THE TECHNOLOGICAL WORTH OF COTTON: TEXTILE INDUSTRY PERSPECTIVE

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Abstract

In this paper, a systematic procedure to determine the technological value of cotton is proposed. This procedure reflects the industrial perspective of the real value of cotton fiber with respect to its various attributes. The underlying concept of this procedure is a premium/discount value model that can be used effectively to determine the technological value of a cotton bale or a shipment of cotton bales. The model provides a better resolution of fiber attributes than that used by the current classing system. The model uses a database consisting of HVI and AFIS fiber properties and corresponding data of processing performance parameters, and yarn or fabric quality parameters to form a multi-variable contribution matrix. This matrix represents the main structural element of the model. Other elements of the model include anchored parameters such as zero-base values, and difference factors. The model output consists of three technological premium/discount indices (PDI Trilobate System): quality premium/discount index (QPDI), performance premium/discount index (PPDI), and fiber defects premium/discount index (FDPDI). These indices may be used separately, or collectively to determine the technological worth of fibers with respect to a particular process or end product.

Introduction

In a typical marketing system, the cotton price may be affected by several factors including laws of supply and demand, regional factors, fiber attributes, and possible chaotic changes from one crop to another (e.g. disease, pests, and weather). In any situation, however, fiber attributes represent the primary factor in determining the premiums and discounts associated with the value of a certain cotton. In the current classing system, these attributes include grade, staple length, Micronaire, strength, and extraneous matter (any substance other than fiber or leaf).

In recent years, the issue of what fiber attributes should be considered in determining the true value of cotton has been re-examined. New thoughts [1,4] have been presented in view of the revolutionary developments in spinning and weaving technologies, and the numerous fiber information produced by powerful systems such as the High Volume Instrument (HVI), and the Advanced Fiber Information System (AFIS). These efforts revealed that the current market value of cotton is yet to reflect the technological worth of cotton.

Market analysis [6,7] performed to determine the current trends of cotton purchasing in the U.S. indicated that traditional cotton attributes, particularly leaf grade and color grade, still dominate the cotton market. In addition, textile mills have not been paying premiums for high strength nor discounting low strength cotton. The analysis also revealed that the pricing structures of cotton at the user-end of the market appear to be substantially different between the Western and South Central regions for all fiber attributes. These regional effects indicate that historical repetition, art and experience are still greatly implemented in cotton purchasing among textile manufacturers.

The establishment of a market value of cotton that is truly representative of the actual technological worth of cotton faces three main challenges. The first challenge is the substantial differences in views of what constitutes fiber quality expressed by different organizations involved in the cotton industry (growers, merchants, manufacturer, etc.). The second challenge is the impact of the current market structure on the value of cotton. The third challenge is the lack of a systematic model by which objective evaluation of the cotton value can be achieved. This study deals specifically with the third challenge. Because of the strong interrelationship between the three challenges, we will briefly discuss the impacts of the other two challenges.

Different Views of the Value of Cotton

From a cotton producer's viewpoint, the primary attribute that determines the value of cotton is the yield per acre. This means that any breeding improvement of a particular fiber quality parameter, to satisfy technological needs, will have to be achieved without impairing the yield per acre. According to Meredith (10), with the exception of Micronaire the association between the yield per acre and most fiber properties is generally weak. The Micronaire reading reflects both the maturity and the lint percentage and thus has a correlation of about 0.70 with the yield per acre. The author also indicated that in any breeding situation, when one feature (such as fiber quality) receives an increase in breeding priorities; progress in other features such as yield declines. According to Deussen (1), certain cotton varieties with superior quality traits, but somewhat lower yield, fall victim to the fact that the current marketing system does not compensate for reduced yield with a premium on desirable fiber properties.

