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APPLICATION OF THE PARAMETRIC COST ESTIMATION IN THE TEXTILE SUPPLY CHAIN

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ABSTRACT

In a current high competitive business environment, cost estimation is a strategic tool in order to make decisions related to products during their design and development phases. Against traditional estimation methods, that needs to wait until the technical description of the product is completed, there exist new methods allowing to estimate the cost quickly and with an acceptable accuracy. Complementarily to cost management methods (for example, standard cost management analytic or Activity-Based Costing techniques), such new cost estimation methods may shorten the design phase when the rapidity of the conception is needed. This way may be valid when there is a huge number of models, and/or high level of new design rate.

This paper compares various cost estimation methods in the textile context : their advantages, drawbacks, and applicability in the product life cycle. The parametric cost estimation model is particularly suited to the earliest stage of design-to-cost approach. It is widely used in different industrial domains such as aerospace, aircraft, telecommunication and automotive industries in order to accelerate and drive the product development process. Even though the industrial contexts seem to be different, this paper shows several possibilities of application of parametric cost estimation methods in the textile and garment industries, and the procedures and tools required for their computation. Finally, this approach has been applied to estimate the unitary cost of a representative family of wool textile fabrics.

Keywords: Cost estimation, parametric costing, product development, product lifecycle,

Introduction

The way textile products are delivered to consumers in terms of lead-time, references and especially in terms of cost, has changed radically during the last years. Today, the competitive environment has become more and more hostile (Kilduff, 2000). The main causes of this situation are the textile pipeline globalization process, the high demand pressures and the speed in the technological changes. All of these factors have different implications depending on the geographical region in the world.

Fortunately enough, the existing information technology and the available computational tools greatly help to manage this supply chain, and they are an opportunity to develop new decisional and managerial tools that can analyze and effectively integrate many information from various sources in the supply chain.

In this paper, the authors study the cost estimation methods which are applicable at the earliest design phase of the textile and garment products. The main goal is to give fast and accurate estimation tools for designers, when the technical description of the product and the possible production circuits are not known or decided. This is, for example, the case for firms with a centralized design department or with international "off-shore" process, where the communication between these early designers and the manufacturers is not yet established. This communication may also need too much delay or excess of information exchange.

The first problem for cost estimation is the total cost allocation of the product. In fact, the total cost has now more indirect cost components, which is a non-negligible share percentage. Because all the activities are being done at different places, the actual supply chain is more complex, and this fact has changed the product cost structure.

However, the cost calculation in the textile industry is still almost exclusively based on the production cost data. A current industrial practice is to estimate the indirect costs (overheads and general sales and administration) as a multiplication of the production cost by an index factor. Specifically in the textile and garment industry, researchers (Hergeth & Rendall, 1999, Mendoza, 1994), showed consecutively that the indirect cost allocation does not have the same behavior and variations as the direct cost. In fact, direct cost usually varies with the level of output, standard time and raw materials consumption. However, the design cost and the indirect cost (overheads sales and administration expenses) cannot be estimated as direct cost factors. In other words, these indirect costs do not necessarily follow the same patterns for all products. For that reason, more accurate cost allocation methods as Activity-Based Costing (ABC) has been introduced (Kaplan et al, 1998), but seems not to be yet widely used in the textile and garment industry. Some criticisms indicate that the main reason for this will be that ABC is more complex and time consuming than traditional costing systems (Lee & Ryder, 1996).

In this study, we assumed this standard cost as exact. Nevertheless, when a new product evaluation is needed, for the coming season, the first cost estimation is an extrapolation on the basis of the standard cost of the previous season. This estimated cost is not necessarily right for the existing products and neither for a new product. The main problem we want to study, is the cost estimation for an innovative or new textile product at the early design stage. The main objective to find a simple and accurate method (at least with the same level of error).

It is well know that the market success for this new textile product is a combination of features (aesthetics and functional characteristics), market schedule, and cost. During the product design and development process, when different alternative designs are being performed, it is difficult to determine the final cost for a new product. It is a challenge to integrate the product cost as an input variable for decision makers at the design process through the cost estimation tools. There is also an imperative need to minimize the time to market. Meanwhile, the products designed must also be economically manufactured.

