MIX POPULATION PROFILES AND BALE PICKING SCHEME

Basic Elements of cotton fiber selection

The following are the typical strategy of fiber selection:

- Establishing the mix profile
- Population profile analysis
- Bale picking system
- Mix evaluation and verification

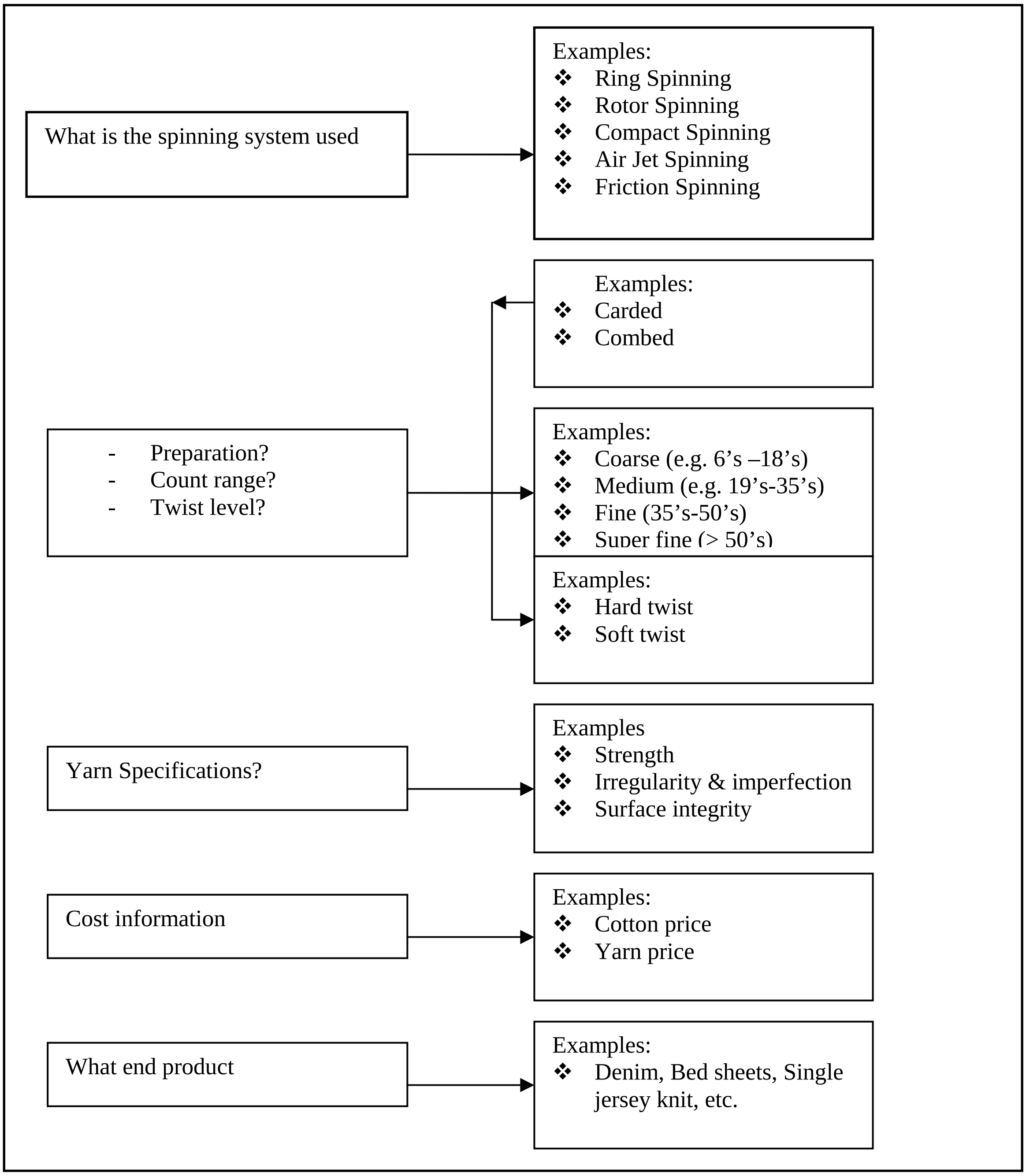


Figure 3.1: Examples of information required for setting the cotton mix profile

Establishing the cotton mix profile:

The starting point of implementing a fiber selection strategy is to establish cotton mix profile, or to determine the desired fiber characteristics of the cotton mix. Specifically, a mill implementing a fiber selection strategy should first establish the average values of different fiber attributes of bale laydown and maximum allowable variability within a bale laydown. Such knowledge may result from long experience with the process or from other source of information such as machine maker or fiber producer recommendation, and independent research results.

Thus: ***A cotton mix of optimum profile is a bale laydown, which exhibits average values and variability levels of fiber attributes that upon processing will result in best yarn characteristics and best processing performance at the lowest cost possible.***

However, particular cottons of low market prices may not necessarily result in significant reduction in manufacturing coast. (i.e. clean ability).

In a fiber to yarn engineering program, cotton mix profile should be selected using following basic steps:

- Gathering information about fiber to yarn conversion system
- Gathering reliable data base of fiber properties, yarn properties, and processing parameters
- Brainstorming of the effects of fiber attributes on yarn quality and processing performance
- Developing reliable fiber to yarn relationships
- Developing systematic methods for determining the optimum cost of the cotton mix.

The second step of establishing the cotton mix profile is gathering reliable data of fiber attributes, yarn characteristics, and processing parameters.