Another fiber attribute which is highly emphasized in the current classing system is fiber appearance and cleanliness. This emphasis is primarily driven by the significant discount points associated with cottons of poor appearance (poor leaf and color grades) and high level of extraneous matter.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:714-719 (1997)
National Cotton Council, Memphis TN

Accordingly, cotton undergoes extensive cleaning during ginning (typically, two to three passes of lint cleaning). Obviously, trash content being a non-fibrous material is worthless to the textile manufacturer. In addition, it has adverse effects on the processing performance of cotton and the end product quality. Although, cotton users (textile manufacturers) fully understand the impact of trash on the value of cotton, they disagree with the extent of cleaning of cotton during ginning. Studies in this regard [5,9, 12] revealed that excessive cleaning in the gin can result in fiber damage, seed coat fragments, and fine trash. None of these problems is accounted for in the current cotton market value.

From a technological viewpoint, it appears that a coordinated strategy between gin and mill cleaning may resolve the issue of excessive gin lint-cleaning. In support of this idea, Liefeld [9] recommended a distribution of cotton cleaning in which the gin should result in about 4% trash content in the bale, and the mill cleaners should reduce trash from 4% to 0.4%, and the cards from 0.4% to 0.04%. The essence of this recommendation is to achieve equal levels of cleaning efficiency in the 3 areas (i.e. 90%) and provide gradual gentle cleaning. We believe that a better approach is to re-design the gin cleaners so that high cleaning efficiency can be achieved at the minimum fiber damage possible. In today's technology, high input trash in the textile mill can result in substantial costs due to the adverse effects of trash on quality, and the increasing environmental constraints.

In addition to the attributes discussed above, extraneous matter has taken a solid place in the market criteria, particularly, in recent years. As indicated earlier, any substance in cotton other than fiber or leaf is considered extraneous matter. The amount of extraneous matter in cotton is determined by the cotton classer. Two levels are usually reported: heavy (level 1), and light (level 2). These two levels are used to characterize the extent of preparation, the amount of bark, grass, seed coat fragment, oil, and spindle twist intensity. Although the method used to characterize extraneous matter is subjective, consideration of this type of attribute in market evaluation is certainly critical due to the obvious consequences of the presence of this matter on processing performance.

The above discussion indicates that cotton producers are mainly motivated by incentives. As long as higher yield and excessively cleaned cottons provide overwhelming incentives over particular fiber attributes, the cotton producer will be reluctant to breed higher quality cottons at the expense of these motivational factors.

The cotton user (the textile manufacturer) views fiber quality from a different standpoint than the producer. In the market place, the primary interest of the cotton user is value discounts. In other words, cotton buyers are often motivated by the lowest possible price of cotton. Traditionally, purchasing discount cottons has been based on the assumption that these cottons can be mixed with high quality cottons to reach a desirable average quality level. The economical and technological feasibility of this assumption is quite understood, particularly when inherent fiber characteristics such as length, fineness, and strength are considered. In case of induced attributes such as short fiber content, fine trash, and seedcoat fragments, the desirable average target should always be zero; this target value can not be achieved by mixing poor and high quality cottons. Only the impact of these induced attributes on manufacturing cost (spinning endsdown, filling stops, and yarn contaminants) should be considered in purchasing cottons.

As we approach the new century, the current views of both the cotton producer and the cotton users will inevitably change. The new era will be solely based on information technology; fiber testing techniques will provide expert information; and machines will be operated by computers and artificial intelligence with fiber information playing a more critical role. These trends are already witnessed in today's modern technology and they continue to develop.

Obviously, new developments bring about new constraints of fiber quality. In the textile process, there are numerous examples illustrating these constraints. For instance, the production of medium to fine yarns on rotor spinning requires levels of fiber fineness, strength, and elongation that are superior to the traditional levels; air-jet spinning, while superior in producing 100% polyester yarns of a wide range of yarn count, is still incapable of producing 100% cotton yarns of acceptable quality. This is because of the limited fiber length and the level of fine trash that is intolerable by this type of spinning. The performance and quality levels of end products such as denim, and wrinkle-free cotton textiles are directly associated with the quality of the fibers from which these products are made.

The information technology of the 21st Century will also result in substantial changes in marketing strategies. The current cotton market (from fibers to retail products) exhibits a complex structure by virtue of the immense organizations involved in the market (see Figure 1). Even within a textile company, personnel involved in buying cotton represents an independent organization (the cotton department) that performs the task of negotiating cotton prices and making purchasing decisions. This structure provides little options to the actual user of cotton (the yarn manufacturer) to impact the cotton market value.