But at this stage, we do not know the entire product details included in the work breakdown structure (WBS), them we cannot use the traditional estimation methods. At the same time the design activity is increasingly under different kind of pressures. The high degree of product innovation imposed by the new marketing strategies varies as the mass customization, the volume and diversity of orders in the producer-retailers cycle, and the numerous new applications in the field of technical textiles.

At these conditions, the economical evaluation of a new product must be done in a real time through the supply chain but at the same time assuring the product profitability.

For that reason, the present research project is looking for methods allowing a better interaction between the design parameters, while keeping an accurate cost estimation.

The next sections show the way we propose to solve the two main cost estimation problems mentioned in the introduction of this paper. Section 2 shows the current practices for the cost estimation, sections 3 and 4 study the possibilities of application of cost parametric models in the textile product life cycle, and necessary steps for parametric cost modeling. Sections 5 and 6 show a case of application in the textile field and the further application and development possibilities.

The Current Practices for Cost Estimation

The first step of this project was a broad analysis of cost estimation methods. For the textile and garment industries, there exists in practice, two main estimation methods: the analogical, and the analytical cost estimation. The last method which may be of interest, is the parametric cost estimation, not yet applied within the textile sector.

I. Analytical cost estimation

Traditionally, the analytical approach is the most demanding in terms of data volume and details. At the design stage, the analytical method allows evaluation of the cost of a product from a decomposition of the work to elementary tasks and parts (bill of materials). Then, one estimates respective costs of these tasks. This method uses data stemmed from the accounting department of the company. In practice, the estimation of costs by the analytical method is used during development and production phases to estimate the production costs of a new product. The limiting factors of this method are: a) it is applicable only when the details of the product and the means of production are well known, and b) it consumes time and resources for very detailed actual cost data.

II. Analogical cost estimation

This is a "comparative" method, based on physical similarities between current products and a new product. The analogical method (Farineau, 2001) allows evaluation of the cost of a product compared with costs of other already existing products. This technique consists of defining a codification of parts, frequently a morpho-dimensional codification, and comparing physical features and functions of a new product with those already released on existing products. This method is mainly used through technologically similar products. The analogical method presents diverse advantages: a) its low cost, and b) its ability to propose rapidly a solution. However this method generally requires an important database. Under huge variation of products, simplistic or subjective analogical estimation may not be effective, and requires expert competencies. However, the "case based reasoning" (Duverlie, 1996) will make a more accurate estimation and works in a transparent way for the for the user.

III. Parametric cost estimation

Today, parametric models are widely used throughout the world, and often are used as the primary or, in some cases, the sole basis for estimating. They are especially useful at the earliest stages of design in a program where detailed information is not yet available. The parametric model is a series of Cost Estimation Relationships (CER), ground rules, assumptions, relationships, variables and constants that describe and define a specific situation. The CER is a mathematical expression, giving cost as a function of one or more cost driver variables. The main advantages in using CER are

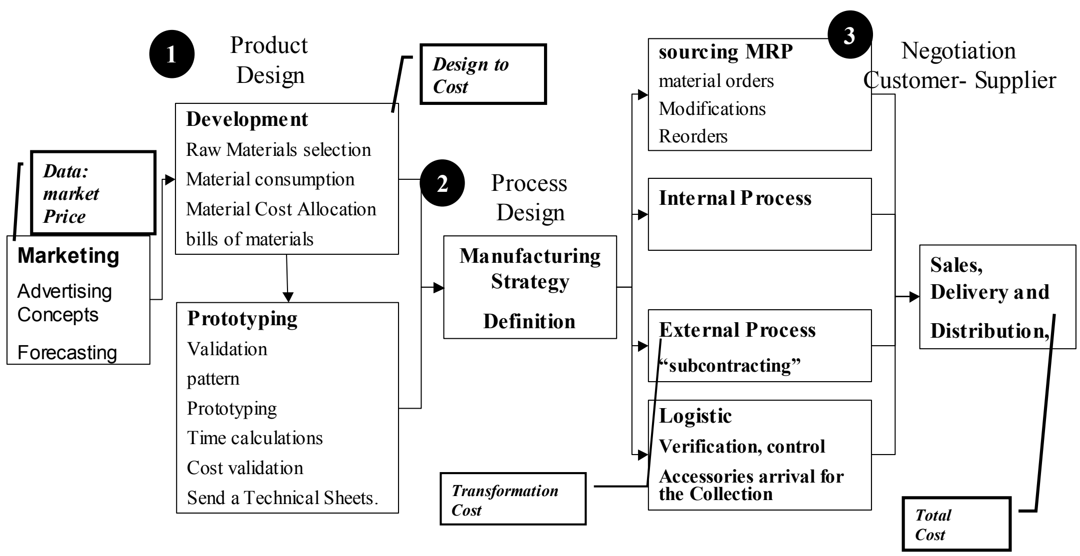
- It allows the user to provide quick estimates without a great deal of detailed information (Long, 2000)