The third step is brainstorming of the effects of fiber attributes on yarn quality and processing parameters. Experience and daily practice provide a great deal of insight into the desired cotton mix profile. There are no specific tools to perform brainstorming, but a layout of the different yarn parameters and fiber attributes that are expected to influence these parameters proves to be useful in this regard. An example is shown in figure 3,2.

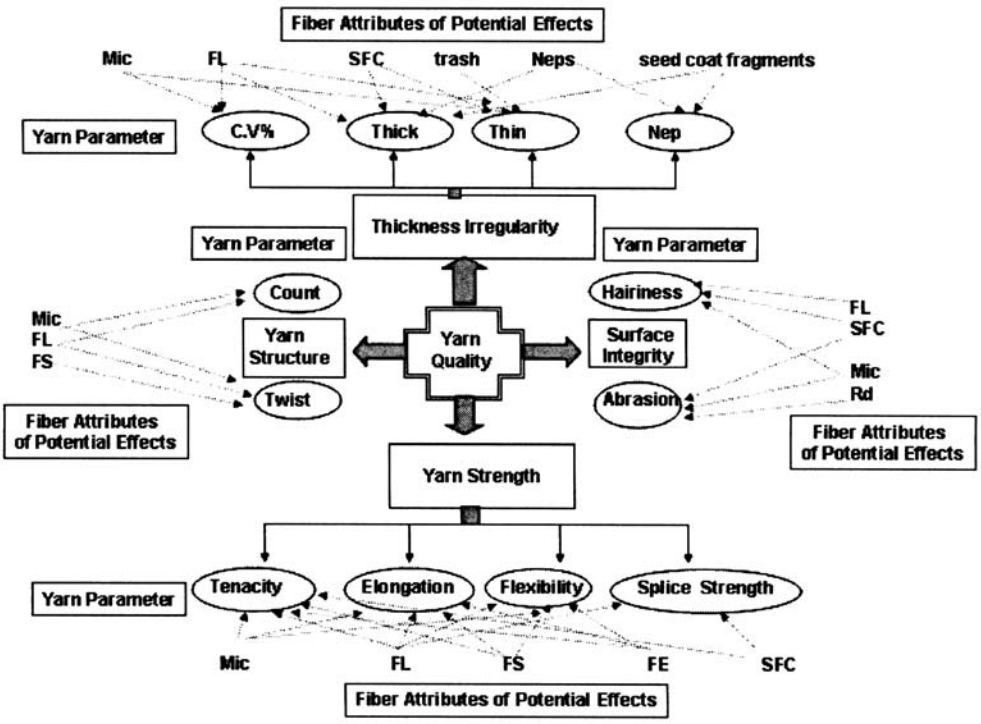


Figure 3.2 General brainstorming outline of fiber – yarn relationship

The only way to establish an optimum cotton mix profile is through the use of reliable and accurate fiber to yarn relationships. The process of developing fiber to yarn relationship is commonly called "fiber to yarn modeling". A general modeling scheme may be illustrated as shown in figure 3.3.

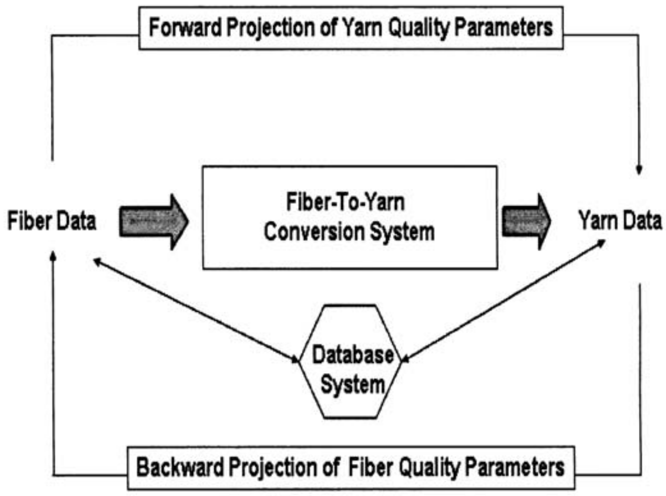


Figure 3.3: The fiber to yarn modeling process

Data of fiber and yarn are essentially needed. These data are available in today's modern textile mills; their use requires two main criteria: reliability and traceability. Most data produced by modern testing techniques are largely reliable. Figure 3.3 shows two types of yarn modeling: forward projecting of yarn quality and backward projection of yarn quality. The first type addresses the question of "what values of yarn quality parameters cab be obtained from a cotton mix of particular values of fiber attributes?" The second types addresses the question of "for some pre-specified values of yarn characteristics, what are the average values of fiber attributes that we should use in the cotton mix?". Fortunately, these two questions can be easily answered using a wide range of analytical techniques enhanced by the powerful computing capability of today's technology. Some of these techniques will be discussed later.

Analysis of cotton mix profiling:

Assume that two fabrics have to be produced, the first one is denim and the second one is a knit yarn. The first step of analysis is to select yarn and processing parameters that are critical to the processes under consideration. The selected parameters should exhibit two important criteria:

- ❖ They should be sensitive to changes in the cotton mix profile or input fiber attributes.
- ❖ They should have significant impact not only on the quality of end product, but also on manufacturing coasts.

