(REFEREED RESEARCH)

A RESEARCH ON MODULAR PRODUCT DEVELOPMENT IN WEDDING GOWN PRODUCTION

GELİNLİK ÜRETİMİNDE MODÜLER ÜRÜN GELİŞTİRME ÜZERİNE BİR ARAŞTIRMA

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ABSTRACT

Recent developments in production management gave way to the “mass customization” strategies, by which companies claim to solve the dilemma of meeting customer’s unique needs still benefiting from scale economies.Delayed product differentiation (DPD) as a design strategy is implemented in agile manufacuring systems. Modularity is one of the key strategies in mass customization as it enables component commonality of products, thus differentiation of the products can be postponed to the assembly stage.In this research, production process of wedding gown is examined in this aspect and possibility of applying platform based modularity in wedding gown production is tested. The process flow and processing times of most basic wedding gowns were recorded to determine the stage in which the customization will take place. It had been tested whether there will be parts that can be standardized as modules or not. According to this preliminary examination, it will be possible to decide if the customization can be postponed to a later stage.

Keywords: Wedding gown, agile manufacturing, customization, delayed product differentiation, modular design, bus (platform) modularity.

ÖZET

Üretim yönetimindeki son gelişmeler, şirketlerin müşterinin özel taleplerini tam karşılarken ölçek ekonomilerinden de hala yararlanabilmesini mümkün kılan "kişiye özel seri üretim" stratejilerinin yolunu açmıştır. Çevik üretim sistemleri içerisinde, ertelenmiş ürün farklılaştırması (DPD), bir tasarım stratejisi olarak uygulanmaktadır. Modülerlik, ürünler arasında ortak bileşenlerin sayısını arttırdığı için kişiye özel ürünlerin seri üretiminde en önemli stratejilerden biridir. Bu nedenle ürünlerin farklılaşması, montaj aşamasına ertelenebilmektedir. Bu araştırmada, gelinlik üretim süreci bu açıdan incelenmiş ve gelinlik üretiminde platform tabanlı modülerlik uygulama imkânı test edilmiştir. En temel gelinliklerin süreç akışı ve işleme süreleri, özelleştirmenin hangi aşamada gerçekleşeceğini belirlemek için kaydedilmiştir. Modül olarak standardize edilebilecek parçaların olup olmayacağı test edilmiştir. Bu ön incelemeye göre, özelleştirmenin sonraki bir aşamaya ertelenip düzenlenemeyeceğine karar vermek mümkün olabilecektir.

Anahtar Kelimeler: Gelinlik, çeviküretim, kişiyeözelleştirme, ertelenmişürünçeşitlendirme, modülertasarım, platform modülarite

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1. INTRODUCTION

Marriage is a turning point in human life and it is celebrated in many cultures with wedding ceremonies, which emphasises its importance. Women's ceremonial wear can vary between cultures. However,in 20^{th} Century "white wedding dresses" have turned into world’s favourite ceremonial gown (1). Today fashion brands are competing to produce this prestigious product. On one side luxury couture companies like Channel, Dior create tailored bridal gowns, which are fully designed for the customer including their fabric and embellishments. On the other side there are those who prefer to buy ready-made bridal gowns that fit their body with slight modifications. Wedding gown brand Pronovias, provides ready to wear wedding gowns with affordable prices while they sustain their reputation and desirability via high-end wedding gowns designed by worldwide famous designers.

Wedding gown ateliers located in Izmir are producing 70% of wedding gowns in Turkey (2).Since 2007, IF Wedding Fair takes place in Izmir setting a meeting point for retailers, producers and suppliers all around the world(2,3,4). Local wedding gown ateliers trying to connect to the world markets are seeking ways of developing their competitiveness (4,5). However, majority of the ateliers continue to produce garments that are tailored by one person and the time constraint is largely neglected (2). Besides, they avoid standardization as their experience indicates that customers consider spending more time and more money to buy the product that they are involved in the design process (6). These habits prevent traditional ateliers from evolving into a more competitive strategy. Nevertheless, competition with large scale wedding gown brands, increases the pressures ontraditional ateliers to utilize all resources more efficiently.

Wedding gowns are mass produced on assembly lines and sold through retail shops, or they are tailored using standard fabrics available in the market, in a small batch operation. Couture gownsrequire high skilled hand craft in job shop and every detail is designed and produced unique for the customer at all costsit takes (time and money).A company may adopt all these strategies at the same time like in the case of Pronovias, or may choose one of them according to the market segment. Using one product across different process types illustrates that, process type isa strategic choice (7).