As cotton progresses in the market flowchart to the yarn market, two conflicting economical phenomena takes place, simultaneously: a significant contribution of fiber cost to the total yarn manufacturing cost (above 50%), and a significant reduction in the correlation between the cotton price and the yarn price (< 0.2). As cotton reaches the retail side in the form of an end product, the correlation between cotton price and retail item price becomes even weaker.

These market phenomena were best demonstrated in the United States in early 1995 when cotton surged to record price levels; at the same time, the retail apparel industry was experiencing its second straight year of declining retail prices. Market researchers explained this trend as being a result of changes in consumer demands, the competitive retail environment, and the shift in consumer's buying behavior [11]. We believe that although these factors may have contributed largely to this situation, a good correlation between fiber price and yarn price is hindered by the lack of a cotton valuation system that reflects such correlation. The absence of this system results in a great deal of vulnerability of profit margins to the changes in fiber price.

In the new era of information technology, the cotton market strategy must be associated with product development strategy which involves both the producer and the user in a more direct fashion. The proposed market scheme shown in Figure 2 illustrates this point. In this scheme, different sectors involved in producing cotton should form a coalition which deals directly with the textile mill. The decision making process of parameters constituting the technological worth of cotton should begin at the extreme end of the market flowchart (the end product development center). Through a feedback development strategy, a price/cost/quality balance can be achieved. Such a scheme should result in a reduction of the contribution of fiber quality to manufacturing cost, and an increase in the correlation between fiber value and yarn or retail item value.

From a technological viewpoint, the above proposed scheme can be achieved provided that scientific tools to determine the technological value of cotton are available. In this study, we developed a generic model that can be used for determining this value for different processes or for different end products. Using this model, two objectives can be met: (a) to compare the market value to the actual technological worth of cotton, and (b) to value cotton in relation to its actual contribution to processing performance and end product value. The first objective aims at providing the textile mill with a scientific mechanism by which judicious cotton purchasing decisions can be made. The second objective implies engineering the worth of fibers to the worth of end product (yarn and product development).

The main difference between this model and previous models [1,4] is twofold: it provides a great deal of flexibility so that it can be implemented for any process or end product, and it accounts for the effect of variability. The inclusion of variability in the process of valuing cotton lies in the heart of the inevitable transition from pure art and experience to scientific development of cotton products. In this transition, subjectivity and variability will be the two major challenges facing the textile industry.

The Technological Value Model: Structural Elements

The main structural elements of the proposed technological value model are: the model variables, the multi-variable contribution matrix, and the model anchored parameters. These elements are illustrated in Figure 3. The model output is the technological premium/discount index. The process of building the technological value model consists of steps that represent familiar tasks routinely performed by textile mills. It is the integration of these tasks, however, that provides the basis for developing the technological value model.

The Multi-Variable Contribution Matrix: Relative Association Analysis

The heart of the technological value model is the multi-variable contribution matrix. This matrix provides weighing factors of the relative effects of different fiber attributes on yarn, fabric, or processing parameters.

The textile end product is normally evaluated based on several characteristics that must endure collectively to meet its expected performance. These characteristics result from manipulation of many factors including yarn properties, fabric structure, and finishing treatments. The same concept holds for yarns where manipulation of factors such as fiber properties and yarn structure determines the expected performance of yarn during weaving or knitting. The extent of manipulating these factors depends on several technological and economical constraints.

Traditionally, art and experience have played a primary role in manipulating material-related factors to produce an end product of specified performance characteristics. This approach has already proven to be costly. Alternatively, scientific product development techniques should be implemented. A major initial stage in this regard is the establishment of reliable relationships between different process variables.

In the context of the technological value model, accurate relationships describing the association between fiber properties and different process variables is the key to a reliable model. Ideally, this effort should be undertaken by the textile manufacturer.

Any association analysis requires three basic types of activities: database collection, analytical work, and results interpretation. Among these three activities, database collection is the most critical one. In practice, a typical textile mill may have an immense amount of data collected on daily basis. However, when the data is needed to perform association analysis, they are often found to be scattered and untraceable. The process of performing reliable association analysis in a textile mill permits better planning of data collection, and better utilization of the information provided by the data.