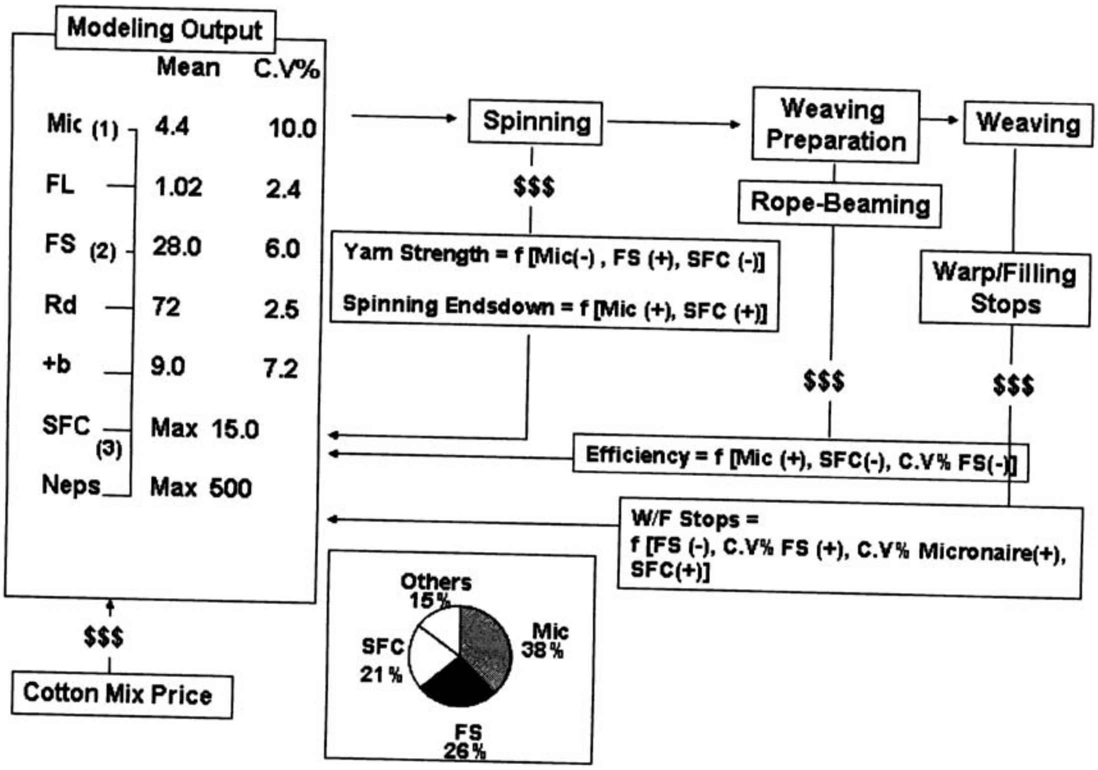
The data of fiber attributes of bale laydown and corresponding data of yarn quality and processing parameters are available, analysis can be performed in a short period of time. Most companies maintain weekly or bi-weekly records of their data.

One key issue related to this analysis is the availability of what is called "model stimulants". This is the need of some extreme values of input variables (fiber attributes) to provide

modeling boundaries. Because of lack of stimulants, few special experiments should be made to track a number of cotton mixes with extreme values of fiber attributes throughout the different stages of processing and to examine their effects on the parameters selected by the manufacturer. Later on some modeling technique will be discussed.
Figures 3.4 and 3.5 illustrate the outcomes of modeling analysis for the denim yarn process and the knit yarn process, respectively. The denim yarn was produced from an open end spinning process at English count 6'^{s} and card yarn preparation. The single-jersey knit yarn was produced from a ring spinning process at English count 30'^{s} and combed yarn preparation. The outcome of the analysis should agree with our understanding of the physical effects of the fiber attributes on yarn and processing parameters.

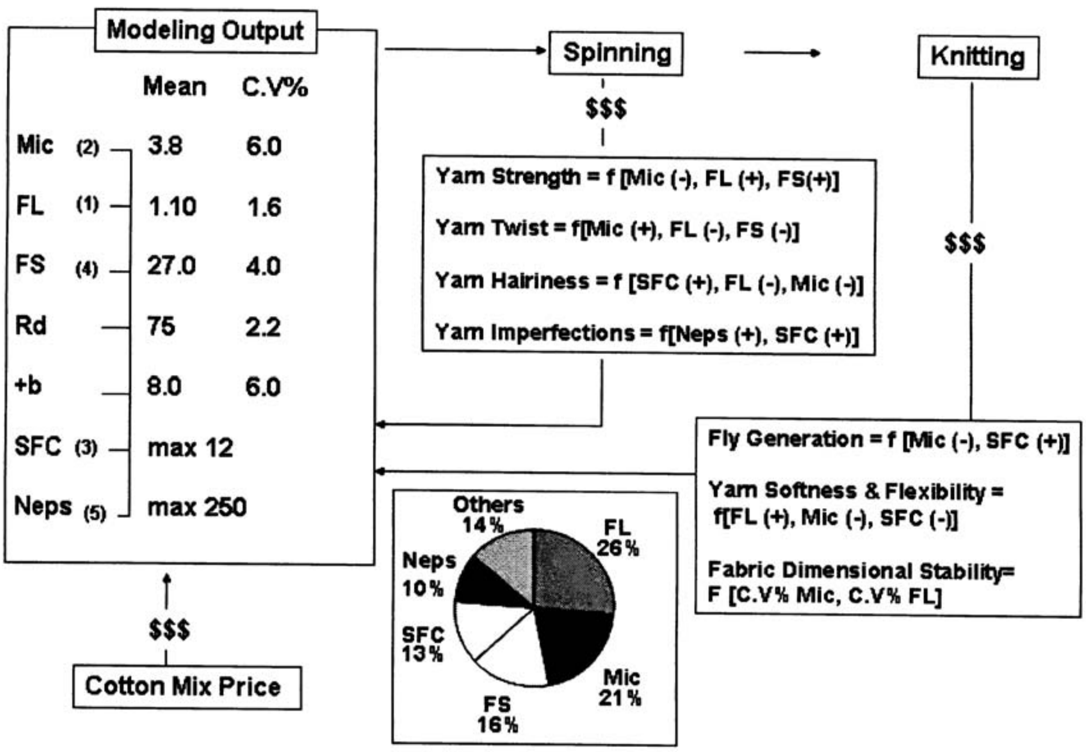
For **denim** yarn process, the following outcomes can be drawn Figure 3.4):

