A COMPARATIVE STUDY OF THE FLEXIBILITY OF THREE TYPES OF APPAREL PRODUCTION SYSTEMS TO VARIATIONS IN COLLAR DESIGNS

by

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(ABSTRACT)

The purpose of this study was to examine and compare the flexibilities of three apparel production systems to variations in products manufactured on them. The production system used by a company was determined based on five system attributes (i.e., type of workflow, level of WIP inventory, number of tasks, mode of transportation between workstations, and level of interaction between operators). The product line of the company (i.e., staple, semi-staple, fashion, and high-fashion) was determined based on the number and type of collar designs manufactured by the company. Flexibility of a system was determined by the range of collar designs manufactured by the system.

A stratified proportionate random sample of manufacturers producing men's and women's shirts and blouses was selected for the survey. The questionnaire was pilot tested for content validity and reliability. The adjusted

response rate was 39% (n=52). Non-parametric tests were performed to test the statistical significance of the hypothesized relationships.

Three production systems (i.e., bundle system, progressive bundle system [PBS], and modular system) were compared for their volume of production. The size of the company (i.e., number of employees and the total volume of production) was compared between the three production systems.

The five system attributes were found to be significantly related to the system used. The procedure adopted for determining the product line of the company was also found to be significant. The relationship between production systems and product lines was significant in some of the cases and not significant in others. PBS was found to be most flexible due to its ability to accommodate a greater style variation followed by bundle system and modular system. The relationship between production systems and the volume of production and also between the system and the size of the company were not significant.

Dedicated to my Parents, Husband, Sister, Brother, and

for their unending love and support

&

my advisor

Dr. Doris H. Kincade for her invaluable patience and support

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CHAPTER I

Introduction

Background

The U.S. apparel market is fast changing and offers a challenge that few other consumer products offer to marketeers and manufacturers alike. The American apparel market is characterized by increasing number of imports, an individualistic consumer, and fast turns in fashion (Lowder, 1991). In a world of ever changing fashions, more and more apparel manufacturers are adopting strategies suitable to capture the growing apparel market while keeping in mind the customers' individualistic needs. With foreign producers often using low cost labor and maintaining a competitive price for their goods, the U.S. manufacturers will have to take a closer look at their manufacturing strategies and management techniques (Soni, 1990).

The apparel industry has traditionally been a low capital and less advanced industry compared to the hard goods industry, but the picture is rapidly changing with the introduction of new and more productive apparel production equipment (Brown, 1992). Apparel manufacturers are now choosing more appropriate and effective production systems to face the challenges of increased competition.

On the other hand, the nature of the competition is constantly changing with more emphasis being placed on improving the characteristics of the products and being responsive to differing customer requirements (Gerwin, 1987). According to the U.S. Office of Technological Assessment (1987), current trends in the apparel market indicate greater variations in styles, frequent changes in styles, shorter lead times and smaller lot sizes.

In today's world of variety and Just-in-Time (JIT) manufacturing, flexibility of apparel manufacturing systems attains great importance and is fast emerging as an important factor in determining the competitiveness of a manufacturing system (Miller & Roth, 1987; Ramasesh & Jaikumar, 1991). Flexibility is used to describe objects that are capable of conforming to changing or new situations. In manufacturing, flexibility implies or refers to the ability of a system to cope with changes (Gupta & Buzacott, 1989). Flexibility is required to cope with uncertainties both in the internal and external operating environments. Changes in the demand for particular products is an uncertainty in the external environment (Buzacott, 1982). Flexibility of a production system is considered one of the most important attributes in selecting an apparel production system (Hodge & Canada, 1989).

Statement of purpose

Apparel is a highly complex product that varies greatly in terms of style features and length of product life. The frequency of style change in apparel is growing and the size of orders is getting smaller (Hodge & Canada, 1989). Changes in the market caused by changing fashions and seasonality leads to a wide variation in the demand for apparel items. This situation affects the styles of apparel products that are to be produced. The styles of apparel product influence the assembly operations during manufacturing. The fast changing nature of the apparel market requires manufacturing systems that are capable of responding to changes in the market, as revealed in the changes in apparel product styling (Lin, Kincade, & Warfield, in press). With more consumers tending towards one-of-a-kind clothing, manufacturing systems need to be highly flexible to enable customized production with shorter production runs, while still maintaining the economy of production (Sisselman, 1990). This type of flexibility is referred to as mix flexibility (Gerwin, 1987). A system that is highly flexible can respond more easily to demand than a system with little flexibility (Hodge & Canada, 1989).