Majority of the wedding gown companies produce generally one unit at a time, but it is not possible to classify them as "couture" for their materials are supplied ready-made(2). Knitted or embroidered lace is used in the decoration of the gown. These are the types of decorative fabrics available in the market and ateliers utilize them in their own style, cutting them into small components in order to compose different patterns fitted on the customer. Modularity arises from the breakdown of a complex part into simple and functionally independent components which are assembled to make customized parts, first presented by Ulrich and Tung (9) is one of the key strategies in mass customization. Ulrichand Tung, classified modularity in fivefundamentaltypes: Component-sharing Modularity, Component-swapping Modularity, Cut-to-Fit Modularity, Mix Modularityand Bus (Platform) Modularity (9).Tailored segment of wedding gown production resembles bus modularity, however to develop it as a strategy requires developing a more deliberate design methodology.

Mass produced parts will be assembled to create new forms. In 2000, Duray et al., conducted a survey that measures production efficiency in 126 apparel companies, which have mass-produced customized products. The survey reveals that the customization practice in mass production has replaced production in craft workshops and reduced production costs. According to this research, the intermediate parts which make up the special product have been prepared in the form of mass produced modules, thus enabling more efficient production. In this study, Duray and colleagues, modelling the adaptation of the types of modularities described by Ulrich and Tung (10) to the production cycle, have reached the conclusion that modularity should be used as the most basic way to overcome the problems that customization produces (11).

In this research, adopting modularity as a process strategy in wedding gown production is tested. The process flow and processing times of most preferred wedding gowns were recorded to determine the stage in which the customization will take place for the wedding dress production. It had been testedwhether there may be parts that can be standardized as modules or not. According to this preliminary examination, it would be possible to decide if the customization can be postponed to a later stage.

2. LITERATURE REVIEW

Mass customization is a realistic strategic choice for many manufacturers, by which companies claim to solve the dilemma of meeting customer's unique needs still benefiting from scale economies (7).Hayes and Wheelwright's (8) product process matrix is a ground-breaking typology showed the interaction of product type and production processes and highlighted the need for coordination between marketing and operations functions (7,11)(figure 1). This matrixillustrates the growth and development of a product, a company, or an entire industry through four stages: jumbled flow (job shop), disconnected line flow (batch), connected line flow (assembly line), and continuous flow. The trade-off between flexibility (variety) and low cost (because of economies of scale) are clearly stated. According to this matrix the more product is customized, the more complicated process becomes (11). Companies which are placed on the diagonal shown in this matrix are following a path that fits the nature of the product and majority of the companies, producing in the same field are choosing a strategy alike.

Lampel and Mintzberg, classified customization strategies in 5 different levels such as: Pure standardization, segmented standardization, customized standardization, tailored standardization and pure customization. These strategies, illustrate the stages of production in which customization can be applied. When a product is purely customized, it must be designed, fabricated, assembled and distributed to the individual. Postponing customization to a later stage determines more standard workflow in the process (12). Modularity in design of the product delays product differentiation. According to Elgård and Miller the later the customization stage is, the more common resources it will be able to use (13)

Senanayakeapplied a survey to apparel companies to test Lampel and Mintzberg's theory in apparel production. That research, showed the current mass customization practice in apparel could be characterized using five distinct points of customization; post assembly, fabrication,feature, fit, and design. The survey indicates that fit and design customization is less commonly practiced today. For many consumers, cost of variation in size may exceed the perceived value of fit and design customization, however technology solutions have become gradually more affordable (14).

Technical product development is a part of the design phase of the production of industrial products such as heavy machinery, automobiles, or home appliances. In apparel production,this process includes pattern development, marker making, supplying and planning that are often referred to as production preparation and are usually outsourced and carried out as a sub-function of production. However, the process that provides the most important input to the planning of production is the product development process. Recently, approaches such as DFM (Design for Manufacturability) have provided integrated and systematic approach to the product development process, addressing significant part of the production problems in the design and planning phase. Today, the issue of designing the quality within the production process or even in the product development process is the agenda (15). Products that do not advance in the production line due to poor or inadequate design, or that are not suitable for customer needs, are unnecessarily costly to operate (11).