- ❖ The critical yarn property is the strength, and the critical parameters for processing are spinning ends-down, rope beaming efficiency, and weaving performance.
- ❖ The fiber attributes that contribute significantly to these parameters are fiber fineness (micronaire), fiber strength, and short fiber content.
- ❖ The effect of the individual fiber attributes on the given property is given from figure 3.4.
- ❖ Rope beaming is one of the critical processing of denim industry. Warp yarns are typically dyed in the rope form, and ropes are converted into beams prior to the sizing process. A major issue in rope beaming is machine efficiency, which can be as low as 40% when problems such as high hairiness, excessive yarn splicing, and excessive weak point occur. According to the analysis provided by El-Moghazy [ ], short fiber content, micronaire and variability in fiber strength significantly influence the efficiency of rope beaming.
- ❖ Weaving performance is influenced mainly by fiber strength, the variability in fiber strength (C.V% strength), the variability in fiber micronaire (C.V% Mic.), and short fiber content.



For **knit** yarn process, the revealed that the following outcomes (figure 3.5.):

- ❖ The critical parameters are yarn strength, twist hairiness, imperfections, fly generation, and yarn softness and flexibility.



- ❖

- One of the important criteria of apparel knit yarn is soft or low twist. This is the main reason that ring spinning is commonly used in this type of yarn instead of open-end yarn. In general, an optimum twist level of a knit yarn is that which is high enough to provide yarn integrity (good strength, high abrasion resistance, and low hairiness), yet low enough to provide the pliability and flexibility required during knitting and the softness of the knit apparels. Longer, stronger and finer fibers allow this optimum trade-off.
- Yarn imperfection is also critical in apparel knit yarns, particularly for medium to fine counts. Short fiber content and fiber neps significantly influence knitting parameters. Spinners that produce very fine knit yarns (>50) consider fiber neps to be the most fiber attribute.
- Fly generation is one of the common problems in knitting process. It influences both the knitting performance and the quality of the knit fabric produced. Short fiber content and micronaire are the main reasons for fly generation.
- Dimensional stability is a critical parameter of apparel knits. In relation to fiber attributes the variability in fiber length and micronaire reading significantly influence this parameter.

POPULATION PROFILE ANALYSIS:

Once a cotton mix profile is established, the next step of implementing a fiber selection strategy is **population profile analysis.** *The objective of this analysis is to ensure that cotton bales available in the warehouse exhibit fiber attributes that satisfy the cotton mix profile.* Cotton bales should be purchased with values of fiber attributes falling within the range dictated by desired cotton mix profile.

In a fiber selection process, the bale population profile is typically identified by three main parameters:

1. The size of the population,
2. The mean values of fiber attributes, and
3. The variability of the fiber attributes.

These three parameters are described by the frequency distribution of the population. As the population size approaches infinity, its distribution approaches the normal distribution (figure 3.6) defined by the mean µ and the variance σ^2. In an ideal fiber selection strategy, the cotton mix profile should statistically match the population profile. This point is illustrated in figure 3.7. Therefore, we should select cotton bales from the warehouse that are truly representative of the bale population. The basic criteria used for evaluating the mix population correspondence are as follows:

- **Cotton mix mean** $(\overline{X})$ **= population mean** (μ)
- **Within mix variance** (S^2) **= population** (σ^2)
- **Between mix variation** $\sigma_{\bar{x}}^2 = \dfrac{(1-f)\sigma^2}{n}$

Where $f = n/N$ = cotton mix size/population size

In practical terms, these criteria indicate that:

i. The average of fiber attribute in the cotton mix should be equal to its corresponding average value in the bale population,
ii. The variability within single cotton mix should be equal to the corresponding population variability,

iii. The between mix variability will depend on the mix size or the number of bales in the lay-down in comparison with the population size and the population variability.