Hodge and Canada (1989) indicate that the net worth of the system, its manufacturing flexibility, quality, and serviceability are the most important attributes in selecting a production system in the apparel industry. The importance of flexibility has resulted in a need for research on issues related to product and production characteristics as a function of degree of flexibility of a production system (Soni, 1990). Information on flexibility also helps operations managers in making decisions related to strategic issues related to flexibility (Ramasesh & Jaikumar, 1991).

Conceptual Framework

Planning is the basis for all future managerial activities. Planning establishes the guidelines and actions that must be taken to meet the company's objectives and goals (Evans, Anderson, Sweeney, & Williams, 1984). A company's decision making process is influenced by a number of factors like economic conditions, government regulation, competition, and technology (Troxler & Blank, 1989).

Planning and decision-making for a company could be classified hierarchically into strategic, tactical, and operational planning. A strategic plan should recognize specific capabilities of the company and tools that can be used to enhance its competitiveness (Chase & Aquilano, 1992). Strategic plans are broad in scope, and include activities related to marketing, production, and finance. Identification of the factors that affect each of these activities in relation to the company's objectives and goals will help evaluate each of the three activities. For example, in the production activity, the various internal and external factors that affect production need to be identified. The external factors affecting production include type of products, product mix, processing requirements, training and skill of operators. The internal factors include machine and material handling system material flow, (i.e., the intrinsic qualities of the production system), processing time, operator absences, and quality (Buzacott, 1982). The internal factors exist within the company and are therefore easier to control. The most important internal factors affecting a system are the intrinsic qualities of the production system.

Production systems are one of the major components of production in an organization and constitute a major portion of the company's investment (Evans, Anderson, Sweeney, & Williams, 1984). Selecting the right production system assumes great importance since investors would want a system worth the investment. Production systems have to be evaluated to help companies make informed choice of production systems.

Evaluation of Production Systems. Evaluation of a production system is a multi-factor decision analysis. The evaluation must consider cost issues, technology, and operations in relation to company objectives (Troxler & Blank, 1989). The evaluation of a system follows three steps: (a) identifying the elements that characterize the system, (b) categorizing the elements into some rational groups to give a comprehensive indication of the value of a system, and (c) aggregating the groups and measuring the contributions of each group to the system (Troxler & Blank, 1989).

Troxler and Blank (1989) have identified suitability, capability, performance, and productivity as the groups that comprehensively reflect a manufacturing system's value (Table 1). Suitability of a manufacturing system refers to compliance of the system with the corporate strategy. Capability of a system refers to the intrinsic ability of the system. The capabilities of a production system are evaluated in terms of the products manufactured on the system (Frank, 1953; Georgia Institute of Technology, 1980; Wise, 1990). Performance of a system is a measure of achievement in terms of the system's physical performance. Productivity of a system refers to the total cost and financial benefit of the system.

Table 1
Set 1-Manufacturing system elements and groups by Troxler and Blank(1989)

Groups	Elements	Groups	Elements
Suitability	Investment Growth Technology position Market Position Employee relations Workforce composition Organizational structure Operations management	Performance	Throughput Quality Inventory Information Capacity utilization
Capability	Design of the system Function Reliability Availability CIM ability Flexibility Human factors Technical feasibility	Productivity	Economic infrastructure Customer response Environment al influence

Piener, Kruger, and Adendorff (1986) have identified utility, availability, and cost-benefit (see Table 2) as the groups that comprehensively reflect a manufacturing system's value. Utility of a system refers to the user's desirability of the performance capabilities of a system. Availability is the ability of the system to assume a functional state at any point of time. Cost-benefit is the benefit obtained on cost incurred through the life cycle of the system. Each of the groups is a combination of two sub-groups (see Table 2). Sub-groups consist of elements.

