

Designing Textile Products for the Full Life Cycle with a Special Focus on Maintenance during Usage

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Abstract: It is a common idea about designing in light industry that only those product parameters are focused on which are realized at the moment of delivery to the user. We developed a new, innovative design method, which considers the full life cycle of the product. We extended the widely used QFD method into a complex set of customer demands about the product. For the contradictory demands we set into the design process a modern method that provides the optimal compromise level. Computer software supports the use of both methods in everyday practice.

Keywords: designing textile products, full life cycle, maintenance during usage, Quality Function Deployment, seeking compromise solutions, Harrington optimization method, desirability, compromise function

1 A Modern View of the Design Process

A complex design process should precede the production of a quality product that is to meet all the requirements of the modern consumer society. Designing is a complex problem-oriented process, which must fulfil all the demands and expectations concerning the product. The phases of the design process should be implemented according to a well-defined and fully controlled method. Designing for the full life cycle is a new and modern extension of the actual demands concerning the product, as well as fulfilling these demands.

Designing for the full life cycle is not an extensively used method at the moment. Many designers still have a conventional view of the design process. This conventional view restricts the demands concerning a product to those characteristics that are realized at the delivery of the product to the customer.

2 Phases of the Life Cycle

This conventional view, however, fails to admit that there are far more demands concerning a product than those realized at the delivery. The suitability of the product is obviously not constant. At the end of its life cycle the product much less meets the demands and functions, and finally it breaks down or gets outdated. The modern design process has to take into consideration all the demands and aspects concerning each and every phase of the life cycle.

Table 1
Design aspects according to the different phases of the life cycle

<i>Phases of life cycle</i>	<i>Design inputs</i>
<i>Designing the product</i>	<ul style="list-style-type: none"> - methodology is needed (documentation, sizing, composition, cost analysis etc.) - knowing the available materials (type, size, costs, performance parameters etc.) - knowing the available technology (production line, equipments, costs, human resource demand) - the risk types caused by the product - customer demands (function, performance, aesthetics etc.) - etc.
<i>Implementation</i>	<ul style="list-style-type: none"> - human resource capacity - knowing the available technology (production line, equipments, costs, human resource demand) - waste analysis, expected waste rates - condition and maintenance of equipment - etc.
<i>Putting into use</i>	<ul style="list-style-type: none"> - available commercial channels - product information for customers - etc.
<i>Supporting maintenance during usage</i>	<ul style="list-style-type: none"> - planned frequency of usage - expected lifetime of parts - maintenance possibilities, used equipment and material - changes in the characteristics expected during maintenance (functional, aesthetical) - etc.
<i>Improvement</i>	<ul style="list-style-type: none"> - users' experience (e.g. guarantees, customer complaints) - compatibility of the improved parts and units - etc.
<i>Withdrawal from circulation</i>	<ul style="list-style-type: none"> - knowing alternative products - expected lifetime - consequences of withdrawal - etc.
<i>Recycling/destruction</i>	<ul style="list-style-type: none"> - collection possibilities - recycling possibilities and neutralization characteristics - type and measure of pollution in different destruction methods - etc.

The delivered products will undergo regular maintenance procedures. During usage, different types of faults can occur resulting that the original function of the product can only be recovered with replacing parts. In case of textile products maintenance can mean cleaning (washing or chemical treatment), hot shaping (ironing, steaming), replacing some parts (changing decoration, fringes, etc.).

In the design process, all the demands of the different phases of the life cycle should be considered. The most important aspects are maintenance and cleaning, for which special demands can occur. Failing to regard these aspects can cause a product originally designed for a longer lifetime to be destroyed or lose its functional and aesthetic value after the first cleaning.

Most products lose from their quality and their parameters are changed during usage. In case of textile products this change can involve a worn-out and rugged surface, which is not only an aesthetical question, but also affects the mechanical parameters of the product. In case of knitted textiles, non-expected stretching can also be a problem. These changes of the quality can be eliminated with choosing the proper material and textile structure during the design process.

3 Designing Products for the Full Life Cycle

a) Quality Function Deployment for the Full Life Cycle

The basic condition for a product design based on customer needs is to get acquainted with the expectations of the customers and the society (everyone concerned), and to translate these demands to technological terms.

In order to regard all the demands concerning the design process, a complex methodology is needed. The basis of the design process can be the Quality Function Deployment (QFD) method. The main advantage of this method is that it can be used under very basic circumstances, but, on the other hand, in case of complex innovation projects, a more elaborated form of the method can be applied. The present study aims to extend in an innovative way a method widely used in car designing.