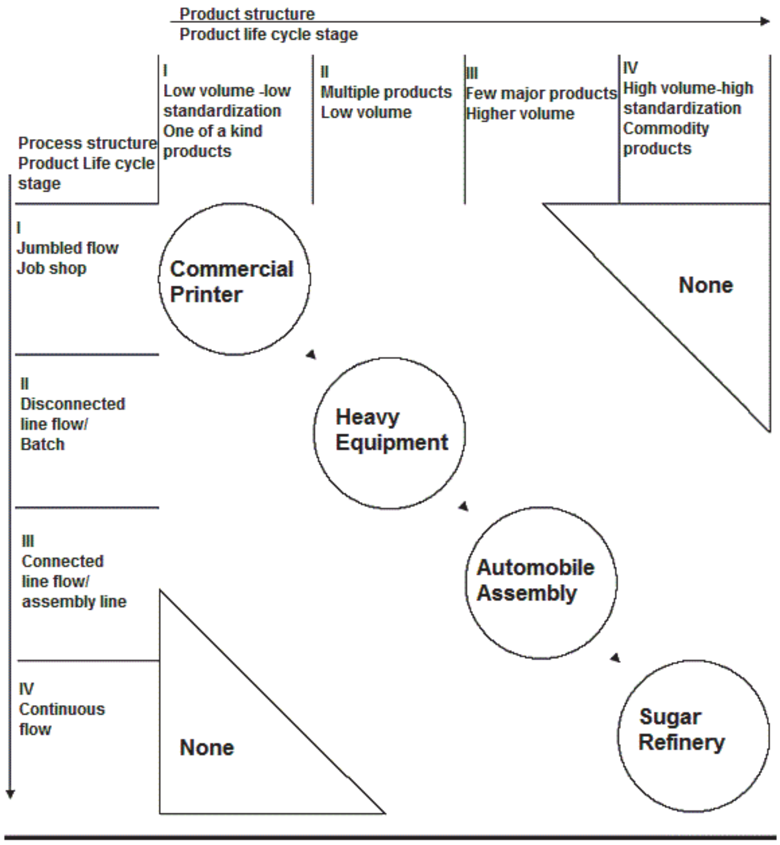

Figure 1. Matchingmajorstages of productandprocess life cycles (8)

Production of customized products to respond to changing markets in a short time and at a low cost for agile manufacturing can be implemented with delayed product differentiation in a manufacturing system (16). Senanayake refers to the design concept of Delayed Product Differentiation (DPD) which is aimed at increasing product variety while maintaining manufacturing efficiency. Increasing the level of part commonality at the early stage of the manufacturing process will help to delay the product differentiation (17). Lampel&Mintzbergdefine this as “customized standardization”that focus on modularityin which variables are created by combining standard modules with different combinations (12). To apply modularityin product design, the basic principle must be that the parts of the product should be produced as compatible units as in Lego toys (18). In the best experience,the assembly process does not need to be realized at the firm, and the customer can also assemble the modules themselves once theyreceive the goods.

Studies for standardizing parts is one of the principles of customized production. In this way, the flexibility of the production system is ensured. Pine stated that real customization requires modularity in production (19). Salvador et al. suggested that it is possible avoid the tides between product variety and operational performance by targeting modularity in design (20). The standardization of customization, is achieved by design of modules, which allows variety in the assembly process by their combinations. Shared common resources include standard modules.Apart from increasing variability, modularity is preferred because it reduces the complexity of design and manufacturing processes. It allows different components to be developed as independent units by separating the product into its functional parts (21).

3. MATERIAL AND METHOD

3.1. Material

In this research, the productsofa wedding dressatelier settled inİzmir were examined to find out stages which customization can take place.32ateliers and 2 fabric suppliers are interviewed, and different wedding gown models are scrutinized between 2013-2015 to find out market dominating silhouettes and establish product trees in which commonalities of products are grouped. 13 of these companies have capacity of 3000 and more pieces per year.This research contains data collected from the production ofspring-summer 2015 designs.Thepartner atelier, offers only custom-made products to the customer. The products at the assembly level have many common properties, such as the upper body part that has a strapless corset structure that surrounds the body is common in all models. We can speak about a difference isvisible on the main silhouette of bridal depends on the form of the skirt and lace appliques selected. These silhouettes are also the most frequently preferred ones, making 98% percent of all orders in 30 companies, interviewed.

Theratio oftheproducedsilhouettes by the partner atelier, between April and July 2015,is 76% A-line, followed by 17% mermaidsilhouetteand 7%ball gowntype bridals. In other ateliers the ratio was slightly different (72% A-line, %18 Mermaid, % 9 Ball gown, and 1% other), so these three silhouettes are examined in this order.