Table 2
Set 2-Manufacturing system groups and sub-groups by Piener, Kruger and Adendorff (1986)

Groups	Sub-Groups
Utility	Suitability Effectiveness
Availability	Reliability Maintainability
Cost- Benefit	Cash-flow Timing

The groups identified by Piener et al. (1986) are similar but not identical to the groups identified by Troxler and Blank (see Table 3). The utility group of Set 2 is split into two groups in Set 1 (i.e., suitability and performance).

Table 3
Similarities between Group 1 and Group 2

Set 1	Set 2
Suitability	Utility
Performance	
Capability	Availability
Productivity	Cost-benefit

The attributes of the system are compiled and lastly, they are evaluated mathematically to determine the value of a manufacturing system (Troxler & Blank, 1989). For an aggregate value of a manufacturing system, all the groups and the corresponding elements of the groups needs to be evaluated. For example, in order to determine the capability of a system all the elements of capability need to evaluated.

Definitions

For clarity in understanding the important terms have been defined:

Collar is a decorative and functional feature on the neckline of a garment (Kopp, Rolfo, Zelin, & Gross, 1987).

Collar types is defined as the shape of the collar neckline (Kopp, Rolfo, Zelin, & Gross, 1987).

Collar styles is defined as the shape of the outeredge of the collar (Kopp, Rolfo, Zelin, & Gross, 1987).

Collar design is defined as the look of a collar with variation in the collar type and collar style.

Degree of Style Variation is the variation that occurs between the first and following styles (Lin, Kincade, & Warfield, in press). For this study the degree of variation may be defined as the variation that exists between any two styles on a continuum. The wider the range of characteristics between the part types of two styles, the higher the degree of variation.

Flexibility of a manufacturing system is defined as the capability of a system to continue to function effectively in response to a wide range of changes in the manufacturing environment (Mandelbaum, 1982; Ramasesh & Jaikumar, 1991; and Zelenovic, 1982).

Mix flexibility is defined as the ability of a system to produce a number of products at the same time (Gerwin, 1987). For this study, mix flexibility has been defined as the ability of a system to produce a number of part types (i.e., collar designs) at the same time.

Operation is a function whose input parameters consist of a workpiece, a machine, or a group of machines together with their corresponding operating job (Chase & Aquilano, 1992).

Part is one component of a garment (eg., collar, sleeves, placket). A part is manufactured by performing a required task or set of tasks.

Part types refers to the varieties of a part. In womens' blouse for example, a sleeve could be a part and the different types of sleeves would be the part types.

Product is made up of a set of assembled parts, in this case a garment (Evans, Anderson, Sweeney, & Williams, 1984).

Production is "the process of converting the resources available to an organization into products"(Evans, Anderson, Sweeney, & Williams, 1984, p. 9).

Production/ Manufacturing System is a set of activities and operations related to production (Evans, Anderson, Sweeney, & Williams, 1984). A production system is defined as a set of components whose function is to convert a set of inputs into some desired output through a transformation process (Chase & Aquilano, 1992).

The terms production system and manufacturing system are used interchangeably (Ramasesh & Jaikumar, 1991).

Task is defined as a function whose input parameters include one or more operations. A task could be all the operations performed at one workstation, or single operations. Tasks maybe input to higher level tasks (i.e., assembly and subassembly) (Hopeman, 1971).

Work-in-Process (WIP) is the stock of partially finished goods.

Workunit is a physical object that undergoes a sequence of transformations during the production process. When a workunit undergoes an operation, it is changed in some physical manner (Hopeman, 1971).

CHAPTER II

Literature Review

The purpose of this research was to compare the flexibilities of three types of apparel production systems across variations in the collar designs of men's and women's shirts and blouses. The literature for this research is reviewed in the following broad sections (a) apparel products and classifications, (b) production systems, (c) flexibility of production systems, and (d) production systems as related to products.

Apparel Products

Classifications of Apparel Products

Apparel is a highly complex manufactured product. Meeting the consumers' demand for apparel products is an extremely challenging task for manufacturers because of the wide variety of styles demanded by the consumers. Classification of apparel products is an extremely difficult task. Apparel products have been classified for various purposes but none of the classifications are exhaustive.

The various classifications are explained in the following sections: (a) the merchandise classification, (b) the American Apparel Manufacturers Association (AAMA) classification (1982), (c) the Standard Industrial Code (SIC) classification (1950), (d) product line classification by Glock & Kunz (1990), (e) product line classification by Johnson and Hill (1978), and (f) product line classification by Lin, Kincade, and Warfield (in press).