The most important practical means of implementing the QFD method is the matrix technique. Customer demands give rows of the matrix, whereas those technological, quality and product parameters that are capable of fulfilling these demands give the columns. The matrix contains numbers that express the connection between the rows and the columns.

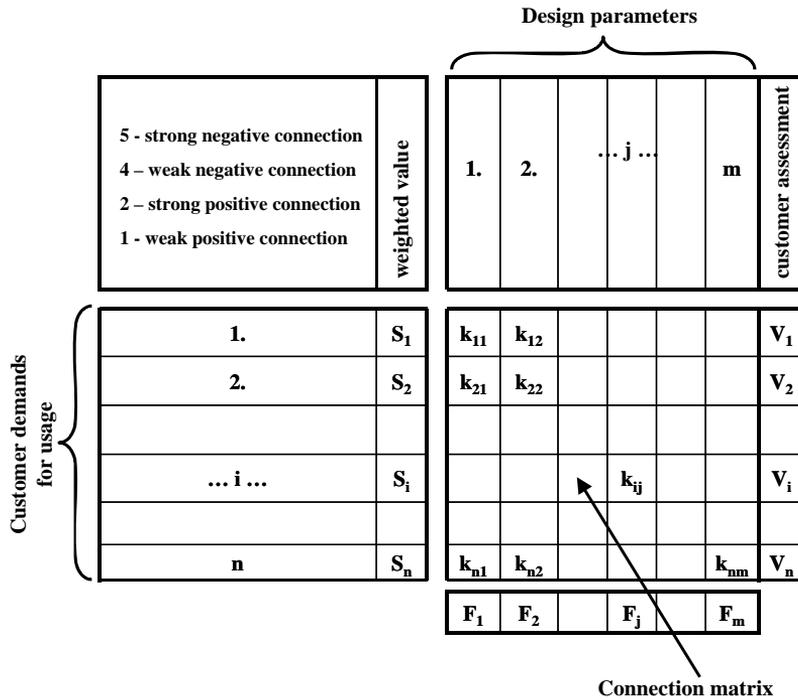


Figure 1
General QFD matrix

Entries of the connection matrix are numbers (k_{ij}) defined by team members, expressing the connection between every aspect of the customer demands and the designing parameters. In defining the values, we consider the direction and the strength of the connection:

- 1 – strong; 2 – weak negative connection (in case of negative connection increasing the value of the design parameter results in a reduction in the level of fulfilling customer demand).
- 5 – strong; 4 – weak positive connection (in case of positive connection increasing the value of the design parameter results in an increase in the level of fulfilling customer demand).
- 3 – there is no connection between the customer demand and the design parameter. In the matrix, we omitted number 3, in order to make the table clearer. So the meaning of an empty box is 3.

The numbers expressing the strength of the connections are based on subjective evaluation, but their value is in proportion with the correlation coefficient. The correlation connection close to +1 means the number 5, that close to -1 means the number 1, and that around 0 means the number 3.

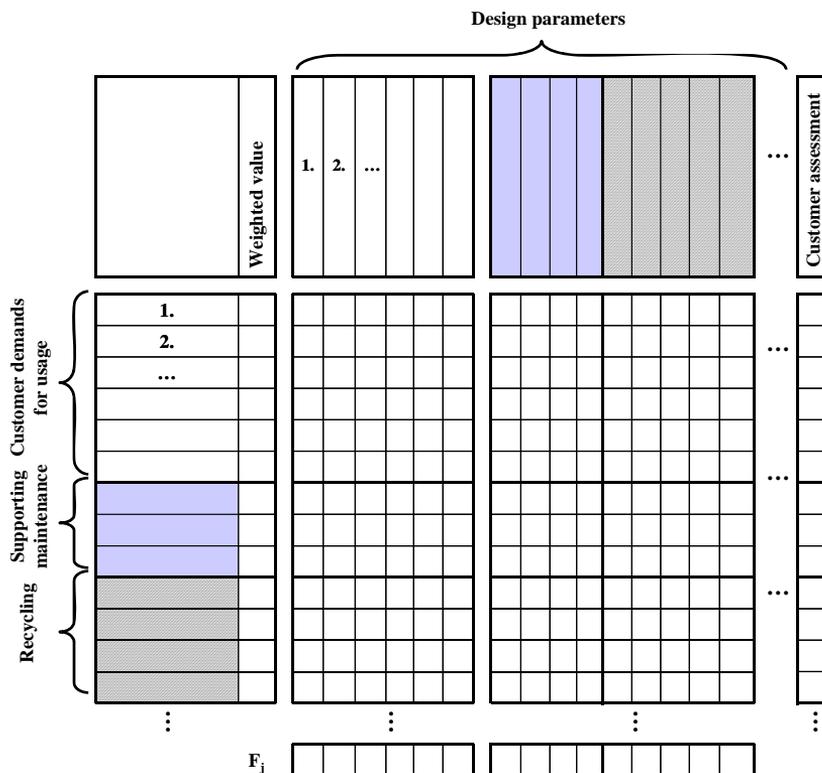
As a result of the QFD method we get a list of the design parameters that have to be improved, in the order of priorities.