Machine embroidered lace is selected as the means of modularity in this research, as its technology allows creating variety and short set up time enables flexibility of differentiating. Besides it is demanded in around 86% of all bridal gowns. Knitted lace has a share of 12%, and its production has lessflexibility than machine embroidered. Other types of fabrics meet the requirements of 2% of the products.

Standard lace is embroidered on tulle fabrics. Other fabric types become a part of discussion only when customer makes a special request. Even in most cases, components are cut off from the embroidered tulle fabrics and applied on the platform.

Material and information are used as a common source for the production stage of the wedding dress form. The variety expectations of the brides are not based on the silhouette. Fundamentally, it depends on the texture, fabric design and uniqueness of lace or surface embellishments. The three silhouettes mentioned have the bodice part in common. This part of the dress is reinforced with a corset and baleen. It is produced using white, shiny white or beige satin lining and fabric and laminated bra cups that exactly fit the customer's measurements. The wedding gown is produced as a basic dress that shapes body like corset. Embellishment such as beads, cordon, lace, embroidered tulle applied on this platform are added onto the basic garment during the later stages of the process. Which means product differentiation is delayed to later stages.

3.2. Method

It is important to define product families to achieve modularity in design. Figure 2. Shows the most popular 3 silhouettes of bridals. Identifying similarities in terms of design and function will help to decide the common components. Silhouette is the most important identifier of the wedding dress structure. It affects the form and pattern pieces therefore the product trees are formed accordingly, and three basic groups are determined. To identify repeating tasks study on production processes is carried further. In this research, typical examples of these three basic silhouettes are selected to record duration and sequence of operations.

First, wedding gown production operations were listed and ambiguities in process flow are defined. The absence of fluent and sequential way of production as in ready-made clothing was a challenge when using MTM (Methods-Time Measurement). The whole process of decorating the body part with appliques is measured as one operation. This process requires thinking and deciding for the position and fixing or fastening of the lacework. A significant portion of these processes include inactive thinking and decision-making periods.

Production durations of three basic product groups measured on size 38. Process time of six different wedding dresses from the A-line silhouette were measured and recorded one by one, for the calculations.The averages are taken, and no significant differences were observed between basic dress form production times. However, time measured in the elaboration of the lace showed variations due to pattern size, pattern placement on the body and pattern density of the desired model. The mermaid silhouette has a similar workmanship and sequence. This form was produced less frequently,sotime measurement was made on three samples and their averages were used. The production time for ball gownsilhouettewas measured on twosamples.

Components are designed, considering embroidery machine properties, after defining product trees and analysing repeating tasks. The new designed After the development of modular samples one sample from each type is measured. Results are compared, andeffects of modularity is evaluated.