The Merchandise Classification. The merchandise classification is used by retailers and is based on product attributes such as price points, fashion level, consumer use, body type, and product type. Table 4 indicates the attributes considered in the merchandise classification and the examples of products under each category. The merchandise classification is oriented towards retailing and does not include production attributes such as volume of production and degree of style variation. The categories in the merchandise classification are not clearly defined and lack exclusivity.

Table 4
The Merchandise Classification

Product Attributes	Product Examples
Price Points	budgeted price, moderate price, price of designer products
Fashion Level	basic, missy, fashion forward
Consumer use	outerwear, sportswear, bridal/maternity wear
Body type	petite, plus sizes, misses, juniors, long
Product type	shirt, skirt, trouser, blouse, shorts

The American Apparel Manufacturers Association (AAMA) Classification (1982). The AAMA classified apparel products, based on the degree of variation, into product category, product types, and product styles. The AAMA classification takes on the shape of an inverted pyramid with product categories at the base of the pyramid. Product category refers to product identification (e.g., shirt, skirt, trousers). The degree of variation between the products within a category is very high. Product type refers to variations within a product category. The variations between product types is not as high as the variations between product categories. Product style refers to design variations that exist within product types. The degree of variation between product styles is less than the degree of variation that exists between product types. Figure 1 shows how a product would be classified in the AAMA classification.

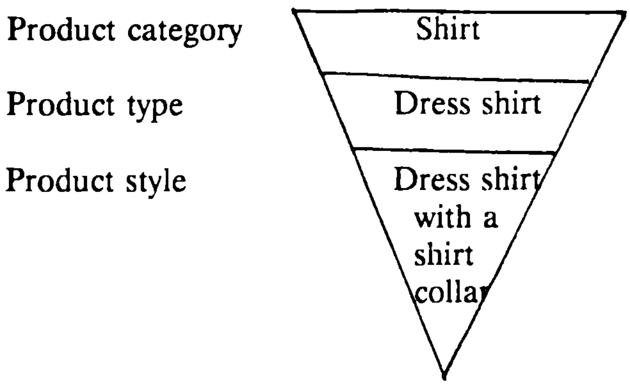


Figure 1
Example of AAMA Classification for Apparel Products

The AAMA classification lacks clarity of definitions. For example, the types of variations within the categories needed to identify product types are not explained. The variations may be in terms of the end use of the product or in terms of the construction features. The AAMA classification is more production oriented than the merchandise classification and does not include attributes like price points and body type.

The Standard Industrial Code (SIC) Classification (1950). The U.S. Department of Commerce (1950) categorized all manufactured products to obtain economic data and assigned a multiple digit code to each of the categories. This system is the SIC classification. Apparel products have been classified based on gender, age category and end use of the apparel item. Table 5 reveals the categories in the SIC classification.

Table 5
SIC Classification

SIC Code	Apparel categories
2300	apparel and other finished products
2311	men's and boys' suits and overcoats
2321	men's and boys' shirts except workshirts
2322	men's and boys' underwear and nightwear
2325	men's and boys' separate trousers and slacks
2326	men's and boys' work clothing
2329	men's and boys' clothing and NEC
2331	women's misses, and juniors blouses and shirts
2335	women's and juniors dresses
2337	women's misses, juniors suits and skirts
2339	women's misses outerwear and NEC
2341	women's misses underwear and nightwear
2342	brassieres, girdles, and allied garments
2353	hats, caps and millinery
2361	girls', childrens', infants dresses and blouses
2369	girls', children's, infants outerwear and NEC
2381	dress and work gloves except knit/leather
2384	robes and dressing gowns
2385	waterproof outerwear
2387	apparel belts
2389	apparel and accessories NEC

Although apparel styles and clothing behavior have changed greatly, the SIC classification has not been updated since 1950. The SIC classification does not consider either the production or retail attributes like seasonality, volume of production, degree of style variation, or price points. Also, the categories in the SIC classification have not been clearly defined.

