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Moda Tasarımı için Estetik Değerlerin Matematiksel Modellemesi

Mathematical Modeling of Aesthetic Values for Fashion Design

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MATHEMATICAL MODELING OF AESTHETIC VALUES FOR FASHION DESIGN

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ABSTRACT: Fashion designers are mainly concerned to create certain aesthetic values on fashion products. Most of the technical work to prepare fashion drawings, garment patterns, surface and structural designs etc. has now been taken over by computers.

It is however important that the aesthetic aspects should be compatible with physical aspects of product, both being in harmony with product's end use and with available technology. Although the relationships between physical and technological aspects are well known, those between physical and aesthetic aspects are somewhat obscure.

The paper gives a short account of studies made to build mathematical models to estimate aesthetic values of textile products as functions of structural parameters. This knowledge may help in training fashion designers and may also be employed in new enhanced design software. It is also shown how an appropriately organized data base can be used creatively in computer aided fashion design.

Keywords: Fashion design, aesthetic value, design parameter, colour, garment model

MODA TASARIMI İÇİN ESTETİK DEĞERLERİN MATEMATİKSEL MODELLEMESİ

ÖZET: Moda tasarımcıları genelde moda ürünlerinde belirli estetik değerleri yaratmakla ilgilenirler. Bugün moda çizimlerinin, giysi kalıplarının, yüzey ve yapısal tasarımların hazırlanması için gereken teknik çalışmaların çoğunu bilgisayarlar üstlenmiş bulunmaktadır.

Ne var ki, estetik özelliklerin ürünün fiziksel özellikleri ile bağdaşır olması yanında, her ikisinin de ürünün kullanımı ve var olan teknoloji ile uyum içinde olması önemlidir. Her ne kadar fiziksel ve teknolojik özellikler arasındaki ilişkiler iyi biliniyorlarsa da, fiziksel ve estetik özellikler arasındaki ilişkiler bir ölçüde belirgin değildir.

Bu makale tekstil ürünlerinin estetik değerlerinin yapısal parametrelerin bir fonksiyonu olarak tahminlenmesini sağlayacak matematiksel modellerin oluşturulması için yapılan çalışmaların kısa bir özetini vermektedir. Böyle bir bilgi moda tasarımcılarının eğitimine yardımcı olabilir ve aynı zamanda gelişmiş yeni tasarım yazılımları için kullanılabilir. Ayrıca, uygun biçimde düzenlenmiş veri yapılarının bilgisayar destekli moda tasarımı için yaratıcı biçimde nasıl kullanılabileceği de gösterilmektedir.

Anahtar sözcükler: Moda tasarımı, estetik değer, tasarım parametresi, renk, kumaş modeli

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1. INTRODUCTION

Fashion designers of today are mainly concerned to create certain aesthetic values on the fashion products they design. In the past, they were people trained in arts who somehow, by education or practice, equipped themselves with background knowledge of materials and production techniques.

The situation has greatly changed after 1980's with the advent of progress in clothing technology and trade, as well as with growing emphasis on marketing and design functions in textile business, getting extraordinary but not so surprising aids by rapidly advancing computer hardware and software technologies. As a consequence, the image created for textile and fashion designers and the attitude to and methods for their training have, thus, been based on new concepts, shifting the centre of gravity to less technical but more artistic and creative work.

Most of the technical work needed to prepare fashion drawings, garment patterns, fabric surface and structural designs, product definitions, production data, cost estimation etc. has been taken over, now, by computer software. This software may also provide huge stored information about materials, product specifications and methods of production.

The existing computer software for both fabric and garment design provide instruments to create designs with a variety of aesthetic and structural components, being greatly facilitated by CAD graphics. Instruments for fabric design are point paper medium to create fabric structure, colour creation and management tools, yarn and fabric simulation facilities, graphics program for free drawing and colouring, in particular for surface design of jacquard fabrics, and means to make certain alterations in the process of designing on computer screen. Software packages also include components for technical calculations and costing.

Software developed for fashion design include artistic drawing medium with three dimensional simulation and cladding facilities, programs for pattern development, grading and lay planning which are supported by technical calculations and cost estimation.

As a result, design work is now carried out mostly on computer screen with all its aspects, the principal task of the designer being to activate the programs by making appropriate selections of design functions and parameters in a certain order. These selections may be personal preferences or those based on knowledge accumulated by the designer's previous artistic and technical training and professional experience. In consequence, the training of fashion designer should include learning of the management of design software and the actual experience of creating designs on computer screen, in addition to basic artistic and technical skills acquired in the course of lectures and practical work as before. It is not so far from truth that fashion design is now an activity implemented mostly by the aid of computers and therefore the software used should be most reliable for the job.

It is, however, most important, for the design of industrial products in particular, that the aesthetic aspects should be compatible with physical aspects of the product, both being in harmony with the product's end use, as well as being producible with the available technology. At this point, it is not so easy to say that existing design software are satisfactorily developed at such levels as to fulfill this important requirement, since existing design software are not generally equipped with algorithms to solve such problems.

It may be argued that the compatibility of the aesthetic aspects of the created design with the physical aspects required by product function and available technology could be secured by designer's appropriate management of software and selection of design parameters, but this may not be so easy as it seems, especially when working within the framework of a certain computer software.

Moreover, although the relationships between physical aspect of textile products with materials and technology are well known and understood, those between aesthetic and physical aspect are somewhat obscure.

The aim of this paper is to give a short account of studies made on these lines to build mathematical models to estimate aesthetic values of textile products as functions of structural fabric and garment parameters. Such models developed may be employed in new enhanced computer aided design software. Nevertheless, this does not mean that the designer, whether equipped with an enhanced software or not, need not care to pay any attention to problems of matching the chosen aesthetic parameters with the structural ones, leaving all the thinking to the computer. The knowledge gained by this search may help in the training of fashion designers by providing some knowledge and understanding to tackle these problems. It can be argued that it is at least imperative that the designer should have an awareness of such problems and know how they can be approached. The paper will also show how aesthetic demands have reflections to product cost and how an appropriately organized data base can be employed creatively in computer aided fashion design.

1.1. Creation of Aesthetic Values in Fashion Design

The aesthetic values obtained in textile products will be the result of the employment of three basic aesthetic design parameters, namely colour, form and texture, in a certain harmony, composition and style.

Colour is used in various ways in fabrics as uniform colour, colour and weave effects or as coloured figures arranged in a certain composition in fabric surface. In garments, however, colour perception may be the reflection of overall fabric colour when colour components are small, and as a combination of colour and form effects when coloured areas or figures are relatively large. In some cases certain garment components like collars, pocket flaps etc. may be of a different colour or fabric.

Form is as important as colour especially in garments. Form effects in fabrics may be obtained as fancy weave effects, figure effects, large scale colour and weave effects like in check, stripe and figured designs. In the case of garments, however, apart from form effects in surface design of fabrics used, form as a design parameter manifests itself in the structural model of the garment as the general appearance or the interaction between various parts of garment like shoulders, pockets, collar and lapel of coats and between top part, legs and turn ups of trousers. It is desired that these parts should be in a harmonious assembly and the general appearance be attractive, reflecting a certain quality which is called style.