The association analysis can be performed using several techniques ranging from simple bi-variable correlation analysis to multi-variable analysis. Several well-established analytical techniques ranging from simple statistical correlation analysis to regression or neural network multiple variable analysis were used [2, 3, 8].

As indicated above, the association analysis results in coefficients that indicate the relative weights of fiber attributes to each yarn, fabric, or processing parameter considered in the analysis. These weight coefficients can then be used to formulate a relative contribution matrix of the following form:

	X_1	X_2	X_3	X_m	R^2
Y_1	$w_{y1.x1}$	$w_{y1.x2}$	$w_{y1.x3}$	w_{y1xm}	R^2_1
Y_2	$w_{y2.x1}$	$w_{y2.x2}$	$w_{y2.x3}$	$w_{y2.xm}$	R^2_2
Y_3	$w_{y3.x1}$	$w_{y3.x2}$	$w_{y3.x3}$	$w_{y3.xm}$	R^2_3
.	.....	.....	.....	......	......
Y_n	$w_{yn.x1}$	$w_{yn.x2}$	$w_{yn.x3}$	$w_{yn.xm}$	R^2_n
C_i	C_1	C_2	C_3	C_m	Total R^2

In this matrix, the variables Y represent the desirable process parameter (e.g. yarn characteristic, fabric characteristics, or other processing performance parameters), the x variables represent the fiber properties, and the $w_{yi.xj}$ represent the weight or association coefficients. Each row in the contribution matrix represents a model, and the last column represents the R^2 value associated with the model.

The bottom row of the matrix represents the sums of the weight coefficients expressed as percentage values of the total R^2. Each one of these percentage sums will be called a "contribution index, C_i ". It represents the overall percent relative contribution of a fiber property to the process under examination.

Model Anchored Parameters

In order to formulate the technological value model, two anchored parameters are required: a zero-base value, and a target or variability difference factor. These two parameters are discussed below.

The Zero-Base Value [μ_o ,σ_o]

The zero-base value of a fiber attribute is the base point of the premium/discount scale of the fiber attribute. It is the point that separates the premium side of the scale from the discount side. The choice of this point will mainly depend on the type of fiber attribute used, and the type of application. With regard to the attribute type, we should classify fiber attributes into three main categories: "nominal the best", "smaller the better", and "larger the better". The "nominal the best" category describes fiber attributes whose values are desired to be at some average levels (i.e. not too high, not too low). Examples of this category include fiber fineness, Micronaire reading, and fiber friction. The "smaller the better" category describes fiber attributes whose values are desired to be at their lowest levels possible (e.g. short fiber content, neps, and trash content). The "larger the better" category describes fiber attributes whose values are desired to be at their highest levels possible (e.g. fiber maturity, length uniformity, and color reflectance). Obviously, the zero-base value for a "nominal the best" fiber attribute should be an intermediate value, and the zero-base value for "smaller the better" or "larger the better" attributes should be located toward the top or the bottom of the premium/discount scale, respectively.

With regard to the type of application, we indicated earlier that there are two main types of applications of the technological value model: performing comparative analysis between the market value and the technological value of cotton, and improving the cotton mix of a particular process through proper purchasing decisions. In the first application, available current market basis of cotton may be used as zero-base values. This allows direct comparison between the market premium/discount profiles and corresponding technological profiles. When the model is used to improve the cotton mix through proper purchasing decision, zero-base values should be selected on the basis of the desired levels of fiber properties utilized in the cotton mix. In this regard, we recommend the use of the mean (μ_o) and standard deviation (σ_o) of fiber properties in the cotton mix as the zero-base values.

The Difference Factor, D_i

The difference factor, D_i , represents the departure of the actual average or variability measure of a fiber property from the zero-base value. Thus, two types of difference factors may be used: (1) target mean difference factor, and (2) variability difference factor.