Product Line Classification by Glock and Kunz (1990). Glock and Kunz (1990) classified apparel products by product line, class, assortment, style and design. A product line is a group of items that are closely related, because the items satisfy certain consumer needs and wants (e.g., coats for warmth). Class refers to a subdivision within a product line. Assortment is the styles within the class (e.g., parkas, dress coats). Design is a specific unique version of a class. The product line classification by Glock and Kunz (1990) is both retail and production oriented. This classification is similar to the AAMA classification in some aspects. The system is a multi-stage pyramid as is the AAMA classification with parallel levels. Product line in the Glock and Kunz (1990) classification is similar to product type in AAMA classification. Product style in the AAMA classification is split into design and style in Glock and Kunz classification (1990). Although the Glock and Kunz (1990) classification is more broad and includes both retail and production attributes, the classification lacks clarity of definitions.

Product Line Classification by Johnson-Hill (1978). Johnson-Hill (1978) classified apparel product line on the basis of three attributes. The attributes are volume of production, degree of style variation, and seasonality of the products. This classification considers product lines rather than products alone. According to the classification, product lines are classified as staple, semi-staple, fashion and high-fashion based on the degree of variation between them. The degree of style variation for the product lines is described as being basic, semi-basic, various styles or great style variety for the four product lines respectively. A staple product line includes basic garment styles by adding or changing small areas of the garment such as pockets, collars, sleeves, yoke, placket. The variation between styles, in terms of construction features, is minimal. For example, between two styles of staple garments a change in the shape of the pockets would be the degree of variation between the two styles of garments. Staple products are produced in long and continuous production runs. A manufacturing system that produces staple products tends to be highly inflexible.

A semi-staple product line includes styles with more variation between them. The variation, between styles of one basic garment, in terms of construction features, is greater than the variation in a staple product line. A semi-staple product line consists of various styles of a basic garment. For example, with two similar types of trousers, the various types of pocket, belts, loops, and pleats provide the style variation. Semi-staple product line are produced in moderately small batches.

A fashion product line includes styles with more variation when compared to styles in the semi-staple product line. A fashion product line is produced in small batches of various styles. A high-fashion product line includes styles that have the highest degree of style variation between them. A high-fashion product line is produced in very short production runs.

The product line classification by Johnson-Hill (1978) considers the frequency of style change, determined as the number of style changes in a season. Another factor considered in this classification is the production volume. The production volume is categorized as mass volume, mid volume, low volume, or very low volume. The attributes of product lines are, however, not completely operationalized in this classification.

Product line Classification by Lin, Kincade, and Warfield (in press). Lin, Kincade, and Warfield (in press) modified Johnson-Hill's (1978) classification by operationalizing the volume of production and frequency of style change. The volume of production is expressed as dozens of units of a style per season, and a season is equivalent to 13 weeks. The frequency of style change is expressed as the number of style changes occurring per season. The number of style changes per season range from none to more than six style changes for the categories of product line. "Degree of variation is the variation that occurs between the first and the following styles" (Lin, Kincade, & Warfield, in press, p. ?). The variations in styles within a product line is less than variations in styles between the product lines. Variations in styles of garments may be in color, type of fabric or component parts (AAMA, 1982). Table 6 indicates the relation between product line and product line attributes.

Table 6
Relation between Product Line and Product Line Attributes

Product line	**Degree of Style Variation**	**Frequency of style change/season**	**Vol./style/ season**
Staple	basic style	0-1	mass volume
Semi-Staple	semi-basic style	2-3	mid-volume
Fashion	various styles	4-6	low volume
HighFashion	great style variety	> 6	very low volume

Note. From " An Analysis of Sewing Systems with a focus on Alabama Apparel Producers" by Lin, Kincade, and Warfield (in press), Clothing and Textiles Research Journal.

This classification considers more factors than other classifications yet has some limitations. The classification is more production oriented and is limited to product line. The classification does not consider specific products within a product line. Although the classification identifies the four categories of the degree of style variation between products, they are not completely operationalized. For example, the classification does not explain the variations occurring within the product line. The classification also does not consider any measures of consumer usage (eg., price point, body type).