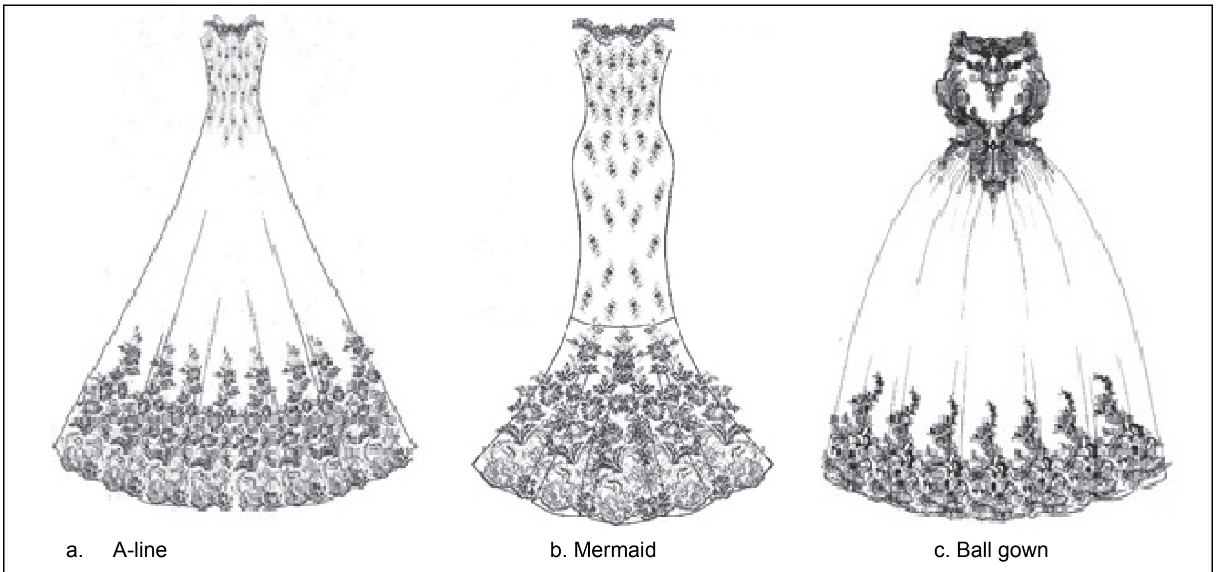

Figure 2. Most popular wedding gown silhouettes

4. FINDINGS

After defining and recording theprocess timeof the three main product groups, non-value added operations become more visible and it is then possible todefine and eliminate the steps that need to be improved. When these samples are completely producedincluding the embellishment on top and come to the delivery stage, they are finally looking different from each other. These three basic silhouettes can be grouped in two when their workmanship methods are considered.The first groupis consisted of mermaid and A-linesilhouettes.These two show the common properties in the construction of basic body. They both are whole dresses made ofsevenpattern pieces cut along.The basic dress constructed is used as a platform to attach the decorative lace appliques on the body. The flare at the skirt is supported with full circular tulle skirt placed on top at the waist or knee levels. The second group is ball gown silhouette. This wedding gown type is a combination of a fitted strapless corset with a hugeskirt connected to the body on the waist level.This product line has the corset as the platform and decorative lace appliques are applied after bodice and skirt are assembled. Table1.Illustrates the platform production process times of the three product groups.

Cutting the parts at the required size, and sewing the draft to prepare for the fitting can be completed in about 25 minutes. Larger allowances on the sample provide an advantage in adjusting the size of the bride, during fitting process.On the other hand, fittings, waiting for a fitting appointment, modifications due to unsatisfying look, the duration of the wedding gown production can be extended for days or even months. Variable waiting times due to prolonged periods are not included in the calculation of production times.

In Table 2. shows that the longest processes in all product groups are handcrafting stages. The total time of the craft work on A-line dress was calculated as 18960 seconds (316 minutes), 21270 seconds (355 minutes) on the mermaid form, and 20650 seconds (344 minutes) on the ball gown (Table.2).

The border lace is pinnedon the tulle skirt hemin 5940 seconds (99 minutes) and upper body laces pinned and glued in 13020 seconds (217 minutes). These processes constitute 72% of the total production time (26337 seconds). In order to be able to provide modularity, it is necessary to decide on the layout and the interactions between the components of the designs during product design and pattern making phase. Applying ofthe lace components on the platform and the placement of these components points to a complex product structure (14). Existing operations are reviewed and components are analysed for modularity.

4.1. Modularity at hem trimming border lace

Inmodulardesign, intention is toreplace a unique integral partwiththeassembly of commoncomponentsthatmay be manufactured in themachining stage or bought directly from suppliers. Modular design sinc reaset he number of assemblyoperationsandtheassembly time and, hence, they mayre quiread ditionalas sembly stations in thesystem (15).

In the production of wedding dresses, embroidered lace pattern is applied on tulle fabric. Wedding gown tailors are accustomed to use a variety of material.They cut out embroidered patterns into components in different ways then they make a new layout from these components. If the wedding gown designer, designs the product at an early stage and pattern is constructed accordingly, the lace can be produced according to the pattern. deciding the modules' size and form properties are limited with the technical constraints of the raw material production.

Table 1. Platform production durations (seconds) according to product groups

	A-line	Mermaid	Ball gown
Platform assembly periods (seconds)	3457″	3457″	5959″

Table 2. Classical tailored wedding gownprocess durations (seconds)

