hemline. The module covering the waist and hip area is located at the middle front of the skirt and continues symmetrically from the waist to the hem. This module in this design can be applied to models whose structures are different in this design by moving the module to the left or to the right.

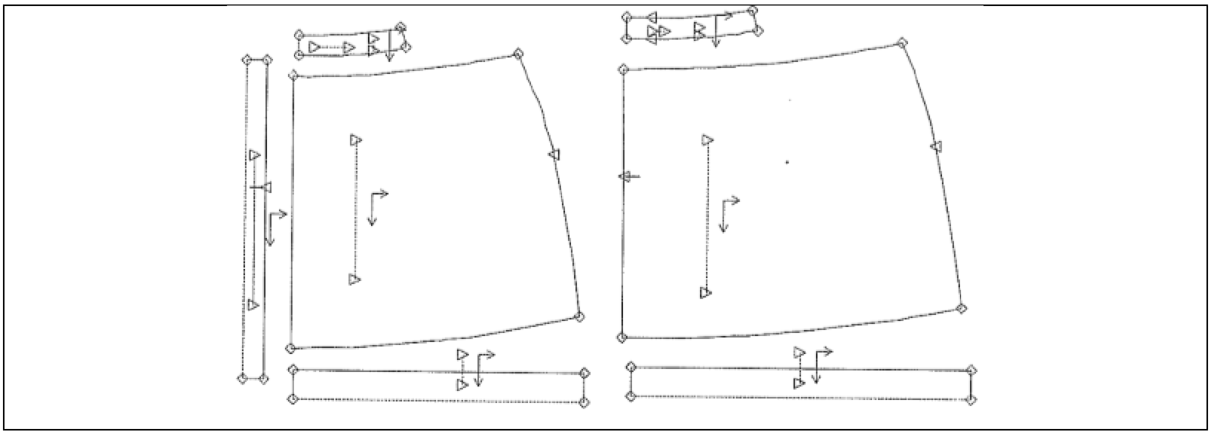


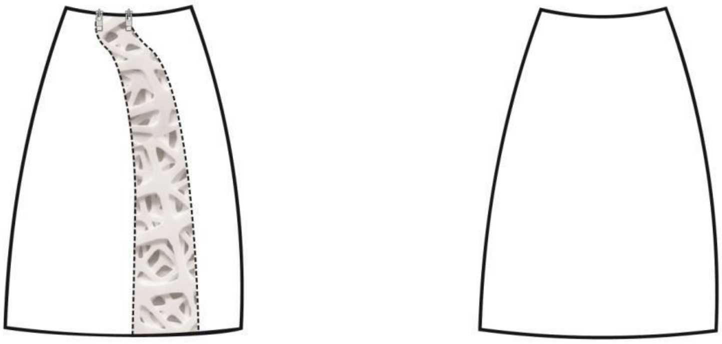
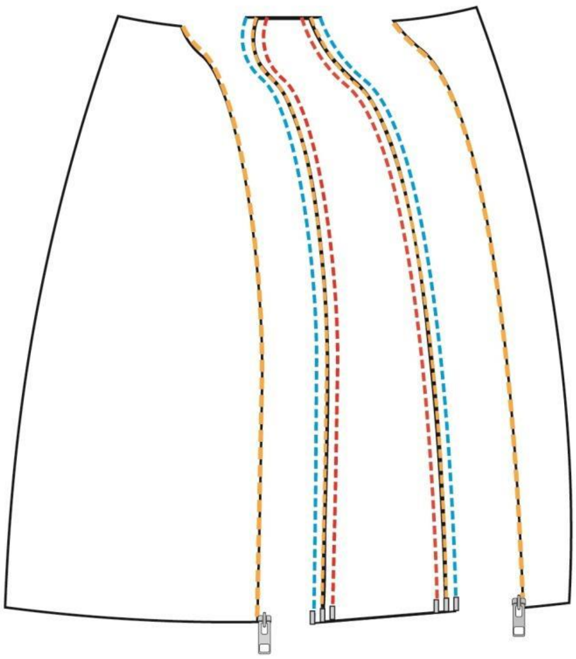
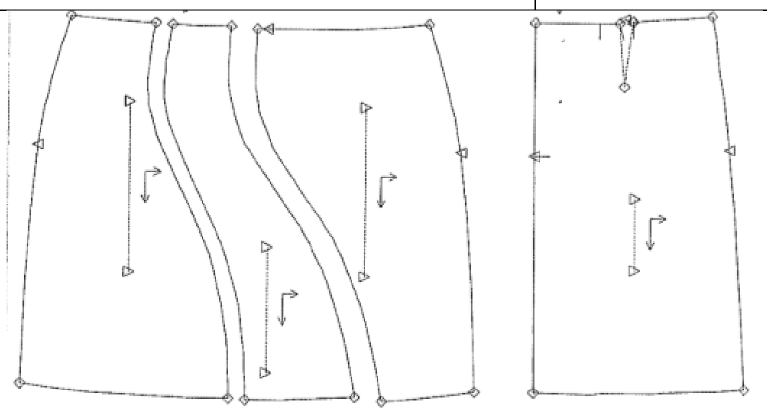
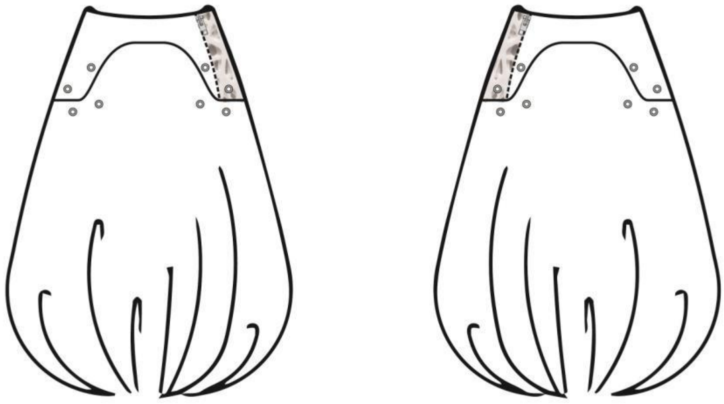