Classification Systems applied to Collars

Garment styles in general may vary in number of components or in the characteristics of components. Variations in the number or characteristics of components require production systems to have mix flexibility (Gerwin, 1987). Mix flexibility is the ability of a system to produce a number of different products at the same time (Browne et al., 1984; Gerwin, 1987; Ramasesh & Jaikumar, 1991). To measure the mix flexibility of a production system, the range of component characteristics handled by the system is considered a better measure, because the characteristics of the components are more important than the number of components (Gerwin, 1987). The characteristics of components are exemplified in the style of a garment. Innumerable styles of garments exist. To study the variations among each of these styles, all products and their variations would have to be included. A bottoms-up approach is suggested where the degree of variation can be identified separately for different parts of a garment and then aggregated for the entire garment.

An upper body garment has components such as collar, sleeves, bodice, placket, pockets, and belt (Hollen & Kundel, 1987). The collar is one of the most important components of an upper body garment. Also, collar making involves additional construction steps (Brown, 1992; Stamper, Sharp, & Donnell, 1986) and adds substantially to the cost of the garment due to the additional time, fabric, and labor required (Stamper, Sharp, & Donnell, 1986). Making and attaching of the collar to the neckline is one of the more difficult operations in the assembly of a garment. This operation requires better skills and manipulation to produce a better quality product (Smith, 1987; Y.B. Nayak, personal communication, March,1992). The collar attachment area is one of the top-priority areas for inspection by quality control personnel, because the collar area attracts the first attention in a garment when worn (Hertal, personal communication, March, 1992). Good quality garment construction is said to be revealed in a finished collar (Hertal, personal communication, March, 1992; Lawrence & Yurick, 1977).

Collar Characteristics. A collar is a decorative and functional feature on the neckline of a garment (Kopp, Rolfo, Zelin, & Gross, 1987). The design of the collar varies with the product line of garments. For example, simple collars are more appropriate for casual sportswear styles, while complex collars are more appropriate for tailored garments (Brown, 1992,).

Collar designs can be determined by the collar type and collar style. Collar types are defined by the shape of the collar neckline, and collar styles are defined by the shape of the outer edge of the collar (Brackelsberg & Marshall, 1990; Brown, 1992; Hollen & Kundel, 1987). The shape of the collar and the shape of outer edge of the collar determine the difficulty in construction. The shape of collar neckline also influences the type of finish at the neckline (e.g., full facing, facing at front). The outer front edge of the collar (i.e., collar style) is either rounded, pointed, or other shapes. The collar style may also determine the number of pieces required in the construction of the collar. If the collar neckline finish is complex and the shape of outer edge is complicated, the construction becomes very difficult.

Collar types. The shape of the collar neckline (i.e., collar type) determines if the collar is flat, rolled (i.e., partial roll or full roll), or standing (see Figure 2). The closer the shape of collar neckline to the shape of the garment neckline, the flatter the roll (Brackelsberg & Marshall, 1990; Hollen & Kundel, 1987; and Stamper, Sharp, & Donnell, 1986). The shape ratio of the collar and garment neckline generally affects the construction, appearance, and the neckline finish of the collar. The neckline shape ratio dictates the amount of stand in a collar. The stand in a collar is the material under the collar at the center back which extends upward from the garment neckline to the point where a collar rolls or folds over.