Texture is a property associated with the surface structure of fabrics described as smooth, hairy, porous, shaggy, irregular, cellular etc. It is a reflection of yarn and fabric structure as well as a result of special finishing treatments like milling, raising, polishing, cutting, calendaring, etc. Piled structures like velvets and plush fabrics have special surface textures. Texture is an aesthetic parameter as well as a physical one, affecting the way light is reflected from the surface of fabrics or garments. The human eye is a perfect sensor to differentiate and appreciate texture.

It is the particular use of these three design parameters which create the aesthetic value or merit of the designed product. They may have been employed singly or together, in an orderly and harmonious fashion and in good composition reflecting a certain style. We can then reach at the judgment that the product designed looks beautiful or, to be more modest, nice or attractive.

1.2. Definition of Beauty

Can beautiful be defined and if so how? The answer to the question “what is beautiful” may commonly be like: something which is attractive, something that gives one a feeling of joy, something which is interesting and something which inspires good feelings etc. So this sensation of beauty is the result of stimuli received by brain via vision of shapes, colors and perception of structure as a harmonious and interesting mixture. The rules of harmony in the employment of colours are explained by Watson in terms of harmonies of analogy and contrast [1]. Those of the forms are expressed by Güngör as repetition, interrupted repetition, balance, association, domination and unity [2].

In defining what is beautiful Eric Newton takes nature as the real source of beauty and concludes, in the context of forms, as: “So far, one can say that beauty is the underlying mathematical behaviour of phenomena apprehended intuitively [3]. And that it varies objectively with the number of interactive laws and the resultant mathematical complexity, and subjectively with the intuition of the beholder”. In simpler terms, he draws attention to mathematical and personal (subjective) aspects of the perception of beauty. Following his approach, the creation of harmony and interest may be interpreted as the manifestation of complexity of mathematical relations. Eric Newton draws attention, also, to the fact that mathematical forms like hexagons in honeycomb and logarithmic spiral in sea shells, symmetric forms of leaves are related with growth and function, thus mathematical might also mean functional [3].

To complete the picture, it is to be noted that in fashion design of textile products, as in other fields of industrial design, fashion trends play important roles in the selection of principal design parameters like colours, materials, forms etc. Fashion is a phenomenon stemming from people’s need of change and desire to escape boredom. Hann describes it as “a process of continuous change”. It surely is in the centre of all marketing activities for the sale of textile products [4].

1.3. Ways of Defining Aesthetic Values in Mathematical Terms

If we may assume that what makes a design beautiful, or using weaker adjectives like attractive, appealing or interesting, is related to its mathematical context, then we can start a search to define aesthetic value in mathematical terms. In consequence, if we gain any success on this attempt, we can incorporate in computer aided design software an aesthetic value function defined in mathematical terms since the language of computer is mathematics. Such a function should express aesthetic value or merit for a certain design object in term of design parameters expressed by numbers.

It is obvious that structural parameters like yarn count, fabric weight, garment size, pocket size, lapel width can be expressed by numbers in standard units of measurement. But there are so many design parameters that need a system of being expressed in numbers to be suitable for mathematical handling. The parameters like fabric material and type, colours, garment model, style of fit for garments etc. cannot be expressed by numbers in essence but can be expressed by a class number or index if they have prior been classified based on some accepted rule. This classification may depend on objective or subjective assessment.

It will not be so difficult to select somehow, from among the design parameters expressed in numbers, those which are independent by our background knowledge of materials and technology. The design and thus the aesthetic value function will be based on these design parameters that can be freely and independently selected. Other parameters to be defined for the implementation of design and actual production will then be calculated or evaluated as function of those independent parameters on which they depend.

There is, however, one other difficulty, namely how to reflect the personal or subjective aspect of beauty. The way to overcome this difficulty and incorporate this important factor in defining the aesthetic value function may be expert or layman (non-expert) jury judgments as done in subjective assessments of fabric quality attributes like fabric handle, softness and drape.

It will be best to explain how the aesthetic values can be modeled mathematically and how these model may be employed for computer aided fabric and garment design software by examples, reporting researches carried out on these lines, mostly unpublished.

2. RESEARCH ON THE RELATIONSHIP BETWEEN AESTHETIC VALUE AND FABRIC STRUCTURE

It is thought to be appropriate to examine how aesthetic value can be mathematically expressed in context with fabric design first for two reasons: The contemporary approach to creating textile fashion is to build it up in connection with the overall fashion trends of the year like fashion colours, garment models and style and fashionable life modes in all industrial design fields. Thus it is convenient to start defining fashion trends by declaring fashion colours, fibres and fabrics as well as design features in connection with garments or home textiles. Second reason is that the problem is much clearer and soluble for surface design than for design of garment shape in three dimensional forms for which the definition of beauty is a more complicated issue.

Commercial software packages available in the market for fabric and garment design incorporate modules for almost all activities of design such as fashion drawing, colouring and structural design as well as for calculations of material consumption, production parameters and of cost. They are, however, lacking in instruments to secure two aspects of design, firstly the compatibility of aesthetic design features with those of the physical requirements. This problem was the subject of a previous paper in relation to the design of figured woven fabrics [5]. Secondly the computer does not help the designer in any way to maximize the aesthetic merit of the design created, except that it offers various choices for a certain design parameter from which the designer selects one according to his or her taste and experience. Thus, mathematical evaluation of aesthetic value to provide clues to the designer to use aesthetic components more consciously and to incorporate, possibly, some findings in design algorithms was considered to be an interesting topic of research. This becomes of vital importance in figured dobby designs where technological limitations play an important role.

A series of figured woven worsted and cotton fabrics were woven for the M.Sc. research work by Sökmen from different yarn counts in different weaves and yarn sets [6]. The structural parameters of 36 experimental fabrics woven and the weave combinations applied to obtain figure are shown in Table1 and 2. The shape of the figure obtained as a weave combination was chosen to have sides formed by curved and diagonal lines as shown in Figure 1, as one difficult to obtain with clear contour lines in actual woven fabrics.

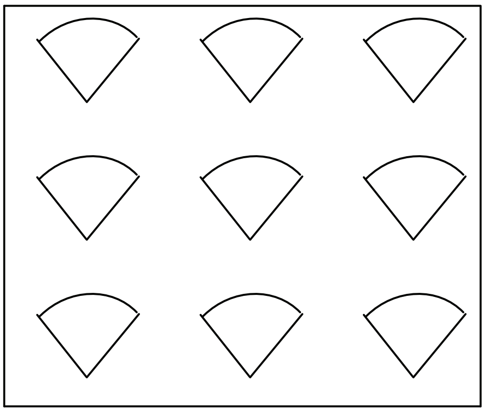


Figure 1. Surface planning

Table 1. Specifications of the cotton fabrics woven

Yarn count	Weave combination	Weave factor	Ends per cm	Picks per cm	Picks per cm at loom	Reed count	Numberof shafts
Ne 20/2	2/1 twill 1/2 twill	0,60	21	18	16	50/4	13-16
	3/1 twill 1/3 twill	0,67	23	21	18	60/4	13-18
	4/1 twill 1/4 twill	0,71	24	22	19	60/4	15-18
	1/2 twill 4/1 satin	0,65	21	19	17	50/4	13-15
	1/3 twill 5/1 satin	0,71	23	21	18	60/4	13-15
	1/4 twill 6/1 satin	0,74	25	22	20	60/4	15-17
	1/4 sateen 4/1 satin	0,71	24	22	19	60/4	15-18
	1/5 sateen 5/1 satin	0,75	26	23	21	65/4	17-19
	1/6 sateen 6/1 satin	0,77	26	24	21	65/4	18-20
Ne 12/2	2/1 twill 1/2 twill	0,60	16	14	12	50/3	13-16
	3/1 twill 1/3 twill	0,67	18	16	14	60/3	13-18
	4/1 twill 1/4 twill	0,71	19	17	15	50/4	15-18
	1/2twill 4/1 satin	0,65	16	15	13	50/3	13-15
	1/3 twill 5/1 satin	0,71	18	16	14	60/3	13-15
	1/4 twill 6/1 satin	0,74	19	17	15	50/4	15-17
	1/4 sateen 4/1 satin	0,71	19	17	15	50/4	15-18
	1/5 sateen 5/1 satin	0,75	20	18	16	50/4	17-19
	1/6 sateen 6/1 satin	0,77	20	18	16	50/4	18-20