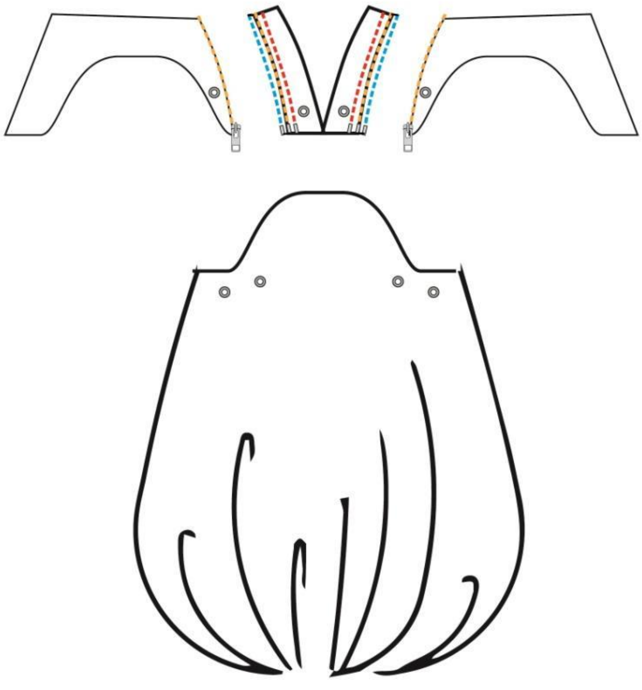
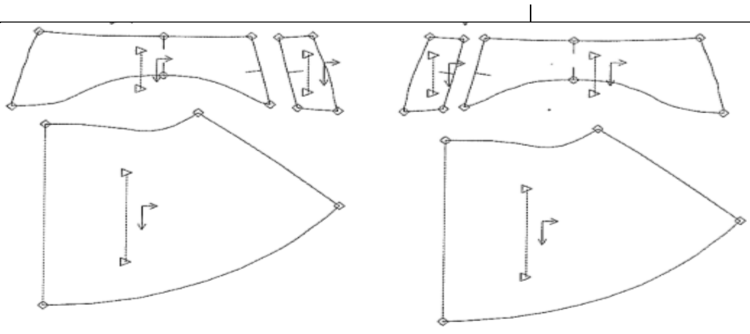
TABLE 2: MODEL 2	MODEL DEVELOPMENT
 	In Model 2, the section between two slightly curved longitudinal blocks which covers the waist and hips, is designed to be the module . In this design, a beltless model with a facing seam on the waist was determined as the characteristics of an asymmetrical module. It is possible to implement improved design in asymmetrical modules with different curves by covering both waist and hips.
	