- The CER are based on actual product cost history, and reflects impacts on cost growth, schedule changes, and engineering changes.

	Parametric	Analogical	Analytical
Conception	▲	▲	
Development	▲	▲	▲
Production	▲		▲
Operating	▲		▲
After sales	▲	▲	▲

Table 1: Applicability of the cost estimation methods in the product life cycle (Long, 2000)

Figure. 1: Fields of application for the cost estimation in product development process.



These methods are not usable during the whole life cycle, some are better than others depending on the context. For instance, the application of analytical, as a complementary method, is that future cost can be predicted with a great deal of accuracy.

One can see in Table 1 the common distribution of the utilization of these different cost estimation methods during the successive phases in the life cycle of a product.

Application of Parametric Cost Models in the Product Life Cycle

Figure 1 represents the typical textile product life cycle in the market. The product life cycle starts from customer or market intelligence until customer reception. In the early phase, the enterprise must take decisions to establish the product target prices and characteristics (aesthetics, structure and manufacturing). For realistic and useful cost estimation, the full product life cycle cost must be considered. Then, nontraditional cost related parameters may be included, as the learning curves, know how complexity, lot sizes, technological advances and maturity, source dependencies and risk assessments, in order to adjust historical cost and price trends (EACE, 2001).

There are three main decisional steps directly correlated to costing estimation: the product design phase, the definition of manufacturing strategy, and the quotation and negotiation process.

IV. Product design phase

The cost estimation model allows to estimate the impact of different structural changes on the product (design to cost). At this stage, before the complete definition of the product, parametric models can correlate costs to the main characteristics of the design the product, in order to obtain an accurate cost estimation. It is also possible to link the cost estimation tools to the design system, either directly to production system. This reduces the solicitation of cost experts without loss of precision, since a cost model captures their knowledge (Roy & Rush, 2001)

V. The definition of manufacturing strategy

The parametric cost model can also be used in "make-or-buy" decisions for component parts and assemblies. It allows to understand the influence of different possibilities in an “off-shore” strategy, in terms of lead time, production configuration and location, lot size, risk assessment and complexity of the product. This estimation must take into account all the cost components for each supply chain possibility, in order to:

- Build and evaluate different scenarios or variants
- Make economical evaluation of several suppliers
- Make strategic investment and technological choices

The cost estimation at this stage, usually includes analysis of material, time, and resource requirements.

VI. The quotation and negotiation process

The main gain expected in product development is to shorten response time and to improve accuracy when responding to a customer bid request or suppliers evaluation. This process can be done taking in to account the internal process complexity, or aggregated capacities in industrial clusters. Also, it must include other variables consuming resources such as: delivery time and delivery place, replenishment frequency, change in business environment conditions and risk evaluation.

Parametric Cost Modeling Steps

The parametric method involves collecting relevant historical data, and relating it to the final product to be estimated through the use of data analysis, mathematical and statistical techniques.

VII. Cost drivers selection

The cost drivers are the characteristics of a product or item that have major effects on its cost. It may be a physical, functional, operational or other identifiable product properties and features (Fournier, 1997).

Functional cost drivers: relate to the product use, differentiation, quality level and behavior parameters.