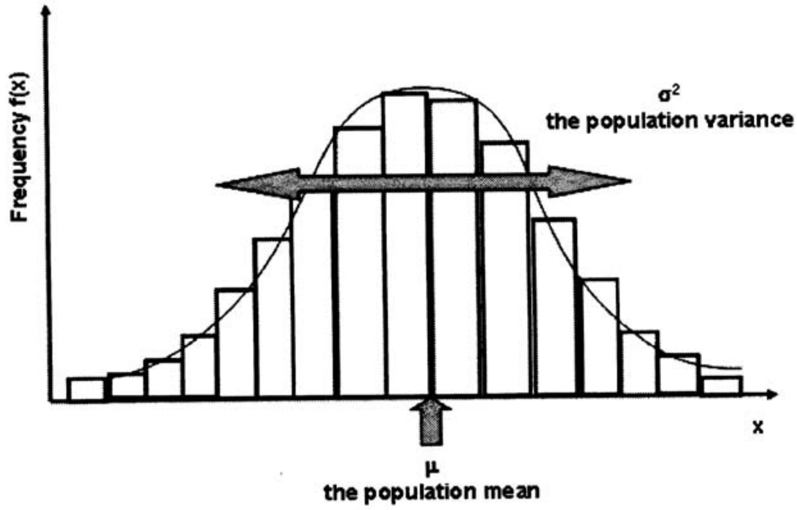
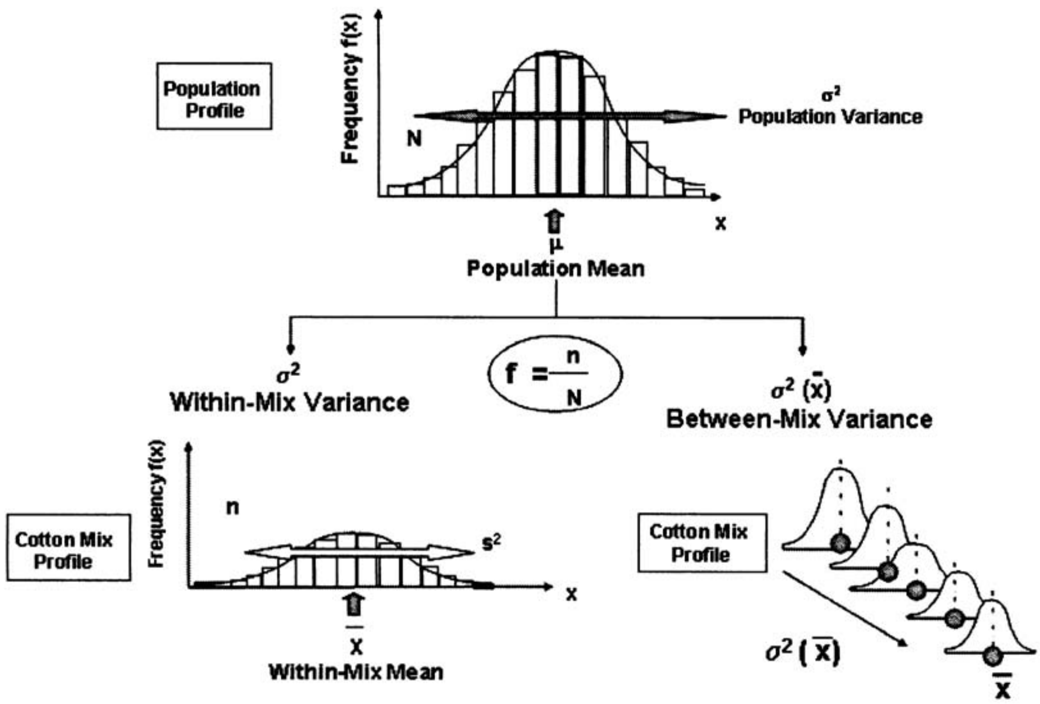


Figure 3.6. Population Profile: The Frequency Distribution

Normal Distribution: $f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$ $\qquad -\infty \le x \le \infty$

In some situation, a company may have to deal with **short bale inventory** (two to three weeks supply of cotton at a time). This situation has some economical merits, particularly in relation to storage and handling coast.



A good fiber strategy should account for dynamic changes in the population profile provided that they are reasonable and that they fall within production and quality boundaries.

In the following section, we will discuss some of the basic methods for **adjusting population profiles under dynamically changing conditions**. Obviously, a company that always purchases approximately the same type of cotton, or purchases the same type of yarn would require minor adjustments in comparison with a company that purchases different types of cottons (different regions, different varieties, etc.) and produces a wide range of yarn styles. The key to any adjustment is grouping and/or categorization of cotton bales according to pre-determined criteria. Grouping is the processes that aim at arranging cotton bales in the warehouse according to major criteria such as: cotton type, growth area, spinning type and yarn style. Categorization is the process that aims at arranging cotton bales within each group by pr-specified ranges (categories) of values of some fiber attributes.

BY-GROUP ADJUSTMENT:

The simplest grouping system is that which a **single group of cottons is used for each particular cotton type or yarn style**. This type of grouping is required when **yarns of substantially different characteristics** are being produced. For example, a spinner producing coarse open-end spun yarns for denim fabrics, and medium ring spun yarns for knit fabrics should divide the bale warehouse into two separate groups, one for each type of yarn. In this case, each cotton group will consist of a bale population matching the mix profile required for yarn style in question. Cotton bales are then picked from each population group to form a mix representing the average fiber characteristics of each group. This grouping structure is illustrated in figure 3.9.