Table 2. Specifications of the worsted fabrics woven

Yarn count	Weave combination	Weave factor	Ends per cm	Picks per cm	Picks per cm at loom	Reed count	Numberof shafts
Nm 56/2	2/1 twill 1/2 twill	0,60	25	23	20	60/4	13-16
	3/1twill 1/3 twill	0,67	28	25	22	70/4	13-18
	4/1 twill 1/4 twill	0,71	30	27	24	75/4	15-18
	1/2 twill 4/1 satin	0,65	26	23	21	65/4	13-15
	1/3 twill 5/1 satin	0,71	28	25	22	70/4	13-15
	1/4 twill 6/1 satin	0,74	30	27	24	75/4	15-17
	1/4 sateen 4/1 satin	0,71	30	27	24	75/4	15-18
	1/5 sateen 5/1 saten	0,75	31	28	25	75/4	17-19
	1/6 saten 6/1 satin	0,77	32	29	26	75/4	18-20
Nm 21/2	2/1 twill 1/2 twill	0,60	15	14	12	50/3	13-16
	3/1 twill 1/3 twill	0,67	17	15	14	55/3	13-18
	4/1 twill 1/4 twill	0,71	18	16	15	60/3	15-18
	1/2 twill 4/1 satin	0,65	16	14	13	50/3	13-15
	1/3 twill 5/1 satin	0,71	17	15	14	55/3	13-15
	1/4 twill 6/1 satin	0,74	18	17	15	60/3	15-17
	1/4 sateen 4/1 satin	0,71	18	16	15	60/3	15-18
	1/5 sateen 5/1 satin	0,75	19	17	15	50/4	17-19
	1/6 sateen 6/1 satin	0,77	20	18	16	50/4	18-20

The criteria for the aesthetic value may be laid down as generally accepted rules stated as opinions or assumptions made by the researcher. They can alternatively be defined by an evaluation of a poll with questions on the components of aesthetic merit applied on an expert jury.

To develop a theory to define an aesthetic value function for figured woven fabrics, it was assumed, as proposed by the author, that such a function could be expressed as a linear combinations of five main components of aesthetic merit for the figured surface design, namely figure size, clearness (or sharpness) of figure contour, surface smoothness, thread setting and bright appearance, each having a certain weight factor. Also, larger size of the figure, higher set of threads and a smooth surface were considered to be desirable [7].

Thus the aesthetic value, E, is defined mathematically by

$$E = W_1Z_1 + W_2Z_2 + W_3Z_3 + W_4Z_4 + W_5Z_5 \quad (1)$$

where Z_1, Z_2, Z_3, Z_4 and Z_5 are components for figure size, clearness of figure contour, surface smoothness, thread setting and bright appearance respectively and

$$W_1 + W_2 + W_3 + W_4 + W_5 = 1 \quad (2)$$

The structural parameters that affect these components were considered to be yarn diameter d, number of warp threads used in the figure A, which is equivalent to the number of shafts used, warp set S, and average float length F in the weave structure. The figure size will increase with increase in number of shafts A and decrease with warp set S, figure contour will be obtained clearer as yarn set S and number of shafts A are increased, but will be blurred as the average float length F increases, surface smoothness will be improved by finer yarns and longer floats, surface brightness will be enhanced by finer yarns in long floats with high set. Therefore Z_i components were expressed as the functions:

$$Z_1 = f\left(A, \frac{1}{S}\right),\ Z_2 = f\left(S, A, \frac{1}{F}\right),\ Z_3 = f\left(\frac{1}{d}, F\right),$$
$$Z_4 = f(S),\ Z_5 = f\left(\frac{1}{d}, F, S\right) \quad (3)$$

A setting rule has to be applied for dimensional stability and weaveability of the fabric which may be defined for finished fabric set as

$$S = kF_wK\sqrt{N} \quad (4)$$

where k is crimp factor, F_w weave factor, K is a yarn coefficient and N is yarn count in metric system. Weave factor is given in terms of average float F by Ashenhurst [8] as $F_w = F/(F+1)$ and yarn diameter d in terms of yarn count as $d = 1/(K\sqrt{N})$.

Assuming, for simplicity, the components to be directly or inversely proportional to structural variables A, S, F and d, we obtain the aesthetic value components as the products of the factors shown in equation 3, standardized as

$$Z_1 = Z_{01}/\overline{Z}_{01},\ Z_2 = Z_{02}/\overline{Z}_{02},\ Z_3 = Z_{03}/\overline{Z}_{03},$$
$$Z_4 = Z_{04}/\overline{Z}_{04},\ Z_5 = Z_{05}/\overline{Z}_{05} \quad (5)$$

where

$$Z_{01} = \frac{A(F+1)}{kFK\sqrt{N}},\ Z_{02} = \frac{kKA\sqrt{N}}{F+1},\ Z_{03} = \frac{kFK\sqrt{N}}{F+1},$$
$$Z_{04} = \frac{kFK\sqrt{N}}{F+1},\ Z_{05} = \frac{kF^2K^2N}{F+1} \quad (6)$$

$\overline{Z}_{0i}$ being the averages of values determined on each fabric, since the dimensions of the products Z_{0i} are each different. In consequence, the aesthetic value function is definable in terms of the design variables, A, F, N, K, namely number of shafts, weave structure, yarn count and yarn type or raw material used in structural design.

The weight factors were determined by jury assessment along with the jury assessment of aesthetic value for the fabrics woven on a handloom. For this purpose fabric samples were divided into eight groups to eliminate bias which might have arisen from different fibre, yarn count and colour and also from the weave combination used. These were three groups of worsted fabrics woven from 21/1Nm yarn as twill-twill, twill-sateen and mixed weave combinations, three groups of fabrics woven from 56/2 Nm yarn as twill-twill, sateen-sateen and mixed weave combinations and two groups of cotton fabrics as twill-twill and mixed weave combinations. Moreover, two juries were formed, one composed of textile experts, the other composed of non-experts following the advice by Howorth ve Oliver [9]. Applying the method of paired comparisons, jury members were asked to make a preference between two fabrics and they were also required so state the reasons for their preferences. Thus by classifying the reasons stated by jury members into five categories of specified aesthetic components and ranking the scores in each class of fabrics five weight factors were calculated as fractions of unity.