<table>
<tr><th></th><th colspan="2">A-line</th><th colspan="2">Mermaid</th><th colspan="2">Ball Gown</th></tr>
<tr><td>Cutting</td><td colspan="2">2836″</td><td colspan="2">2836″</td><td colspan="2">2219″</td></tr>
<tr><td>Fusing (steam iron)</td><td colspan="2">248″</td><td colspan="2">248″</td><td colspan="2">248″</td></tr>
<tr><td>Sewing (lock stitch)</td><td colspan="2">1792″</td><td colspan="2">1792″</td><td colspan="2">5086″</td></tr>
<tr><td>Overlok</td><td colspan="2">241″</td><td colspan="2">241″</td><td colspan="2">254″</td></tr>
<tr><td>Hem(trimming, pinning and stitching border lace – hand craft)</td><td>5940″</td><td rowspan="2">18960″</td><td>4445″</td><td rowspan="2">21270″</td><td>7630</td><td rowspan="2">20650″</td></tr>
<tr><td>Bodicelace(trimming, pinning, gluing lace- hand craft)</td><td>13020″</td><td>16825″</td><td>13020″</td></tr>
<tr><td>Handwork(regulation of skirt layers and wire)</td><td colspan="2">582″</td><td colspan="2">582″</td><td colspan="2">248″</td></tr>
<tr><td>Ironing</td><td colspan="2">1380″</td><td colspan="2">1380″</td><td colspan="2">480″</td></tr>
<tr><td>Trimming (scissors)</td><td colspan="2">298″</td><td colspan="2">275″</td><td colspan="2">123″</td></tr>
<tr><td>Total Production Duration</td><td colspan="2">23501″</td><td colspan="2">25788″</td><td colspan="2">27089″</td></tr>
<tr><td>Total cutting and production duration(seconds)</td><td colspan="2">26337″</td><td colspan="2">28624″</td><td colspan="2">29308″</td></tr>
</table>

A full circle skirt consumes 9 m of border lace at the hem trimming. Each slice is limitedmaximum 90 cm width on a regular embroidery machine. This makes 1/10 of the skirt. Figure 3 presents an image of modules assembled in a circle to form a skirt.

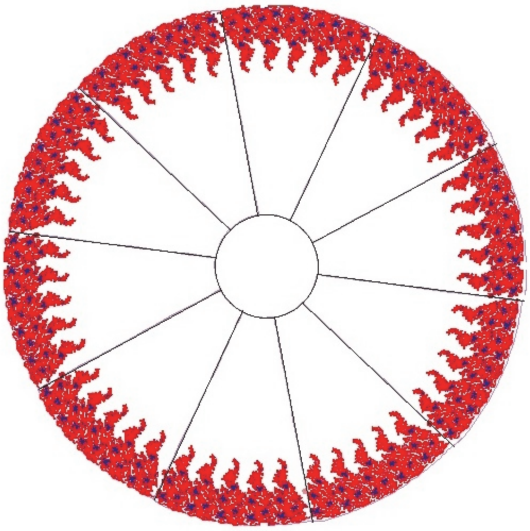

Figure 3. Full circular skirtdivided in 10

Figure 4. Circular skirt module

In the first stage, border lace of skirt is adapted to the circular form and it is produced in maximum module size of 90 cm. To achieve full circular skirt with lace border at the hem line these modules are assembled side by side. 10 of these modules were stitched together to complete full circle (Figure 3&4).In this caset he circular hem caused more component sandmore as semblyoperations. As they replaced hand work, total production time decreased, significantly.

4.1.1. Modular border lace for A-line wedding gown

A-line wedding gown has 6 layers of tulle circular skirt attached on the basic dress at the waist level. The radius of this circle is approximately about 143 cm, it may vary depending on how tall the bride is. This radius gives us a circumference of almost 9 meters. Cutting out, pinning and stitching9 meters of border lace on the hem of A-line wedding gown, takes 5933 seconds (99 minutes). Total production time is 26337 seconds (439 minutes).

As the module is produced and skirt is constructed by the stitching of these modules together, 16% of total production time is saved. This type of modules makes it possible to adjust the form and volume of the skirt by changing the number of modules assembled together. While 10 slices are used to produce a full cloth skirt, using 6 or 7 slices for lower volume skirts is sufficient. This allows the producerenlarge the product range due to the little changes in the appearance.

4.1.2. Modular border lace for mermaid silhouette

In mermaid shape the circular skirt is positioned a little above the knee.The radius of the circle is 115 cm and the circumference is 7.2 m. Instead of making different modules for this radius, it is possible to make use of the modules designed for the A-line wedding gown. 8 modules are enough to construct a full circle for the mermaid style wedding gown. It is sufficient to use 6 or 7 slices for skirts that have less volume. Total time of production is 477 minutes. After application of modularityproduction time drops by 49 minutes.It makes 11% of the total time.

4.1.3. Modular border lace for ball gown silhouette

For the ball gown type, Whole process of production takes 489 minutes. Very simple modification of eliminating applique pieces from the lace trimming reduced the total time to 362 minutes. Saving 127 minutes makes 26% percent of the production time.