$$F_j = \sum_i S_i \cdot (k_{ij} - 3) \cdot (5 - V_i)$$

where S_i - is the weighted value of the customer demand,
 k_{ij} - is the entry of the connection matrix,
 V_i - is the product assessment by the customer.

b) Modifying QFD regarding the Full Life Cycle

Too many times, including the conventional application of the QFD method as well, the customer is interpreted simply as a user of the product, and the definition of the demands is restricted to those expectations realised during the usage of the product. According to the modern view of the designing process, the customer has to be identified in every phase, throughout the full life cycle, so that the demands that occur in the different phases can also be defined.



For a complex evaluation, the QFD matrix has to be extended: we must also consider those expectations realised outside the usage. This way the design process can include all the demands of the different phases of the life cycle.

4 Supporting Maintenance during Usage in the Design Process

A company produces and sells textiles, and also designs collections of curtains, linen, quilts, upholstery and furnishing for hotels and guesthouses. Matching the interior designer's ideas, the company designs products and provides instructions for the usage and maintenance. The company contacted our research group to help to reduce the risks of maintenance of their products. We developed an innovative method to solve their problem.

As the first step of the original procedure, the customer chooses the textiles matching his/her ideas. The interior designer provides designs about the different rooms, halls and dining-rooms. After discussion and approval production plans are made, and production starts. The company is also committed to provide instructions for the handling and maintenance of their products.

In the design process matching the type of the textile to the customer's ideas is not a relevant parameter, so neither the materials, nor their mechanical and chemical parameters are taken into consideration during the design process.

This drawback of the design process results, for example, when confectioning two or three types of textiles for producing a quilt, each requires different cleaning circumstances, or, in more extreme cases, one of them is not cleanable at all. The same product can also have problems with keeping its size, because this important parameter has not either been regarded when choosing the materials.

Products made of different types of textiles can also produce problems in keeping their colour during cleaning. Cleaning textiles of different colours and different colour retention parameters can easily result the light colours spoiled by the dark ones.

After washing, most products require some ironing, but if a textile that must not be ironed even at a low temperature is involved, then obviously the final product must not be ironed either.

As for curtains, the main problem usually comes from handling and cleaning the extra decorations, fringes and borders. These parts can hardly be washed without deterioration, whereas regular cleaning is indeed a relevant demand in case of curtains.

Faults of the design process can be eliminated if identifying customer demands also include handling and maintenance of the product. We developed a method extending QFD with further aspects, taking into consideration the demand for supporting maintenance in the different phases of the life cycle.

Table 2
QFD matrix developed for two phases of the life cycle for curtains

<i>CUSTOMER DEMANDS</i>	<i>DESIGN PARAMETERS</i>													
	<i>WEIGHTED VALUE</i>	Ambitious designer	Brightness	Range of colours and patterns	Textile shrinkage	Number of layers and components	Area density of layers	Accuracy of size at confectioining	Sensitivity to chemicals (textile, fringes)	Stretching and flexibility	Y arm floating inside the textile	Colour -fatness	Heat resistance of the raw material	<i>CUSTOMER ASSESSMENT</i>
Has a nice drape	7	4				4	2			4	4			2
Light resistant	5					4						5		3
Nice colour and texture, matching the surroundings	10	5	4	5						4				5
Should be accurate in size	1					2		5	2					2
Stain resistant	5						4							4
Should ensure darkness	9			4		5	5							5
Should be cheap	10	1		2		2	2							4
Should keep its size	3				5					1				3
Should have a nice shade in indoor lighting	7	4	4	4		4	2				5			5
Should be insulating	1					5	5							4
Should not be vulnerable (drawn fibre, wrinkling)	7		4	4		2	5				1			2
Cleaning should not destroy its colour, light	10		5					2				5		5
Cleaning should not cause surface destruction	9		4			2	5				1			2
Should not be deformed during cleaning	7				4		4		2					5
Can be cleaned without undoing	3					1		2						4
Simple cleaning process with few steps	3					2		2					5	3
Cleaning with standard machines and detergents	5					1		1		2	4			2
Should be creaseless after treatment	9												5	3
	1	48	11	12	-70	72	6	-39	6	-90	35	48		