Statistical analyses were carried out on jury assessments of aesthetic value of the fabrics produced to search consistency of jury judgements and both expert and non-expert juries were found consistent in their judgements. Multiple regression equations were obtained along with theoretical evaluation, for the aesthetic value in terms of the design variables from the scores obtained for each class of fabrics, as

$$y = \beta_0 + \beta_1 F + \beta_2 A + \beta_3 N \qquad (7)$$

and multiple correlation coefficients were calculated. A correlation analysis was also applied to investigate agreement between jury evaluations of the aesthetic value and its theoretical determination as explained above. Results of the multiple regression analysis are given in Table 3 and the coefficients obtained between jury evaluations and theoretical estimations in Table 4, for each class of fabrics.

Although the agreements obtained for some of the classes of fabrics are not so good, it may be concluded that regression equations can be obtained to define aesthetic value in terms of structural design parameters by jury assessments of a set of figured woven fabrics designed and woven. It is possible to carry out these jury assessments on a set of figured woven fabrics not actually woven but designed and simulated on computer screen.

From the examination of correlation coefficients between jury evaluations and theoretical estimations in Table 4 it seems that by a carefully developed algorithm it may be possible to define aesthetic value in mathematical terms. Some of the worsted and cotton fabrics that the expert jury evaluated as best are shown in Figure 2. The computer evaluations of the aesthetic value of these fabrics are also given below each photograph together with the highest and lowest values obtained within the same class.

Table 3. Results of multiple correlation analysis of specialist jury evaluations of aesthetic value

Fabric Class	Variables	Corrected R^2	Multiple regression equation
1	A,F	0,726	$y = 3{,}94F + 7{,}21A - 35{,}8$
2	A,F	0,485	$y = 19{,}64F + 11{,}79A - 182{,}7$
3	A,F	0,216	$y = -13{,}47F + 5{,}85A + 22{,}3$
4	A,F	0,804	$y = 7{,}97F + 6{,}95 - 41.0$
5	A,F	0,0518	$y = 6{,}76F - 7{,}39A + 2{,}67$
6	A,F	0,529	$y = -17{,}13F + 3{,}73A + 54{,}1$
7	A,N,F	0,411	$y = 31{,}11F + 7{,}13A + 4{,}87N - 141{,}2$
8	A,N,F	0,758	$y = -11{,}36F - 14{,}72A + 2{,}17N + 234{,}4$

Table 4. Results of the analysis of correlation and t-test between specialist jury assessments and theoretical estimations of aesthetic value

Fabric class	Correlation coefficient r	Standard error	Calculated value of t	Table value of t
1	0,83	0,176	4,71	2,23
2	0,77	0,260	2,96	2,44
3	0,52	0,270	1,93	2,23
4	0,90	0,138	6,53	2,23
5	0,55	0,341	1,61	2,44
6	0,32	0,300	1,068	2,23
7	0,67	0,235	2,85	2,23
8	0,29	0,304	0,958	2,23

Null hypothesis: The differences between jury assessments and theoretical values are significant

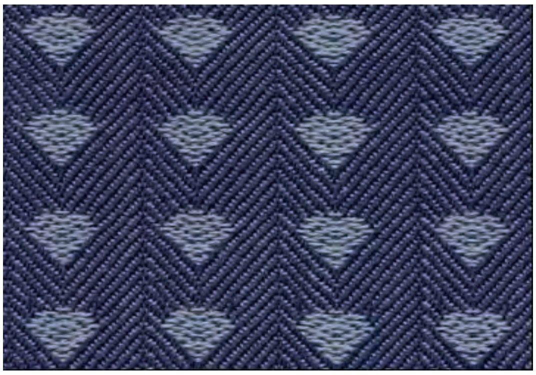
3. RESEARCH ON THE RELATIONS BETWEEN AESTHETIC VALUE AND GARMENT STRUCTURE

In fashion design of garments the issues of aesthetic value or appeal are somewhat complicated. Firstly, it would be unrealistic to ignore the aesthetic reflections of fabrics used in constructing the garment. Fabric colour, brightness and drape would have great contribution to garment appearance. Fabric drape is a factor to be taken into consideration in giving curved shapes to surface parts of the garment as well as in creating certain effects such as protrusions and plies. Also, in certain garments such as ladies' dress colour and weave or figure effects of large size will interact with form effects reflected by garment model in creating the general appearance and style.

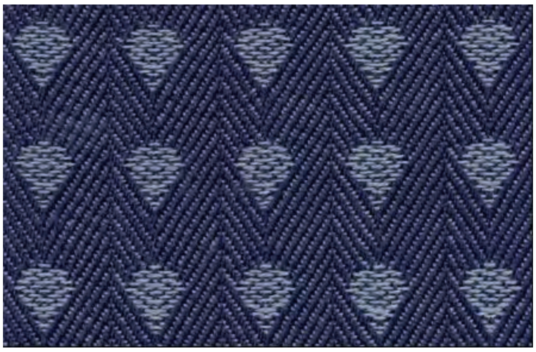
However, the interaction of aesthetic aspects of fabric and garment may be considered an issue to be dealt with by the designer, on the onset of design activity, with the aid of his or her professional knowledge and experience. Concentrating more on the aesthetic aspects created by the three dimensional form of a garment, the components of aesthetic value may be assumed to be model, construction and style.

Model is the definition of shape of the garment with its various main parts joined together along certain lines defined on human body plus various attachments to these main parts as pockets, collars, cuffs, turn-ups, belts, vents, scarves etc. with accessories like buttons, ornaments etc. When all these parts are assembled together, a harmonious look is required by the general vision they create as well as by their relations to each other. In structured garments like coats the structural build up of the garment by the aid of auxiliary materials like canvas, lining, shoulder pads and tapes play important roles in creating curved and built up forms and to some extent the overall style of the garment reflecting a certain life mode and use. Style, however is also related to the bodily fit of the garment and to the impression that the designer wishes to convey to the onlooker.