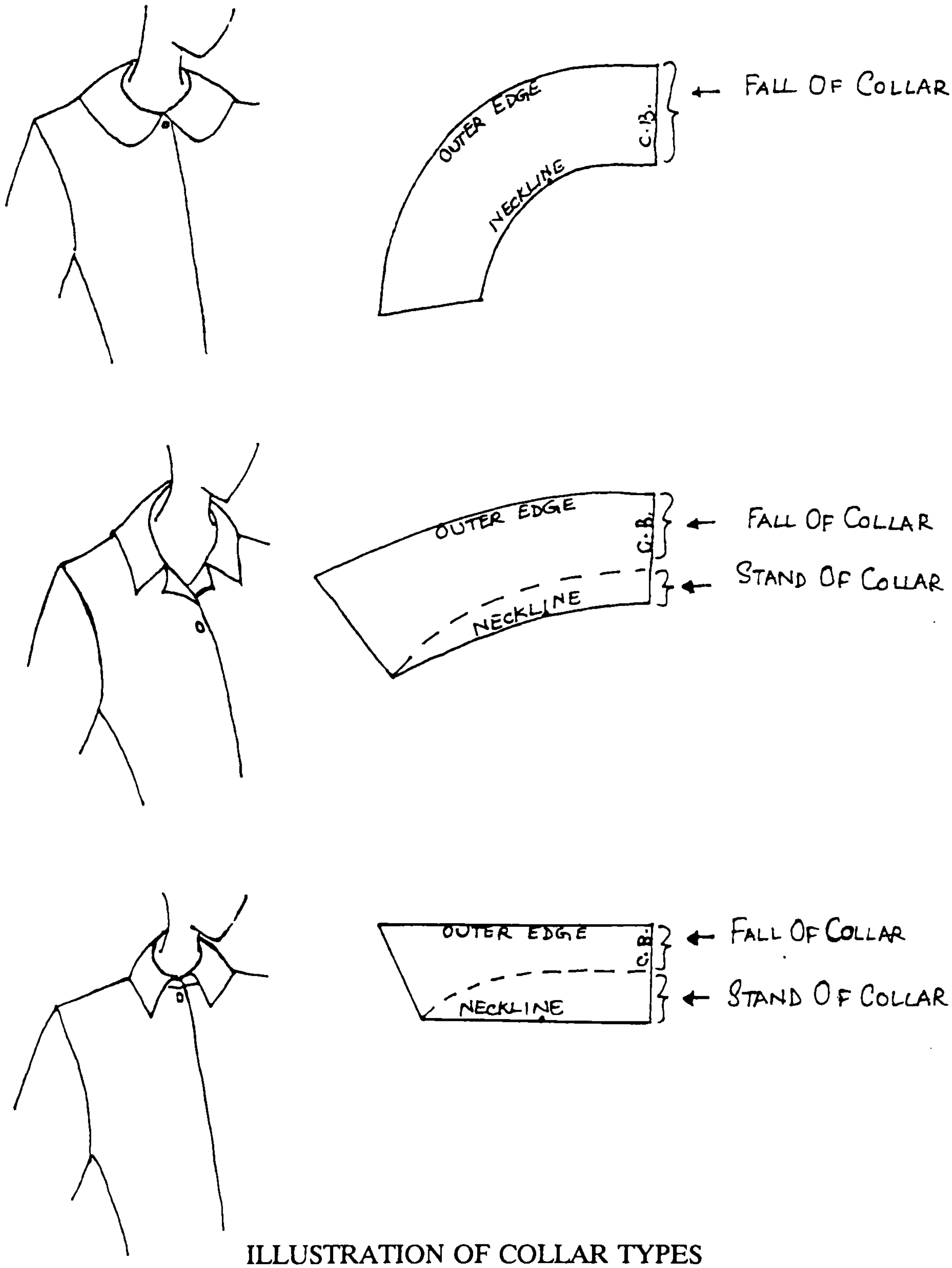


ILLUSTRATION OF COLLAR TYPES
Figure 2

The portion of the collar that folds over is the roll of the collar (Brown, 1992; Kopp, Rolfo, Zelin, & Gross, 1987) (see Figure 2).

In a flat collar, the shape of the collar neckline is concave and matches the neckline of the garment. A flat collar lies flat against the garment all the way around the neck of the garment (Brown, 1992; Kopp, Rolfo, Zelin, & Gross, 1987). The neckline for a flat collar can be finished with a binding, facing, stitching, or other edge finish.

The full roll collar or standing collar neckline is created when the collar neckline is fairly straight. A full roll/standing collar may be simple full roll/ standing collar or a full roll shawl collar. The full roll collar has a full stand and a roll. A full roll collar could be made of one piece or two piece. In a one piece full roll collar, both the collar and the stand are cut in one piece. A standing collar with a band and collar is a two piece collar where the stand and the collar are cut as two separate pieces and then attached (Stamper, Sharp, & Donnel, 1991). This construction makes the two piece collar more complex in construction than the one piece collar. The two piece full roll collar extends to the end of the front neckline (Stamper, Sharp, & Donnell, 1991). The neckline of garment and front facing is generally sandwiched between the collar layers for attachment. If this method is not adopted, a facing or binding is used to finish the neckline, but this operation makes the neckline bulky (Brown, 1992). For most manufactured garments, both one piece and two piece standing collars do not have a facing at the back neckline.