Physical cost drivers: relate to measurable parameters as raw materials composition, the shape, the volume, or the number of components.

Operational cost drivers: relate to specific processes, technological level, and production system.

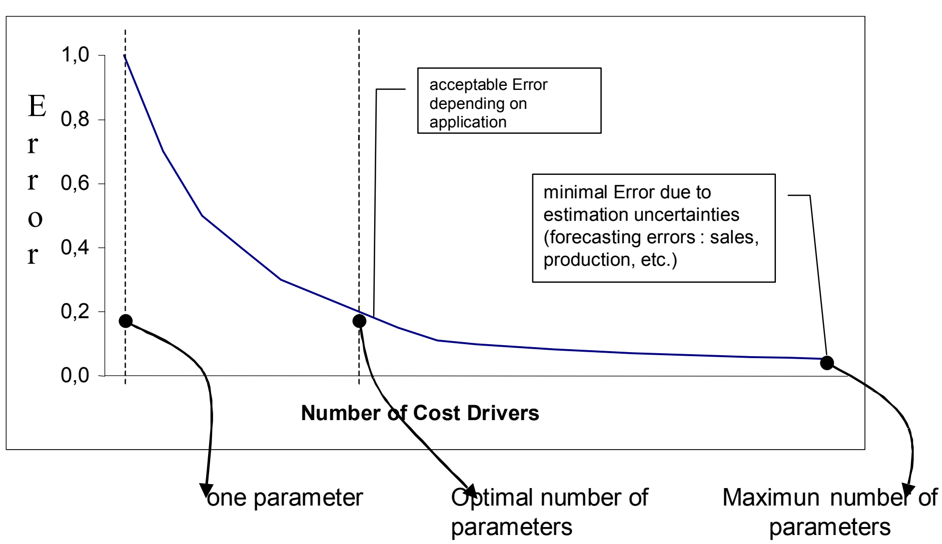
The cost drivers identification is a critical phase, because one will try to understand, quantify and reproduce the technical know-how of the experts to convert it into economical-managerial information (Farineau, 2001); (Roy & Rush, 2001). (Farineau, 2001), investigated the use of causal diagrams as a graphical support for a cost estimation workgroup, which also give a guide line for the structure of the CER.

VIII. Data collection

Historical cost databases are necessary for the development, calibration and validation of models and CER's. This database must be normalized, and evaluated in economical terms. Different enterprise sources of information are the ERP systems, bill of materials, account and process databases. The main complexity is to establish homogeneous methods of allocation for design and indirect cost. Uniform definitions and collection of cost and technical information must be applied for economical and temporal corrections: for example corrections by inflation or interest rates.

The Activity Based Costing may be applied (Lee & Ryder 1996, Rush, et al, 2001) in order to organize the data collection process. But the data collection process should

Figure 2: CER's Accuracy versus the number of cost drivers in the model



be consistent with the accounting procedures and the cost accounting standards.

IX. Regression and curve fitting

A CER is a mathematical expression, expressing cost as function of one or more cost driving variables. In fact, the problem is that the CER complexity increase as one moves from linear to non-linear relationship, and from a single cost driver to more than one cost drivers. But today, the necessary algorithms are well-known and widely available. The main methods to curve fitting are the multivariate regression techniques and cost improvement curve analysis (DOD, 1999). With the use of modern computer tools, it is possible to automatically investigate and test many combination of CER's mathematical forms (linear, logarithm, exponential). One can also use more advanced black-box modeling technique such as neural network if the loss of the readability of the cost model is acceptable.