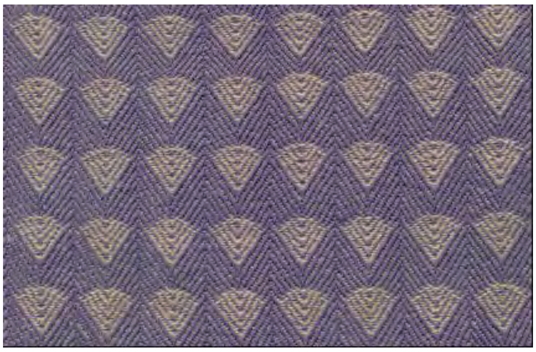
Class 1-C: 112.8
HV: 112.8, LV: 85.9



Class 2- C: 101.5
HV: 106.9, LV: 95.4



Class 3-C: 97.4
HV: 122.7, LV: 87.0



Class 4-C: 107.4
HV: 110.4, LV: 88.6

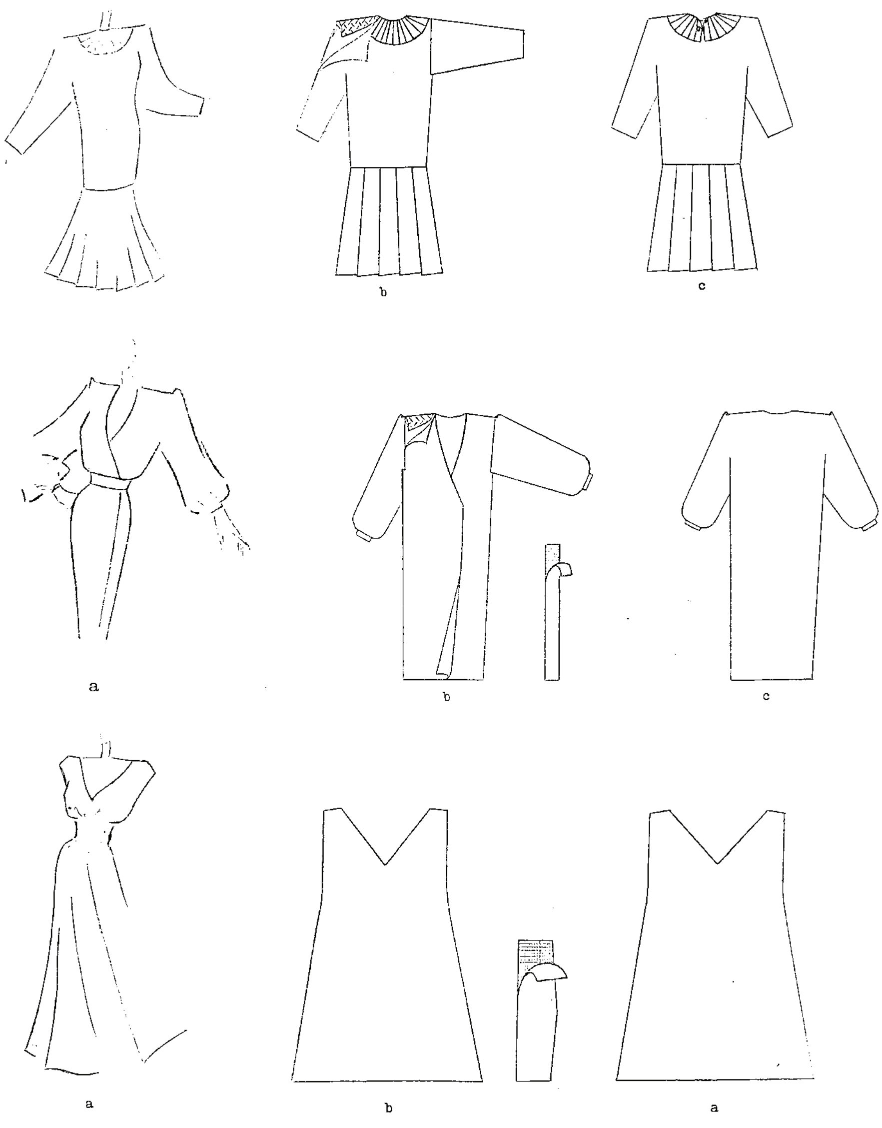
Class 7-C: 110.8
HV: 121.0, LV: 87.2

Class 8-C: 107.4
HV: 115.9, LV: 90.5

Figure 2. Some of the fabrics with highest aesthetic value judged by expert jury with their computed values (C: Computed value, HV: Highest value, LV: Lowest value within the class)

Thus, it was thought to be interesting to study conditions that would maximize the aesthetic value of garment and the interaction between its principal components as model, construction and style. In an M.Sc research work carried out by Öndoğan a series of ladies' dresses were designed in two categories as full dresses and two-piece suits, with a progressive complexity of model features [10]. Style being the same, the interrelations between model, construction and cost were examined and also a search was made how these factors affected the overall quality described as their market value.

15 full dresses and 11 two-piece suits were designed with fabric type and garment structure considered as being appropriate for the model defined, ranging from simplest to most complex ones. Fabrics defined were wool gabardine and blazer fabrics in the high price range, viscose rayon and linen fabrics in the middle and printed cotton in the low price range. Fashion and technical drawings were prepared and patterns were developed for an average size for each model using Muller system and standard measurement tables. Grading for different sizes and lay planning were achieved using Gerber AM-5 computer system with PDS package program giving also unit material consumption values. Fabric and auxiliary material costs were calculated from unit consumption values. Fashion and technical drawing of three models from each categories of low, middle and high complexity, as evaluated by a specialist jury, are given in Figure 3 and 4.



(4)

(8)

(13)

Figure 3. hree designs of full dress with garment codes 4, 8, 13 with complexity assessments being: 128, 69 and 10 respectively (a. Fashion drawings, b, c: Technical drawings of front and back sides) [10].