4.1.4. Module Design for Body Appliques

As wedding gown forms are limited with three basic silhouettes, the most important variable that creates diversity is the lace used in the body ornament. The time spent on the placement of these lace patterns, especially on the body, constitutes the longest part of the time spent in production. To avoid the time taking operations of cutting out lace components, placing, needling and applying them on the body, designing modules that reduces workmanship is targeted.

In classical method customization starts at the design stage and continues in all fabrication, assembly and distribution stages. By trying to apply modularity in fabrication stage, customization will be postponed to assembly stage. It is planned to get a higher standardization by postponing customization. Embroidery pattern is designed according to the body form. It has layers, which enable producer to decide the length where it will end. Upper hip level, hip level or other lengths may be selected by customer. This decision only requires a detailed cutting. When darts are stitched together, components organized accordingly are coming together to complete the pattern. Figure 5 shows an example for this kind of lace for the sizes 36, 38 and 40.

The front and back body modules are prepared for size 38.It is embroidered on tulle which is a flexible material, therefore it is possible to use this module for the sizes 36 and 40. The red component is for illustrating the length module to be separated from the bodice when customer demands a shorter bodice decoration (Figure 5)

Table 5. illustrates that in the modular production of ball gown, cutting time is increasing slightly while hand craft processes decrease dramatically.

Embroidered modules play an important role in the reduction of workmanship and related costs. In this situation, it is necessary to check whether the embroidered modules cost exceed the profit or not.Lace prices are proportional with stitch count of the design. When border lace is fitted to the arc, the change in the stitch count is less than 0,1%. For the ball gown type,stich count is the same in two conditions. Modular embellishment of bodice is more profitable than the traditional lace, because when trimming the embroidery pattern pieces, a small part of it is going to the waste. With modular design, exact consumption may be possible.

Figure 5. Pre-designed front and back modules

Table 3. A-Line wedding gown production process duration (seconds)

A-LINE WEDDING GOWN	**ClassicalMethod**	**Border Lace Modules**	**Bodice Modules**
Cutting	**2836″**	**3582″**	**4062″**
Interlining	248″	248″	248″
Sewing	1792″	2262″	2518″
Overlock	241″	781″	781″
Hem (trimming, pinning and stitching border lace- hand craft)	5940″	0″	0″
Bodice lace (trimming, pinning, gluing lace- hand craft)	13020″	13020″	780″
Handwork (regulation of skirt layers and wire)	582″	680″	680″
Ironing	1380″	1380″	1380″
Trimming (scissors)	298″	298″	298″
Total Production Duration	23501″	18669″	6685″
Total cutting and production duration (seconds)	**26337″**	**22251″**	**10747″**

Table 3 illustrates that in the modular production of A-line dress cutting time is increasing, while hand craft processes decrease dramatically.

Table 4. Mermaid style wedding gownproduction process duration (seconds)

MERMAID GOWN	**Classical Method**	**Border Lace Modules**	**Bodice Modules**
Cutting	**2836″**	**3420″**	**4020″**
Interlining	248″	248″	248″
Sewing	1792″	2090″	2410″
Overlock	241″	584″	584″
Hem (trimming, pinning and stitching border lace- hand craft)	4445″	0″	0″
Bodice lace (trimming, pinning, gluing lace- hand craft)	16825″	16825″	1020″
Handwork (regulation of skirt layers and wire)	582″	680″	680″
Ironing	1380″	1380″	1380″
Trimming (scissors)	275″	275″	275″
Total Production Duration	25788″	22082″	6597″
Total cutting and production duration (seconds)	**28624″**	**25502″**	**10617″**

Table 4. illustrates that in the modular production of mermaid gown, cutting time, an earlier process time is increasing slightly, while hand craft processes decrease dramatically.

Table 5. Ball gown production process duration (seconds)

BALL GOWN	Classical Method	Border Lace Modules	Bodice Modules
Cutting	**2219″**	**2246″**	**2726″**
Interlining	248″	248″	248″
Sewing	5086″	5086″	5342″
Overlock	254″	254″	254″
Hem (trimming, pinning and stitching border lace- hand craft)	7630″	0″	0″
Bodice lace (trimming, pinning, gluing lace- hand craft)	13020″	13020″	420″
Handwork (regulation of skirt layers and wire)	248″	248″	368″
Ironing	480″	480″	480″
Trimming (scissors)	123″	123″	123″
Total Production Duration	27089″	19459″	7235″
Total cutting and production duration (seconds)	**29308″**	**21705″**	**9961″**

Table 6. Total time (minutes) of hand craft process in all product groups and modularity stages

Total hand crafttime (minutes)	A-line	Mermaid	Ball gown
Hand Craft Time withClassical Methods (min.)	**316′**	**355′**	**344′**
Hand Craft Time remaining after Border Lace Module Application (min)	**217′**	**280′**	**217′**
Hand Craft Time Remaining After Border Laceand Bodice Module Application (min)	**13′**	**17′**	**7′**

Table 6. indicates remaining hand craft times after modularity. After achieving fully embellished gown with modular lace, tailor still can use the option of product differentiation with hand crafted beads or appliques. This will add up more value, with less effort and mastery requirement.