TABLE 3: MODEL 3	MODEL DEVELOPMENT
 	In Model 3, it was implemented a module covering a portion of the block crosscut and locating on the side. In this design, the principle of using bodice with a sloppy curvature to cover the waist and hip area was embraced. For the line where module joins the bottom of the skirt to be suitable for the changes in size, eyelets were placed in lower skirt and the module. The joining of lower skirt part with module lines were threaded through eyelets.
	

RESULT

Relationship of fashion, which is based on novelty and distinctness with innovation is rooted in its own nature. TS Eliot says: "A path which is known and is accustomed to is easy to walk. However, memories that are remembered are always the different ones." and continues, " If you want to have different stories to tell our grandchildren, do what is different. " (Ülker, 2009). Especially today for reasons such as thriving globalization trends, diversification of customer demands and desires, dimensions of technological progress, and changes in the living conditions, designers must create their philosophy in this direction considering the increasingly competitive environment. Therefore various products, the cost factors, reasons such as the growing demand to individualization resulted in mass customization model (Pazarcik, 2009). In mass customization defined by Piller (2007) as "changing of product or service features in favor of customer's demands and needs ", modularity appears to be an important method of application. Yuluğkural (2009) states that modularity is the most important feature that makes the word 'mass' in mass customization meaningful and the constituents produced in modular form will respond to different demands and expectations. As a result of modular designs proposed in this research, it is suggested that the common parts of the clothing to be produced with mass production and modules to be produced with 3d printer, chosen by customer during the purchasing. However, texture and material technologies of 3D printer should demonstrate improvements enabling to produce these objectives of designs. The results and recommendations of this study are summarized as follows,

- In this study, 3 + 1 zipper design has been developed for the purpose of being used in the montage of the modules which allows changes in the sizes and models. The changes to be made in the number of and directions of the teeths available in the system can allow clothing to fit a greater number of sizes and body types.

- The production of 3 + 1 zipper design as a montage medium together with the module is suggested as a design solution.

- This study can be applied to plus-size models if the distance between the teeths arranged in accordance with the differences of measurements in size 48 and above.

- Designs that are produced as the results of this study meet different expectations. Customers who have multiple experiences will create an emotional bond with the product and the life cycle of the product will increase. This situation will eliminate the need to purchase new clothes and will ensure the protection of the resources necessary in the manufacture of new products, thus contribute to sustainability.

- The amount of waste resulting from the printing of modules from the 3D printer will be reduced, thereby the waste released into the environment will be kept at a minimum rate.

- The use of 3D printer solely in modules will pave the way to operate high technologies in manufacturing at low-costs.

- 3-D printer technology that is widely used in the production of prototypes, will allow room for to be used in the final product.

- 3D will enable users to produce modules with different features, in different textures and colors as they desire.

- These improved designs will work as a case study for 3D printer technology to be used daily casual wear.

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