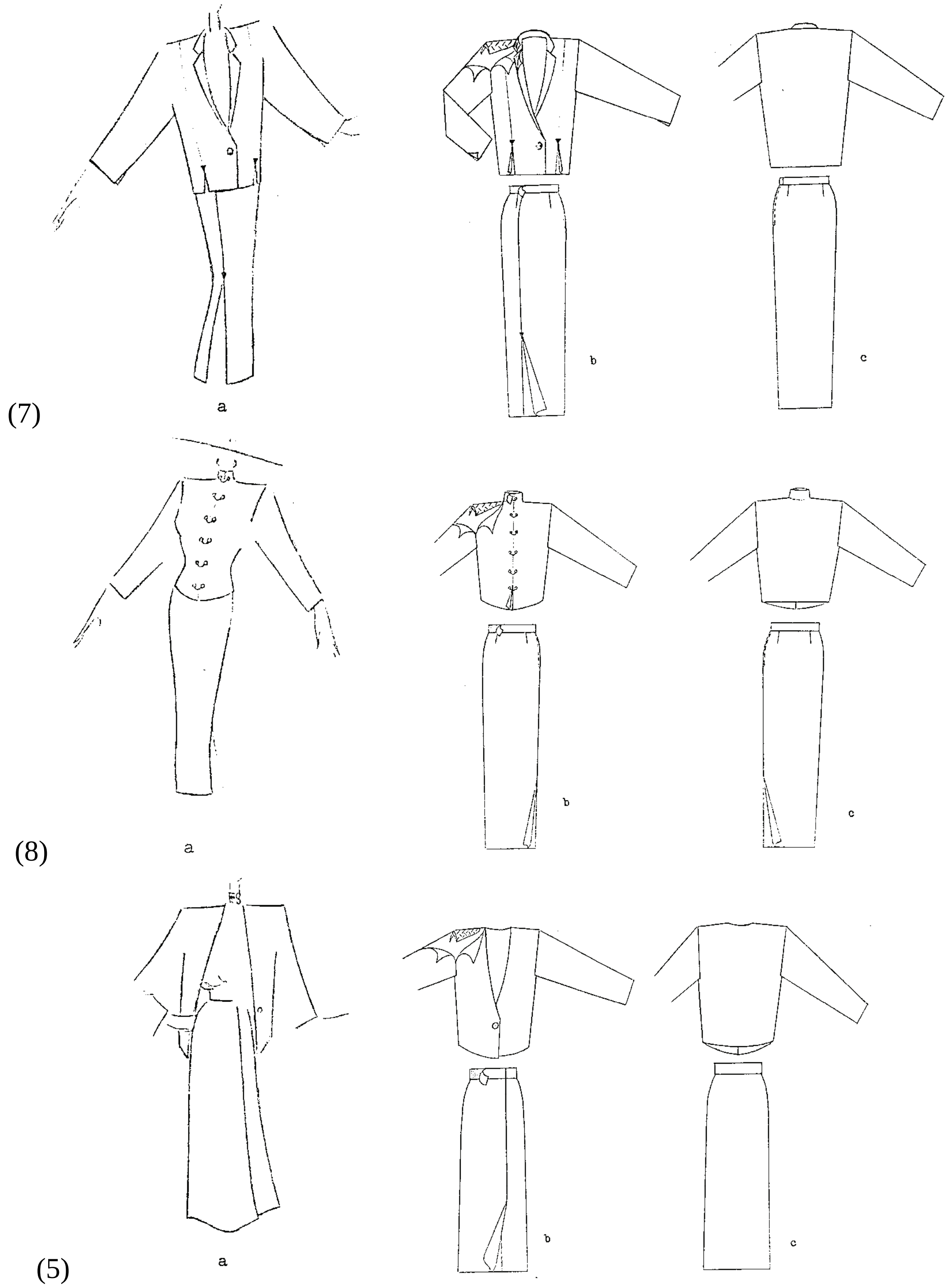


Figure 4. Three designs of two-piece suits of codes 7, 8, 5 with complexity assessments being 92, 53 and 21 respectively (a. Fashion drawings, b, c: Technical drawings of front and back sides) [10].

Before jury assessments the terms model complexity and construction complexity were defined in the following way:

“A garment model is defined as simpler as it is composed of smaller number of main parts like front, back, sleeves etc. and auxiliary parts as collar, cuffs, pockets etc., being also in simple lines and few details. The term simple means to be similar to geometrical forms, the term detail means construction elements like plies, darts which change the appearance greatly.”

“A garment construction is defined as simpler when stitches to join main parts and those used for ornamental purposes are fewer and the use of auxiliaries like button, belt, zip, ornaments and of supporting materials like lining, canvas and pads is scarcer."

The models drawn were assessed by a specialist jury of nine members by the method of ranking from the simplest to the most complex. The scores obtained for dress group were between 128 (most complex) to 10 (simplest) and 92 (most complex) to 20 (simplest) for two-piece suit group. Assessment of construction complexity was done by first classifying the garments into three categories as simplest, medium and complex. Then items in each group were given a grade mark based on 100 full marks expressed in percentages, the final scores being obtained by multiplying these marks by 0.33, 0.67 and 1.00 accordingly. The scores obtained were between 98.2 and 11.7 for dress group and 99.2 and 11.7 for two-piece suit group.

For quality assessment it was thought to be more correct and safer to determine the quality attributes and their respective weights by a questionnaire applied to a specialist jury of 12 members composed of teachers, managers and technologists from textile field. Jury members were asked to rank quality attributes in the order of importance between 1 and 5. Table 5 shows the result obtained.

Table 5. Definition of Quality Function

Code	Quality attributes	Scores	Weight factors (%)
1	Auxiliary materials	26	15.4
2	Bodily fit	25	14.8
3	Stitch regularity	23	13.6
4	Having no defects	16	9.5
5	Fabric quality	16	9.5
6	Fabric colour and design	12	7.1
7	Being fashionable	12	7.1
8	Garment sales price	11	6.5
9	Presentation to market	10	5.9
10	Model properties	9	5.3
11	Fabric handle and drape	5	3.0
12	Fabric weave	3	1.8
13	Label	1	0.6

Omitting bodily fit, presentation to market and label, other quality attributes were evaluated by giving a grade mark based on 100 full marks, depending on their probable positive or negative effects during production and use of the garment. These grade marks were multiplied by their respective weight factors to calculate a quality value for each design. Costing was applied for only material consumptions by determining unit cost of materials for each design. Table 6 and 7 show the results of the assessments and calculations of the four properties, for ladies dress and two-piece suit groups.

Statistical analyses were carried out to find correlation between the four properties evaluated on garment designs in two groups. The correlation matrix obtained between the four factors is given in Table 8 and 9 for full dress and two-piece suits respectively. It can be seen that there is a correlation between model complexity and construction complexity and that they seem to be effective in increasing the cost. The correlation between model complexity and quality seams to be poor and this is in line with the jury assessment of contribution of model properties to overall quality. It is quite surprising that quality and cost are somewhat not correlated at all. As will be seen in Figure 5a and5d model complexity leads to a tendency to design more complex constructions, increasing cost as seen in Figure 5c and 5f. The quality, however, is not improved by model complexity as seen in in Figure 5b and e. On an examination of the graph in Figure 5b, it may even be argued that quality is adversely affected after a certain level of complexity. Although the overall quality function defined here is a reflection of many factors, model having a contribution of 5.3 per cent as shown in Table 5, this is a problem which is worth studying deeper with its interactions with other factors.

Table 6. Results of evaluations on ladies full dress group

Code	Model complexity	Construction complexity	Quality	Cost
1	115	98.2	27.5	14130
2	81	91.6	38.7	12866
3	104	93.2	35.1	26958
4	128	54.9	22.5	23335
5	107	56.6	50.6	14532
6	115	97.2	53.9	38402
7	79	92.2	65.4	12909
8	69	53.3	38.7	11409
9	82	56.6	51.6	22572
10	31	15.0	44.9	10844
11	65	94.9	53.7	12511
12	23	13.3	44.4	8314
13	10	11.7	49.0	8418
14	44	18.3	64.7	9298
15	28	16.7	49.4	9515

Table 7. Results of evaluations on ladies two-piece suit group

Code	Model complexity	Construction complexity	Quality	Cost
1	78	94.9	48.1	32523
2	70	98.2	75.3	28400
3	90	56.6	53.6	39157
4	46	91.6	56,7	29311
5	21	18.3	37.2	30925
6	29	53.3	67.2	26399
7	92	99.2	43.0	34693
8	53	93.2	75.4	29891
9	68	56.6	39.1	17532
10	20	15.0	61.2	19318
11	27	11.7	65.8	18828

Table 8. Correlation analysis for ladies full dress

		MODEL	CONSTRUCTION	QUALITY	COST
MODEL	Pearson Correlation	1	,770**	-,407	,708**
	Sig. (2-tailed)	,	,001	,133	,003
	N	15	15	15	15
CONST	Pearson Correlation	,770**	1	-,155	,548*
	Sig. (2-tailed)	,001	,	,580	,035
	N	15	15	15	15
QUALITY	Pearson Correlation	-,407	-,155	1	-,162
	Sig. (2-tailed)	,133	,580	,	,563
	N	15	15	15	15
COST	Pearson Correlation	,708**	,548*	-,162	1
	Sig. (2-tailed)	,003	,035	,563	,
	N	15	15	15	15

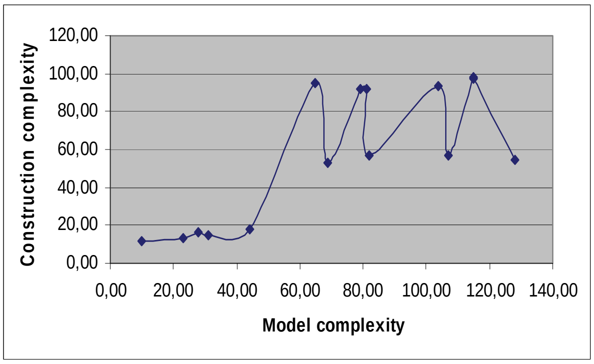
**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