X. Test of the CERs statistical quality

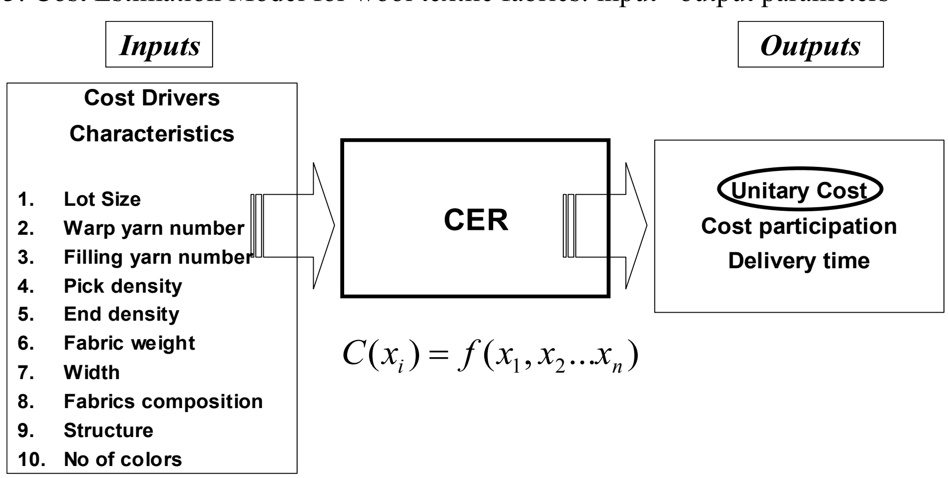
Finally, we must verify the significance and accuracy of the cost estimation models through various statistical tests. The choice of the cost drivers can be statistically established and tested here, complementing their qualitative identification by the cost experts in the previous section. The CER can be simplified by selecting only the most statistically significant terms, for example by using stepwise regression techniques.

XI. Selection of the best CER

At this point, it is usual to obtain a great number of candidate models. In many cases, the statistical regression quality and estimation criteria are not sufficient. For their validation, the CERs must demonstrate reliability for an acceptable number of trials, and they should be representative of the database domain of application. It is also necessary to consider the technical coherence of the CER as defined by the experts in the application domain (Farineau et al, 2001).

At last, some input variables in the multiple regression do not have an important explanatory effect on the response. Then, it is a convenient simplification to keep only the statistically significant cost drivers in the model. The stepwise regression starts with all the terms in the model and removes the least significant terms until all the remaining terms are statistically significant. It is also possible to start with a subset of all the terms and then add significant terms or remove insignificant

Figure 3: Cost Estimation Model for wool textile fabrics: input –output parameters



terms. This process is stopped when the required accuracy is reached.

Evidently, more cost drivers lead to less errors (Figure 2). The construction of the CER model is flexible enough and allows to adjust its precision to the users need or to the available information in the design phase, where the product is not yet completely defined.

Application In The Textile Industry

Our goal is to take in account the specificity of each enterprise, by capturing the product diversities, technological capabilities, and the economical constraints. For that, we will try to develop a CER which include not only the statistically most relevant cost drivers, but the technical coherence included in the experts point of view, and a optimal choice of cost drivers (Figure 3).

As an example, we studied an theoretical industrial application, in order to develop the analysis tools and methodologies. Table 2 shows the main descriptive characteristics for a wool fabric producer. The specific problem is to develop a cost estimation relationship for several design variations in product characteristics.

Table 2: Application example

Enterprise	*Wool fabrics producer*
Characteristic	Integrated mill (spinning, weaving, dyeing)
Products	Wool fabrics and Wool-PES fabrics
Field of application	Design to cost
Internal user	Product designer

We recovered the product descriptive characteristics and the cost drivers suggested by the enterprise experts. This check list of cost drivers represent the feasible group of dependent variables, and the total cost is the independent variable.

At this step our goal is to build a *generalized* representative model capturing the most relevant cost drivers based in independent (design) variables.

We used the methods as ordinary least squares regression and non-linear programming. The equations are represented in the generalized construct as linear, some may be non-linear (e.g. exponential) functional forms, depending on which functional form yields the 'best fit' to the data.

For a specific cost estimation problem, as we gain experience whith the procedures it was more easy to evaluate the quality and sensitiveness of the model. A general statistical quality criteria for linear or nonlinear models has been automatically calculated by using a number of statistical criteria such as (r^2) the determination coefficient, F-statistics, the Rmse, and SNER the normalized sum of residues (Fig 4 and Fig 5). These statistical criteria, enabling to evaluate the CER correlation; significance and precision. as:

SNER the normalized sum of residues

$$\text{SNER} = \frac{\sum_{x=1}^{n} |e_i|}{\sum_{x=1}^{n} c_i} \qquad (1.1)$$

RMSE (Root mean square error)

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (e_i)^2}{(n-p)}} \qquad (1.2)$$

Here;
e_i is the estimation error between the standard cost and the(model) CER Cost estimation for the *i*-th observation.
n is the number of independent variables x_i
p is the number of observations used to develop the model
c_i is the validated standard cost for the *i*-th observation.