Table7. Comparison of Total Production Time with Different ModularityApplications (sec/min)

	A-line	Mermaid	Ball gown
Classical workmanship time (sec/min)	**26337″/439′**	**28626″/477′**	**29308″/488′**
Border Lace Modules at Hemproduction time (sec/min)	**22251″/371′**	**25502″/425′**	**21705″/362′**
Border and bodice lace modules production time (sec/min)	**10747″/179′**	**10617″/177′**	**9961″/166′**

5. CONCLUSION

In the production of wedding dresses, embroidered lace pattern is applied on tulle fabric. Wedding gown tailors are accustomed to use a variety of material. They cut out embroidered patterns into components in different ways then they make a new layout from these components. This requires mastery and it is rare and expensive to recruit a person with required talent. Besides as mentioned before this task is time consuming.

Finding similarities between the physical and functional architecture of the design, makes it possible to group product trees and establish the standards of a design. Structuring upon pre-designed components may seem to reduce product variety however; this exposes repeating tasks or design elements. Therefore, it becomes possible to eliminate unnecessary steps or define standard steps that repeats. To capture the broadest customer preference, more specialized craftsmanship, besides the standard ones may be used in the latest stage. In other words, designing products that are similar enough, makes it easier to produce, and they still can be differentiated as late in the production process as possible.

These benefits of product modularityin wedding gown production can be listed as following:

- Component economies of scale due to the use of components across product families: it requires a complicated preparation process and pre-designed components.
- If this stage is completed successfully order lead-time will be decreased, which makes the most of cost as the workmanship is expensive. However, this brings the responsibility of designing and purchasing the raw material (components) before the assembly stage.
- Flexibility to delay some design decisions, that customer can be a part of it in fitting periods.
- Control over the changes and being flexible to respond to changes
- Less uncertainty in manufacturing requirements: Modular embellishment consumes less trash of lace. Trimming the embroidery pattern pieces, means some lace is cut away. With modular design, exact consumption may be possible.

On the other side modularity may cause:

- Decreased product variety from a limited set of components,

- Excessive product similarity due to similar components (product variety is created using several different combinations of each component).
- Limits the applications: Modularity is only available with applique lace. Simpler look without embellishment will not be achieved with bus modularity.Althoughthenumber of parts in themodulardesign is largerthanthat in the integral design, the total time of machining operation sand manufacturing costare more likely todec rease in themodulardesign. The integral designsresult in complex parts that require more complicate dandc ostlym anu facturing processes.
- Complicate dandin teractives upplier communication. This strategy may workonly when there is a strong connection toem broidery suppliers. Ifthesupplier is ablet oproducecustommadefabrics, this approac hbene fits the **mos**t. Wedding gown designers must bring the lacedesign processto an earlier stage an daccording to their pattern.

In wedding gown production, when design of embellishments is moved to an earlier stage, it is seen that time required for production decreases drastically. The most important challenge preventing companies from this strategy is that the wedding gown ateliers and embroidery producers do not communicate efficiently. If there is a possibility to improve communication between two sides, then there may be a chance to develop modular designs. This strategy requires a more skilled design team that is able to plan the collection beforehand, and develop embroidery patterns in detail. This design function might be adopted by embroidery company, so that they may offer customized services for wedding gown ateliers, or ateliers may adopt this function and increase their customization capabilities. In wedding gown production, this requires more detailed planning and designing of the fabrics and trimmings. Collaborating with design team of lace producers or demanding them to produce the design of the manufacturer is among the options. As embroidered lace production is more flexible in terms of quantity and design size and repeat, as long as embroidered appliques are fashionable, the bus modularity is beneficial in wedding gown production.

Modularity saves from production time, adding to design phase. Ateliers may use this as a competitive advantage. They may either use this time for capacity improvement or for adding more value using advanced hand embellishments and artworks.

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