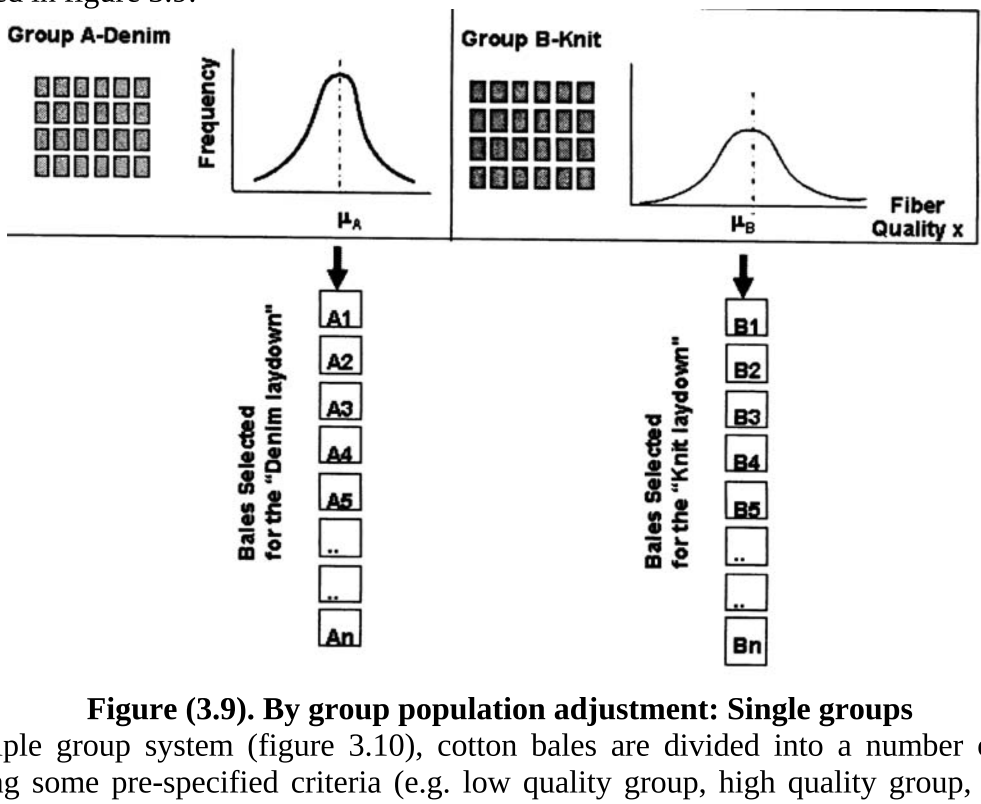


Figure (3.9). By group population adjustment: Single groups

In multiple group system (figure 3.10), cotton bales are divided into a number of groups following some pre-specified criteria (e.g. low quality group, high quality group, Memphis cotton, California, etc.). In this case, a particular yarn style may be produced from cottons combining these several groups, and at pre-calculated proportions that satisfy both quality and inventory constraints.

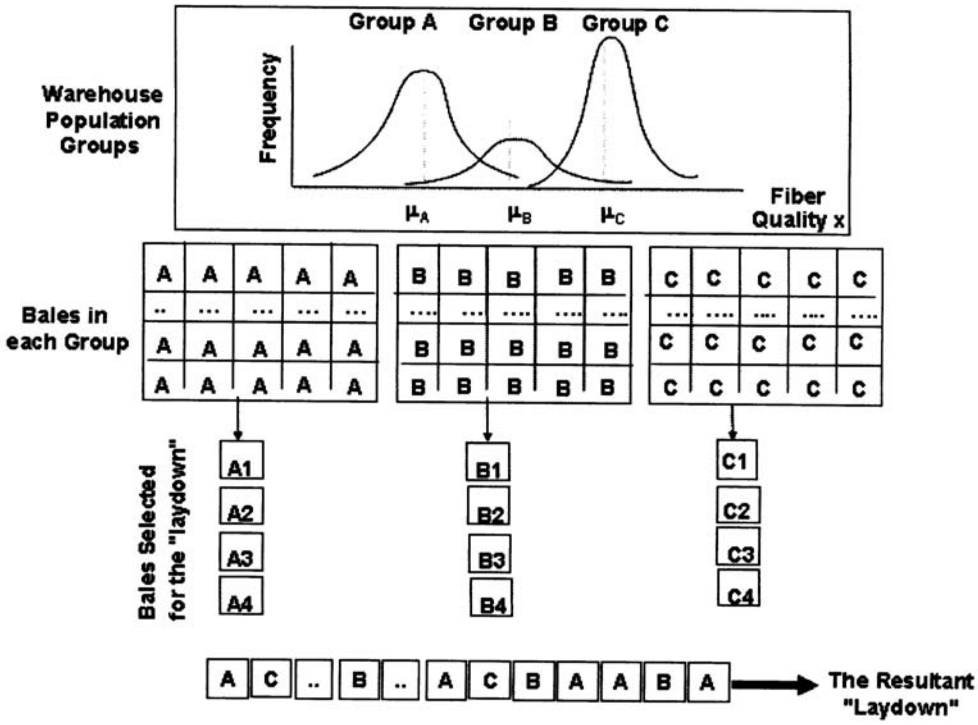


Figure 3.10 By-Group cotton fiber selection: Multiple grouping

BY-CATEGORY ADJUSTMENT:

Categorization implies arranging cotton bales within each group by pre-specified ranges (or categories) of values of some fiber attributes. This method requires evaluation of population distribution of different fiber attributes in each cotton group, and determining category criteria. Figure 3.11 shows a simple by-category arrangement in which two fiber attributes are considered (Micronaire, and fiber length) and a single group (A) is used. As can be seen in this figure, each of the two fiber attributes is divided into three categories. 1,2 and 3. This result in 9 different combinations of values of two fibers attributes (3^2). In other words, cotton bales of group A should be arranged in 9 different lots in the warehouse so that they can be picked in proportion to the size (number of bales) in each category combination. The resultant cotton bale lay-down in this case will consist of repeated patterns of 9 combinations. Each repeat is often called the cotton "minimix". For example, a bale lay-down of 45 bales will consist of 5 replicates of the category combinations shown in figure 3.11. Suppose that the number of properties is 3 (Micronaire, fiber length, and fiber strength), and the number of categories per single property is 3, thus the total number of combinations will be 27.