Authors (DoD, 1999) mention that ideally, the analyst prefers a strong statistical model with a large number of observations, using the fewest number of variables to formulate the equation. As the initial model is judged to have performed satisfactorily using the tests just described, it needs to be simplified, if possible (Armstrong, 2001).

For that reason in our model we introduced criteria allowing to identify cost drivers which not have an important explanatory effect on the CER response. Our method, use minimal error based methods to reduce and optimize the CER, by adding cost drivers and evaluating criterions used to choice the best CER, the AIC (Aikake information criterion) and SBIC (Schwarz Information criterion) defined as :

$$\text{AIC}= Log(1+2\frac{n}{p})RMSE^2 \quad (1.3)$$

$$\text{SBIC}= Log(RMSE^2)+\frac{n}{p}Log(p) \quad (1.4)$$

(Armstrong, ibid) mentioned that the theory favors the SBIC, but there is limited empirical evidence to show any difference in practice.

We used both of them and as shows the Fig.6, in our case the SBIC (optimize the number of independent variables to estimate the cost). The advantage of these criterions is that it take into account not only the error performance, but the system complexity (Fiordaliso, 1999).

Figure 4: normalized sum of residues

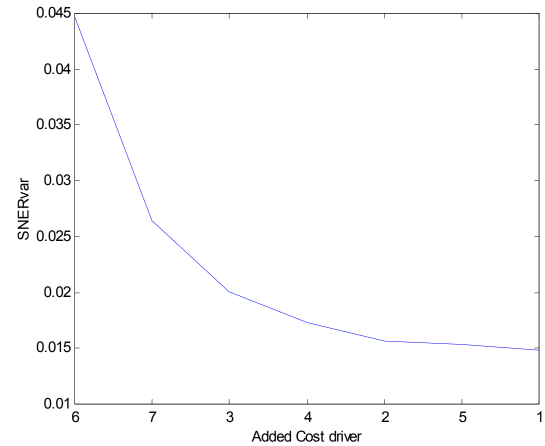


Figure 5: Root mean square error

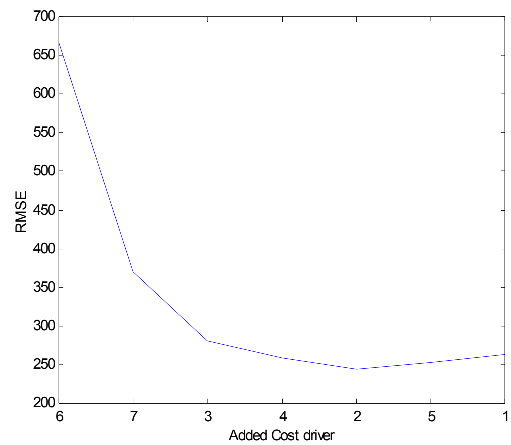
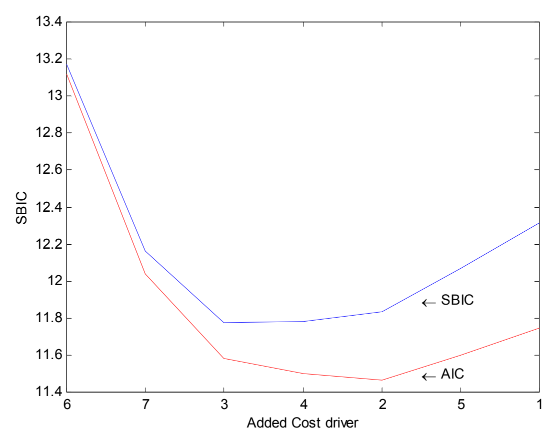