Target Mean Difference Factor, $D_{\mu i}$

The target mean difference factor ($D_{\mu i}$) is given by the following equation:

$$D_{\mu i} = \pm \frac{(\bar{X}_i - \mu_{oi})}{\sigma_{oi}}$$

where $\bar{X}_I$ = the actual mean value of the ith fiber parameter, μ_{oi} = the zero-base value of the ith fiber parameter, and σ_{oi} = the zero-base standard deviation of the ith fiber parameter. Note that the target difference factor is normalized with respect to the standard deviation to produce a non-dimensional difference value.

The use of the plus or minus sign of the difference factor depends on the category of fiber attribute used. For "larger the better" category, the plus sign is used (Figure 4.a), and for “smaller the better” category, the minus sign is used (Figure 4.b).

For the “nominal the best” category, the optimum performance is at some intermediate level of its value range. In case of Micronaire, too low values often indicates immaturity, and too high values indicate fiber coarseness. The adverse effects of these extreme levels on processing performance or end product quality are well realized.

For parameters of the “nominal the best” category, the difference factors should be modified to account for the nature of their contribution. Figure 5 illustrates one approach to this modification. In this case, two threshold zero-base values are assigned, $\mu_{o,min}$, and $\mu_{o,max}$. The difference factor for any parameter value falling around the minimum threshold zero-base value will follow the “larger the better” pattern, and that for any value falling around the maximum threshold zero-base value will follow the “smaller the better” pattern. The threshold values should be determined from the association analysis. In Figure 5, the two threshold values of Micronaire were obtained from extensive analysis of U.S. cotton crop data (1983-1994).

Variability Difference Factor, $D_{\sigma i}$

$$D_{\sigma_i} = -100 \left[\frac{\sigma_i}{\bar{X}_i} - \frac{\sigma_{oi}}{\mu_{oi}}\right]$$

The variability difference factor ($D_{\sigma i}$) is given by the following equation: where σ_i = the actual standard deviation of the ith fiber parameter.
The above equation can be rewritten using the familiar coefficient of variation as follows:

$$D_{\sigma_i} = -[C.V_i - C.V_{oi}]$$

where $C.V_i$ = the actual coefficient of variation of the ith fiber parameter, and $C.V_{oi}$ = the zero-base coefficient of variation of the parameter.Note that the variability difference factor will always follow the “smaller the better” pattern irrespective of the process or the quality level desired. Also note that when the average value of fiber parameter is equal to the zero-base value (i.e. $\bar{X}_I = \mu_{oi}$), the variability difference factor, $D_{\sigma i}$, can be given by:

$$D_{oi} = -100 \left[\frac{\sigma_i - \sigma_{oi}}{\mu_{oi}}\right]$$

The Technological Premium/Discount Index (TPDI)

The technological premium/discount index (TPDI) represents the output of the technological value model. The general form of this index is as follows:

$$TPDI = \sum_{i=1}^{i=m} C_i\, D_i$$

where C_i = the contribution index of fiber parameter i, and D_i = the difference factor of fiber parameter i.

For target mean values, the TPDI will be as follows:

$$TPDI = \sum_{i=1}^{i=m} C_i D_{\mu_i} = [C_{Mic} D_{\mu_{Mic}} + C_{FS} D_{\mu_{FS}} + C_{FL} D_{\mu_{FL}} + ...]$$

For variability measures, the TPDI will be as follows:

$$TPDI = \sum_{i=1}^{i=m} C_i D_{\sigma_i} = [C_{Mic} D_{\sigma_{Mic}} + C_{FS} D_{\sigma_{FS}} + C_{FL} D_{\mu_{FL}} + ...]$$

The linear additive form of the above TPDI expressions represents the simplest form that one can use to determine target-related or variability-related premium/discount values. This simplicity provides a great deal of flexibility in implementing the technological value model. Other non-linear forms may be used, particularly for variability TPDI. The option of non-linearity should be used only if dictated by the relative association analysis. In this study, only linear forms of the technological PDI expressions will be used.