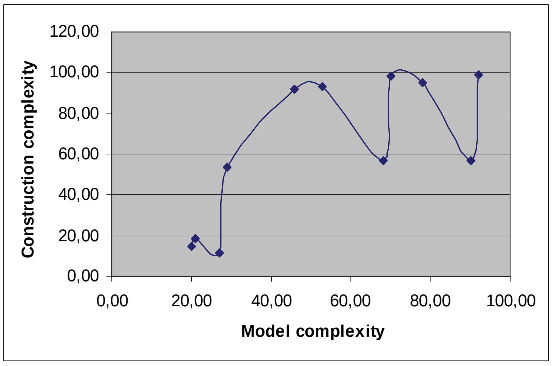
Table 9. Correlation analysis for ladies two-piece suit

		MODEL	CONSTRUCTION	QUALITY	COST
MODEL	Pearson Correlation	1	,714*	-,221	,584
	Sig. (2-tailed)	,	,013	,514	,059
	N	11	11	11	11
CONST	Pearson Correlation	,714*	1	,139	,520
	Sig. (2-tailed)	,013	,	,684	,101
	N	11	11	11	11
QUALITY	Pearson Correlation	-,221	,139	1	-,143
	Sig. (2-tailed)	,514	,684	,	,675
	N	11	11	11	11
COST	Pearson Correlation	,584	,520	-,143	1
	Sig. (2-tailed)	,059	,101	,675	,
	N	11	11	11	11

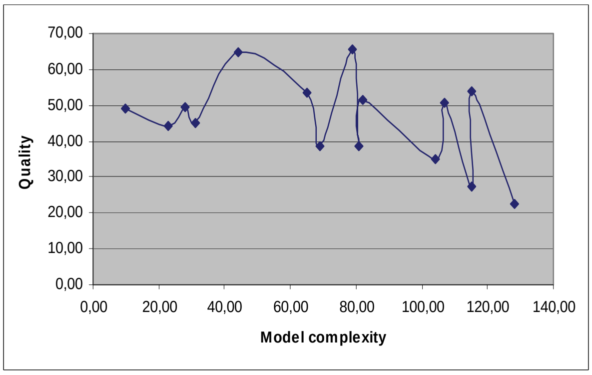
*Correlation is significant at the 0.05 level (2-tailed).



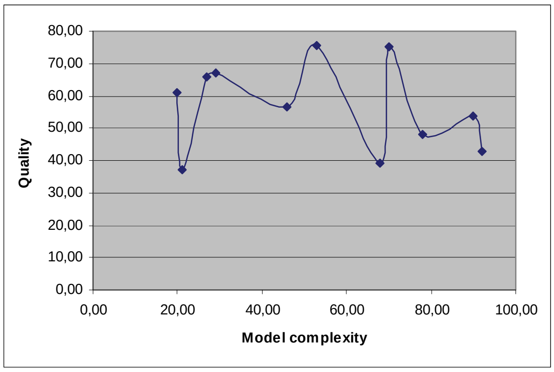
(a) Full dress



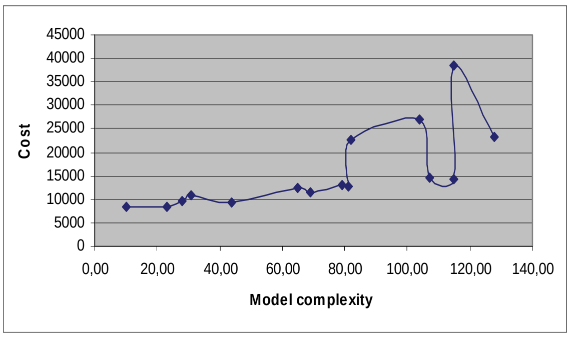
(d) Two-piece suit



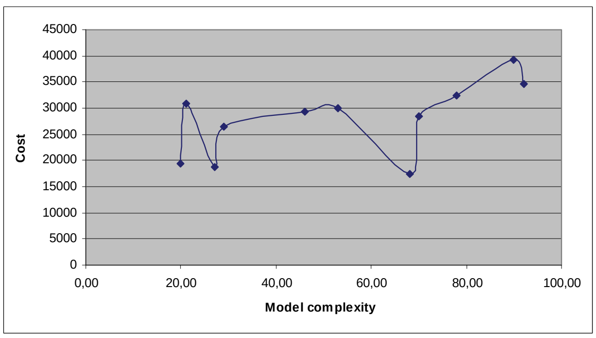
(b) Full dress



(e) Two-piece suit



(c) Full dress



(f) Two-piece suit

Figure 5. Variation of construction, quality and cost with model complexity

4. DEVELOPMENT OF FASHION DESIGN SOFTWARE BASED ON A DATA BASE

Being an early study, the work done by Öndoğan showed that there were complex issues concerned with definition of aesthetic valuet of garment designs in mathematical terms [9]. Despite the fact that jury assessments could be used to quantify certain attributes like model and construction complexity, it was not easy to make a clear definition of quality. Although the components of overall quality were defined by an expert jury, what was actually meant is “consumer response”, which is certainly of utmost importance in industrial design.

A different line of approach to fashion design of garments was adopted by Bulgun and Başer to match consumer or sales demands, both in aesthetic aspects and in others like fabric and auxiliary materials, and of course in cost, making use of a pre-prepared data base for a particular product [11]. The idea was to build up a data base by designing a certain product with almost all possible models with all the material types and unit consumptions and prices. Thus a certain production order would roughly be matched with a previously designed garment and, if necessary, a new design process could be started and carried out with secured parameters. Later, this new design could be added to the existing data stock.

A similar program was developed for fabric design as part of Özden’s M.Sc. thesis work [12-13]. This program stored data of design parameters belonging to commercial fabrics classified according to these parameters in a hierarchical order. The relevant design parameters of commercial fabrics could be called up in the process of designing at the time of a decision to be made to assign a value to a certain design parameter, thus giving guidance to the designer to make appropriate decisions.

In work done by Bulgun and Başer ladies trousers were chosen as an example to develop a computer program and 20 possible models of trousers were defined with their principal properties in a hierarchical classification as shown in Table 10 [11].

Table 10. Hierarchical classification of trousers types

Model No.	Model name	Bottom type		Bottom size		Height of hip line		
		WTU	NTU	N	W	Normal	High	Low
1	P, NB, NTU		X	X		X		
2	P, NB, WTU	X		X		X		
3	P, WB,NTU		X		X	X		
4	P, WB, WTU	X			X	X		
5	WD, NB, NTU		X	X		X		
6	WD, NB, NTU		X	X				X
7	WD, NB, NTU		X	X			X	
8	WD, NB, WTU	X		X		X		
9	WD, NB, WTU	X		X				X
10	WD, NB, WTU	X		X			X	
11	WD, WB, NTU		X		X	X		
12	WD, WB, NTU		X		X			X
13	WD, WB, NTU		X		X		X	
14	WD, WB, WTU	X			X	X		
15	WD, WB, WTU	X			X			X
16	WD, WB, WTU	X			X		X	
17	Blue-jean model		X	X				
18	Smocked		X	X				
19	Smocked		X	X				
20	Tights							

P: Pleated, WD: With darts, NB: Narrow bottoms, WB: Wide bottoms,
WTU: With turn-ups, NTU: No turn-ups, N: Narrow, W: Wide

Fashion design of trousers together with grading and lay planning was carried out using Gerber-CAD system. Pattern preparation and unit materials cost calculations were achieved using Lectra systems. All these data were compiled in separate Microsoft Access files. A program with the interface shown in Figure 6 was developed in Microsoft Visual Basic 5.0 to starts the execution of the following operations by the method of questioning in order: definition of trousers model, definition of bottom width, definition of bottom type, definition of hip height.