Figure 6: Root mean square error

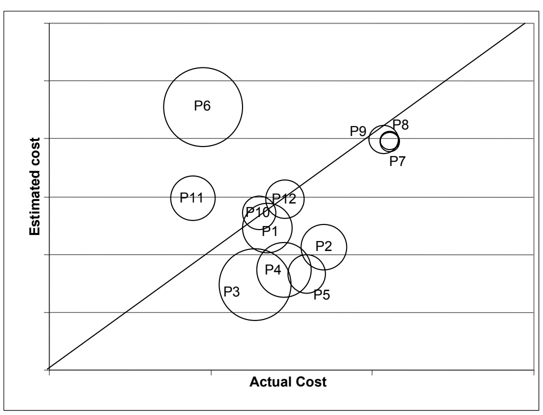


Finally a in order to verify the technical coherence, a method developed by Farianeu (2000), is applied. This technique resolves the problem of the consistency of the regression result with the technical point of view. The main possibility to judge this technical coherence is to take into account the direction of influence (positive or negative) and the importance of regression parameters in the formula. Therefore, we will combine two types of information: the knowledge of experts, and the statistics on the sign, value and confidence interval for each parameter.

The application and computation of the algorithm for the CER development process, allows the evaluation of the statistical parameters of the CER as the correlation quality and significance, the precision, and the technical coherence. At the same time allow to have a quantitative evaluations of a group of candidate formulas.

The CER was validated by using it to estimate the total cost for a new group of wool fabrics. Figure 7 compares the prediction of total costs for this new group with their actual values. The circle around the estimation value represents the confidence interval.

Figure 7: CER's validation: Estimated cost vs. standard



In this example, we have computed a unique CER whereas the accuracy in the estimation depends on the products characteristics. Consequently, the distribution of estimation errors in the Figure 7 puts in evidence product families with similarities in cost and technological parameters. Then, the CER must be adjusted and validated for each product family.

Conclusion And Perspectives

The textile pipeline has a widespread variety of product styles and possibilities, company sizes, organizational characteristics and technologies. In spite of that fact, all of them share the textile chain complexity. The resources optimization and lead-time optimization have become enterprise priorities. In that sense, the total cost of a product must be known at the early design stage, with the maximum of accuracy in order to simplify the trial and error process.

Then the aim is to find the CERs that explain the correlation between not well-defined design data and final cost implications for specific textile applications.

This paper shows the application possibilities of the economic evaluation during the design phase through the Cost Estimation Relationships or parametric methods. We studied the design to cost as a decisional tool, the economical evaluation of the production options, and the quick negotiation.

We have developed and tested the CER in a common textile product as wool fabric, for the design to cost application, using as independent variables (cost drivers) physical parameters and product complexity, and the total cost as a dependant variable.

The generalization for different product families is under study. The use of these parametric estimating models, should provide many benefits, as a reduction in the time needed to develop, time to market, review and negotiation time for a new product.

However, as restrictions we found that the application of the parametric model requires: well-known and accurate cost historical data and the necessary study of the total cost allocation for a textile product, the cost drivers for the main textile and garment cases and the economical impacts of these new estimation tools.

As future development perspectives, a field study was conducted to examine a group of textile and garment enterprises about their costing estimating practices and methods at the design stage. Integrated enterprises (design-facilities), high product variation and design maker enterprises were more concerned in the problematic of developing specific cost estimation models. The need for that kind of enterprises is to increase the flexibility capability by reducing the time to market for the product development phase. There are some specific subjects that are already being studied related to the application of parametric cost estimation:

- The integration of methods for the cost allocation, including the design cost and indirect cost for a textile supply chain like ABC costing techniques.

- The study and development of methodologies in order to identify and capture qualitative cost drivers and knowledge (Stenson, 2001), for applications in the field of technical textiles and garment textiles industries.

- The use of soft computing techniques such as fuzzy logic, neural networks and genetic algorithms in order to compare these techniques, against the CER methods for their adaptability to the textile complex.

Finally, we are looking for correlation between different design parameters and cost drivers for specific products. This interaction could allow the integration of the parametric cost estimation and the 3D and 2D CAD tools. This connection may enable to prepare a product or a collection more quickly and accurately.

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