Number of category combinations = k = (number of categories) $^{\text{number of fiber properties}} = X^J$

From this equation as the number of properties increases, the number of combinations increases exponentially. In recent years the trend has been towards the so-called "virtual warehouse". In this type of warehousing, the cotton bale population has no physical existence in the textile mill.

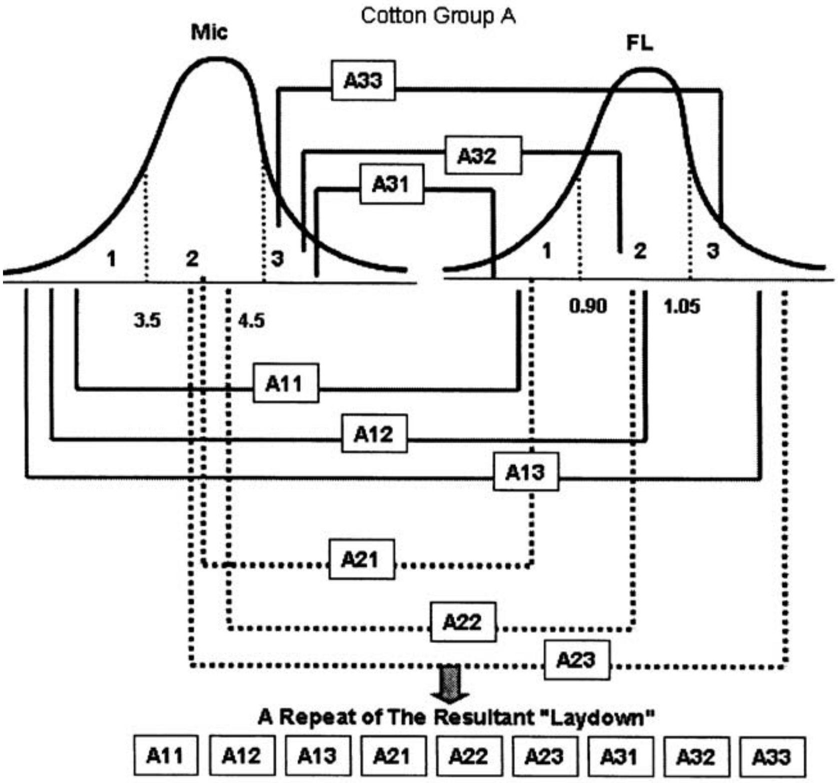


Figure 3.11: By Category fiber selection

It is physically located in (or supplied to) concentration points or central warehouses owned by the cotton merchants or the ginners, and only limited quantities are supplied to textile mill depending on the rate of consumption. The advantage of virtual warehouses lies in more opportunities and greater flexibility in establishing the population profiles.

BALE PICKING: THEORITICAL CONSEDERATIONS

There are many methods that can be used for selecting cotton bales from the warehouse population. These methods include:

- **Random bale picking**
- **Category bale picking**

RANDOM BALE PICKING:

In a random bale-picking scheme, cotton bales are randomly picked from the parent ware house to form the cotton mix. By definition, **any bale in the population will have the same chance of being picked in the mix,** or any value of the fiber characteristic represented in the population distribution will have the same opportunity to be represented in the cotton mix (or bale lay-down). The Probability of obtaining any particular mix of **n** distinct population bales (irrespective of order is

$$\frac{n!(N-n)}{N!} = \binom{N}{n}^{-1}$$

and
$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$$

$$\text{Variance } (\bar{X}) = S_{\bar{X}}^2 = (1-f)\frac{\sigma^2}{n},$$

The above equations simply indicate that in a randomly selected bale down, a low between mix, can be obtained under the following conditions: Low population variability (low σ^2 value), and large number of bales in lay-down (large n).

CATEGORY BALE PICKING

The "By-category" selection is the method in which the bale population is divided into categories from which bales are selected. The **width of each category (or the category break point)** depends on the shape of the population distribution of the fiber characteristics.

In general, a population may be divided into k non-overlapping categories of sizes $N_1, N_2, ..., N_k$ and corresponding weights $W_1, W_2, ..., W_k$, where $W_i = N_i / N$, and N is the total number of population bales. Each category is considered as a sub-population with a corresponding mean μ_i , and variance σ_i^2 .

Within the category picking scheme, different approaches can be utilized depending on the objective of mixing. The most common approach is the so called **Proportional Weight Category-Picking scheme (PWC).** Another approach that can be used under special circumstances is the so-called "**Optimum Category-Picking Scheme" (OPC).**

PROPORTIONAL WEIGHT CATEGORY-PICKING (PWC)

The proportional Weight Category approach (PWC) should satisfy two main conditions:

- Consistent mix or bale lay-down
- Stable bale inventory

The underlying concept of the PWC bale picking is that cotton bale belonging to a certain category are represented in the mix in numbers proportional to the relative frequency of their category in the population. Within a given bale category, bales are picked randomly. Accordingly, a proportional weight category picking scheme should satisfy the condition that the probability of the presence of a cotton bale from a certain category in the mix is equivalent to N_i / N . This means that the number of bales, n_i belonging to a certain category is: $n_i = n\left(\frac{N_i}{N}\right)$, where n is the total number of bales per lay-down, N_i is the total number of bales in population category i, and N is the total number of bales in the overall population.