The PDI Trilobate System

In order to produce reliable premium/discount values, fiber attributes should be divided into two main classes. The first class represents the expected inherent fiber characteristics (e.g. length, fineness, strength, maturity, etc.). The second class represents attributes that should not exist under ideal fiber production conditions (e.g. trash content, short fiber content, neps, and stickiness). These attributes will be called fiber defects (or contaminants). These defects do not inherently characterize a textile fiber, and they can be prevented or minimized using proper growing and ginning conditions. Although the current classing system admittedly consider these attributes as being defects or extraneous matter, only heavy trash and leafs are accounted for in the system.

When the first class of fiber attributes is under consideration, two distinct forms of contribution should be recognized: the contribution of fiber attributes to processing performance parameters, and the contribution of fiber attributes to the quality of the end product (yarn or fabric). Examples of processing performance parameters include: opening and cleaning waste, combing waste, spinning endsdown, spinning potential, and filling stops. Examples of end product quality parameters include yarn strength, yarn evenness, and fabric strength. From the standpoint of process design, some fiber attributes can contribute to these two types of parameters in uniquely different manners. This point is discussed below.

Processing performance mainly involves interaction between the fibers and the machine elements. The end product quality parameter, on the other hand, involves fiber-to-fiber interaction. Accordingly, some fiber attributes contribute to processing performance in a uniquely different manner than to yarn quality. For example, it is well recognized that fine and long fibers are considered premium in relation to yarn quality. This is simply a result of the superior fiber-to-fiber interaction in the yarn which enhances both the integrity and the strength of the yarn. In relation to processing performance, very fine or very long fibers may result in excessive opening and carding waste and in high nep formation due to the high flexibility of these fibers. Similar arguments can be made for other fiber attributes including friction and elongation.

In light of the above discussion, we recommend three different premium/discount indices that can collectively determine the technological value of cotton fibers. These are the processing performance premium/discount index (PPDI), the end product quality premium/discount index (QPDI), and the fiber defects premium/discount index (FDPDI). These three indices form the PDI Trilobate System shown in Figure 6.

The PDI Trilobate provides an inclusive system that can assist in determining the technological value of cotton in view of the three major areas of fiber impact. Different companies may have different points of emphasis regarding the worth of cotton fibers in relation to their processes. The trilobate system provides the necessary flexibility of valuing cottons depending on the company's emphasis, and the level of quality needed. In addition, it integrates the various efforts of cost and quality optimization performed by a textile company into a systematic approach that can lead to more objective cotton purchasing decisions, and better utilization of cotton fibers than the traditional subjective approaches.

The technological value model discussed in this paper has been implemented in several textile mills. Results of these implementations will not be reported here due to the limited space allowed. However, the author will be willing to share many of these results (without pointing out the name of the participant companies). For more information contact Dr. El Mogahzy at (334)844-5463, or E-Mail: yehiae@eng.auburn.edu.

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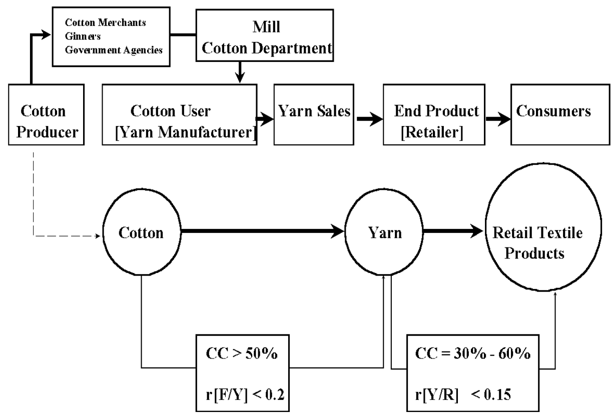

CC= the average percentage contribution to manufacturing cost.
R[F/Y] = the coeficient of correlation etween fiber price & yarn price.
R[Y/R] = the coefficient of correlation between yarn price & retail item price.

Figure 1. The Cotton Market Flow Chart.