The program brings to screen the model of trousers which is most appropriate to user's requirements and also the whole data related to the selected design. The data includes technical drawings, fabric type, total operation time, total sewing time, total production time and auxiliary materials list. The program then calculates unit fabric consumption and total cost. In consequence, working in this fashion a sales offer can be prepared with all the necessary details.

This program was later reorganized and modified as a web based software to be accessible via Internet using Microsoft NET technologies [14].The software included possibilities to be used interactively by designers and customers via mobile phones as well.

5. DISCUSSION AND CONCLUSIONS

From the studies reported and referred to here, it may be argued that the search for mathematical models to express aesthetic values as a function of design components, namely colour, form and texture may give benefits for the understanding of design function in creating aesthetic values and in consequence will provide arguments to use in teaching and training of designers, especially those working in industry.

As for colour it would not be so difficult to express colour harmony in mathematical terms dividing chromatic circle in equal sections and expressing each section by a number and also defining analogy or contrast harmonies by series generated from these numbers.

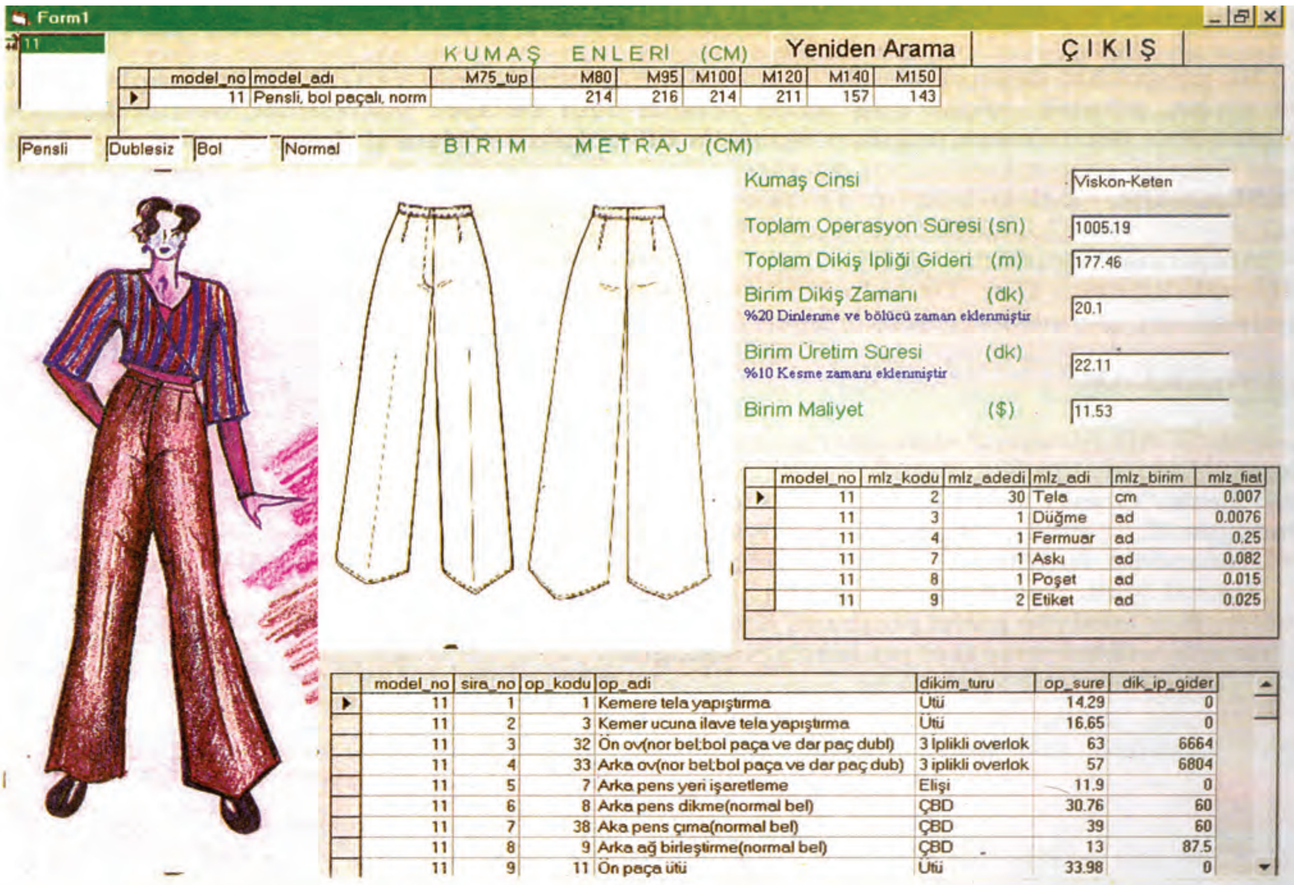


Figure 6: Interface for design program for ladies trousers [11]

As for form an example has been presented here in connection with figured fabric design that an aesthetic value function may be defined in terms of structural design parameters, either theoretically by formulating common assumptions or by empirical methods from which regression equations can be obtained using jury assessment scores. In the case of garment models as three dimensional forms composed of parts, an appropriate level of “mathematical complexity” as pronounced by Newton [3] may be a measure. Other more complicated schemes of geometrical definition such as “a good composition”, “well positioning of parts” or “a balanced structure” that create harmony may be very difficult or perhaps superfluous.

Jury assessments are methods taking into account the subjective or personal aspect of beauty. In consequence, the composition of jury and the knowledge, experience and personality of jury members will be reflected in their judgments. Their responses to different products may also be different. Thus the interpretation of research findings should be made accordingly and the right jury for the right product is essential.

In relation to quality (or appeal) of the design, it is safer not to take the concept of “overall quality” as a measure of success of the design, but take the attributes of “overall quality” individually as objective functions. Thus only the aesthetic merit of the designs prepared by Öndoğan [10] could be assessed by the jury to arrive at more meaningful interpretations. It has also to be stated here that such assessments cold better be made on actual garments produced. The cost and time of such research will naturally be appreciated. That is why many researchers are tempted to develop theories in many fields of research.

To be more practical, and perhaps down to earth, a data base that can be accumulated in many diverse ways can help in developing computer aided design software in most of the available software in the market. It is always easier to improve on a certain design than to create an original one. This is what has been being practiced in industry for years up to our day, both in fabric and garment production. It is however the author’s wish to take the challenge of incorporating more of problem solving and creative algorithms in computer aided design software.

Of course, it cannot be denied that the final goal from the engineering point of view is to have a machine doing everything. Can this be possible even in design field which has many dimensions with diverse and complex problems of technical and artistic nature? Let us leave this question aside for the time and be fair. Let us try only to aid the designer and not place this task into the hands of a machine without inspirations and feelings.

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