The parameters of categorized population can be estimated from lay-down statistics as follows: $\bar{X} = \sum_{i=1}^{k} W_i \bar{X}_i$ $\bar{X} = \sum_{i=1}^{k} W_i \bar{X}_i$

and the variance $(\bar{X}) = S_{\bar{X}}^2 = \frac{(1-f)}{n} \sum_{i=1}^{k} W_i S_i^2$

Where $\bar{X}_i$ is the average value of fiber characteristic in category i, W_i is the weight of category i (or N_i / N), k is the number of categories, f is a constant determined by n / N , and S_i^2 is the category variance.

The above equation indicates that between lay-down variance may be reduced by increasing the number of bales per lay-down, n (or increasing the fraction value f) and by decreasing the category variance S_i^2 . The latter can be achieved by increasing the number of categories.

OPTIMUM CATEGORY (OPC) PICKING SCHEMES

The optimum category picking scheme will depend on the number and type of constraints established by the mill. There are two types of this scheme: "**Variance OPC" and the (coast/Variance OPC".** In Variance OPC, the main constraints are the category variation. In coast/variance OPC, the principle constraints are category variance and coast.
In variance OPC picking scheme, the number of bales selected from each category can be obtained from the following equation:

$$n_i = n\frac{W_i S_i}{\sum_{i=1}^{k} w_i S_i}$$

where n is the total number of bales in the mix, W_i is the weight of category i, N_i/N , and S_i is the standard deviation of the category i,.

A simple coast model is given as:

$$C = c_o + \sum_{i=1}^{k} c_i n_i$$

and the optimum number of bales selected from each category is:

$$n_i = \frac{(C - c_o)W_i S_i / \sqrt{c_i}}{\sum_{i=1}^{k} W_i S_i \sqrt{c_i}}$$

Where c_o is a fixed overhead coast, c_i is the coast of acquiring cotton of a particular category, n_i is the number of bales selected in the mix from the ith category .
The above equation indicates that in a coast/variance OPC, the number of bales selected from each category will depend on the variation of the fiber characteristics within the category, S_i and the coast acquiring cotton of a particular category, c_i .

SIMPLE COMPARISON OF DIFFERENT PICKING SCHEME
An example is given where the total number of bales of population is assumed to be 2000 bale.

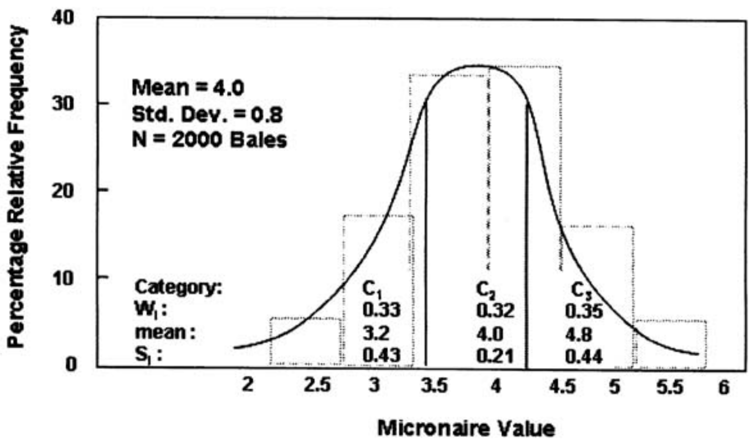


Figure 3.12 Population profile: Frequency distribution of Micronaire
From this population, bales were picked using three picking schemes: random, Proportional weight and variance-optimum category schemes. This division has resulted in two categories

of approximately the same value of standard deviation (category 1 and 3) and a lower standard deviation of category 2.
Figure 3.13 shows the Micronaire average profile of bale mixes selected by the three picking schemes. The actual values of between lay-down variance σ^2, based on 20 bale lay-down are 0.018, 0.004, and 0.003 for random picking ,PWC, and OPC picking respectively.

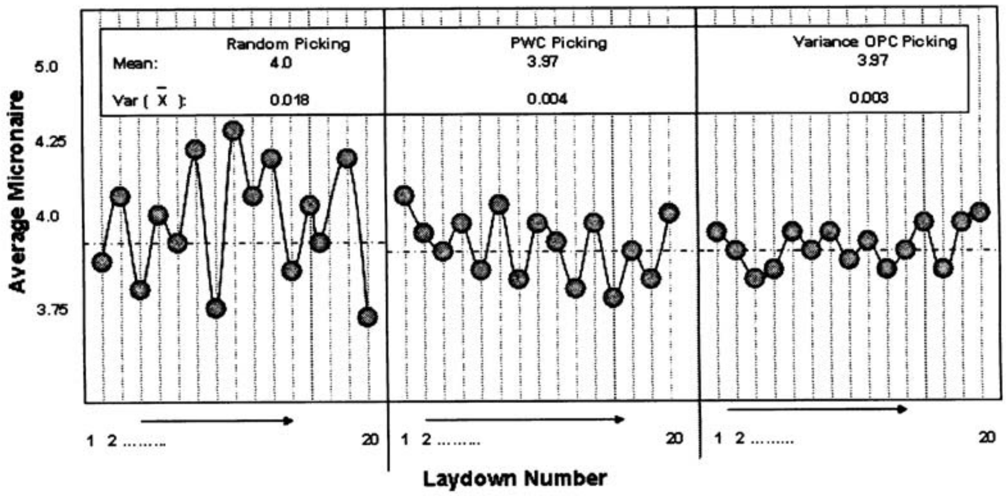


Figure 3.13 Comparison of three different Bale picking schemes.
[n=30, N=2000, population mean of Mic. =4, population S.D. =0.8]