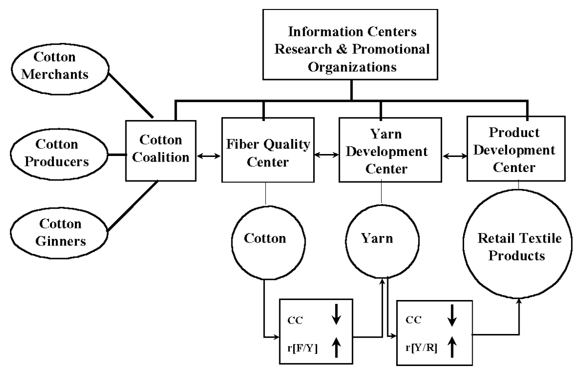

Figure 2. The 21st Century Prososed Cotton Market & Development Flow Chart

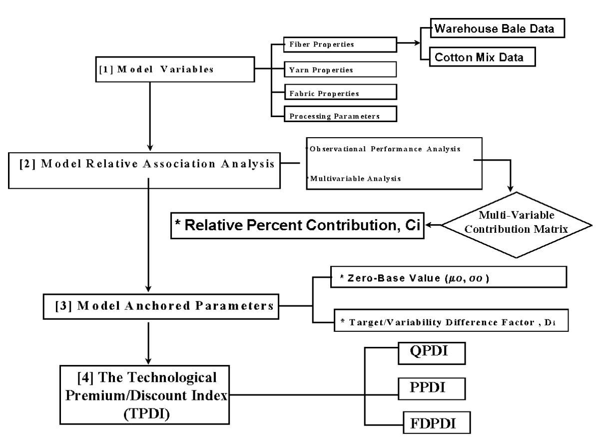

Figure 3. Different Phases of Building the Cotton Technological Value Model

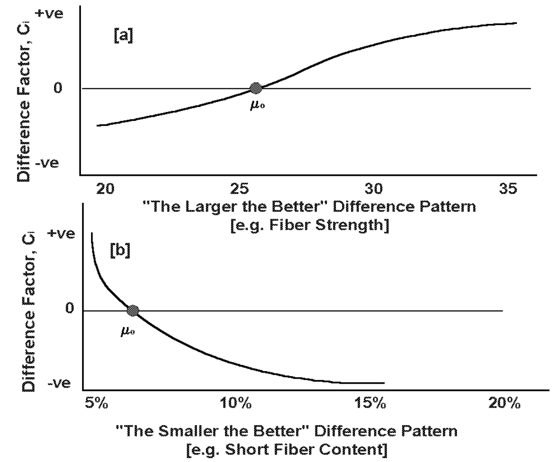

Figure 4 Example of Difference Factor Patterns

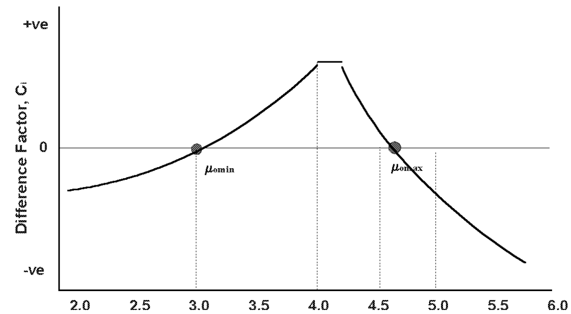

Figure 5. Example of Special Difference Factor Patterns [e.g. Fiber Micronaire]

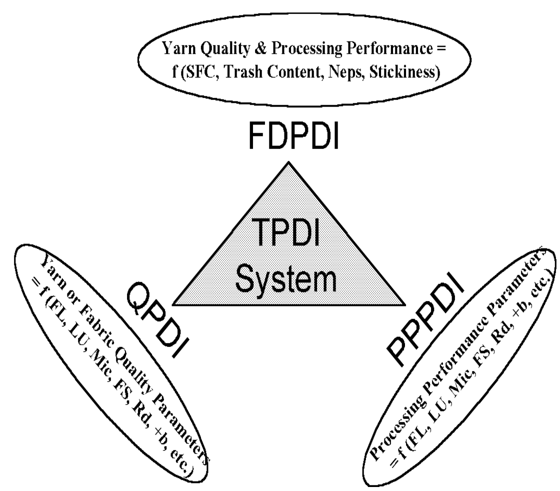

Figure 6. The Technological Premium Diccount Trilobate System