5 Product Improvement Based on Priorities

A common problem in designing is that changing a design parameter that increases the level of fulfilling one customer demand, would reduce the level of fulfilling another. So setting priorities and finding a compromise solution is of utmost importance. One possible method for optimization is the Harrington's desirability function, which handles together the effects of the most important variable parameters.



Figure 4

A theoretical model for seeking compromise solutions

Harrington's optimization method takes into consideration, in a weighted format, every parameter (customer demand) that is changed, and defines the optimal design parameters on the basis of that.

Focusing on one parameter of our case study, that is 'Yarn floating inside the textile', it can be seen that this parameter is in connection with many customer demands that require contradictory changes of this parameter. There are customer demand parameters that are limited from one side (below or above), and one parameter that is limited from both sides.

Table 3

Contradictory customer demands

<i>Customer demands</i>	k_{ij}	<i>Limit</i>	<i>Design parameter demands</i>
Has a nice fall	4	from below	Require increase of yarn floating inside the textile.
Nice colour and texture, matching the surroundings	4	from both sides	
Should have a nice shade in indoor lighting	5	from below	
Should not be vulnerable (drawn fibre, wrinkling)	1	from above	Require reduction of yarn floating inside the textile.
Cleaning should not cause surface destruction	1	from above	
Can be cleaned with standard machines and detergents	2	from above	

For the compromise-based improvement, first the connection between the input and the outputs has to be defined. Then a desirability function (d) has to be associated with this input. The function can take a value between 0 and 1. The values of these functions can be linked to the design parameters.

The $d_i(x)$ desirability function changes depending if the quality parameter is limited from one or both sides.

The optimal level of input can be defined by finding the maximum value of the harmonic average of the desirability function (compromise function).

$$D(x) = \sqrt[n]{d_1(x) \cdot d_2(x) \cdot d_3(x) \cdots d_n(x)},$$

where $D(x)$ - is the function to be optimized, containing a compromise regarding n number of customer demands,

$d_i(x)$ - is the function expressing the fulfilment of different customer demands, according to the modified designer parameters.

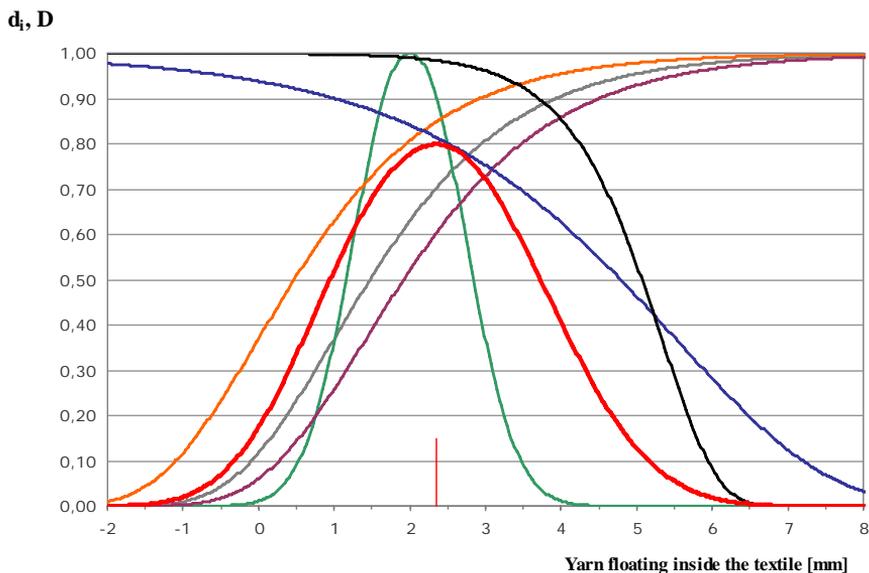


Figure 5

Compromise function calculated from d functions with the optimal value of the design parameter

From the D function calculated this way the optimal value of the design parameter can be defined, which regards contradictory customer demands.

Conclusion

While introducing the extended method, a wide-ranging innovation seems possible to implement. Giving a theoretical underpinning, the analysis of our case study has proved that the new design method is relevant and effective.

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