A full roll shawl collar has a full stand and a roll like the simple full roll collar, but with a varied construction technique. The full roll shawl collar has an attached collar only at the back. The back collar neckline is fairly straight creating the full stand and the roll. The front of a full roll shawl collar is an extension of the front bodice. Shawl collars can only be worn open. Most shawl collars are finished with a facing at the back neckline for hanger appeal. The bodice front forms the front of the under collar, and a two piece upper collar is used for front and back (Knopp, Rolfo, Zelin, & Gross, 1987). The back of a shawl collar is characterized by a seam at center back. A shawl collar has no seam for the facing on the front, because the front facing is an extension of the upper collar. The order of construction steps for a shawl collar vary from the simple full roll collar.

A partial rolled collar can be either simple partial roll collar or a partial roll shawl collar. A partial rolled collar has a back stand and a roll. The stand of a partial roll collar is less than the stand of a full roll collar. If the shape of the collar neckline is concave, but less concave than the neckline, the collar rolls at the back of the neck, and it is a partial roll collar. If the neckline of the bodice extends beyond the collar, the collar has a facing at the front edge of the collar. The neckline of a partial roll collar is, generally, finished with a facing at the front neckline and may or may not have a facing or binding at the back neckline (Brown, 1992; Moore C., personal communication, March, 1994). The use of facing at the back neckline is determined by the amount of stand (i.e., its ability to take in the neckline allowance) and the cost incurred in attaching a facing (Brackelsberg & Marshall, 1977; Hollen & Kundel, 1993).

A partial roll shawl collar is similar to a simple partial roll collar in the shape of the back collar neckline but is different in the type of attachment. A shawl collar has an attached collar only at the back. A partial roll shawl collar is similar to the full roll shawl collar in the attachment technique but differs in the shape of the back neckline. A partial roll shawl collar has a concave back neckline which creates the partial roll with a slight stand. The order of construction steps for a shawl collar vary from a simple partial roll collar.

Collar styles. Collar style refers to the shape of the outside edge of the collar and is grouped into three categories: rounded, pointed, and other shapes. A rounded collar has a round outside edge. A rounded collar is made with two separate pieces, the upper and under collar. If the collar is divided at the back and front, as in opened garments, the collar is made with four pieces. Pointed collars have a pointed outer front edge. Pointed collars are constructed in three ways. A one-piece pointed collar is made with the upper and under collar in one-piece, and the outer edge is a fold line (Brackelsberg & Marshall, 1990). One-piece collars are generally found in low-price lines (Brown, 1992). A two-piece pointed collar has separate upper and under pieces and should have a row of understitching on the edge seam to make the edge of the upper collar roll towards the under collar. Sometimes a two-piece pointed collar is made by stitching all three sides of the outer edge in a single operation (Brackelsberg & Marshall, 1990). Two piece collars require more labor than a one piece collar (Brown, 1992). In a three-piece pointed collar, the upper collar is in one piece and the under collar is in two pieces with a seam at center back. A three-piece collar requires more labor than a one piece or two piece collar, thereby increasing the cost of the garment. In a three piece collar, the two pieces of the under collar are cut on the diagonal. Two piece under collars are selected because of the added shaping and roll that can be developed in the neck part of the collar.

Shaped collars have outer edge shapes that are not just rounded or pointed (e.g., scalloped collars). In the case of the shawl collar, the shape of the bodice can be changed to achieve greater variety. Collars with shaped edges can be made with two or three pieces.

Collar Designs. The type and style of a collar affect not only the construction but also the appearance of collars. Each collar design has a generally accepted name and an accepted appearance. The type and style of collar are combined to determine the design of the collar. Table 7 lists the designs of collars based on the type and style of each collar.

Collar styles		Collar types					
		Flat	**Partial roll**		**Standing/Full roll**		
			Simple Partial roll	**Shawl collar**	**1 pc**		**2 pc**
					Simple full roll	**Full roll Shawl**	
Rounded	2 pc	Peter Pan collar	Notched with a cape	Simple Shawl		Simple Shawl	
		Ruffle collar	Horse shoe	Shawl with a cape		Shawl with a cape	
		Peter Pan with trimming at outer edge					
		Bertha collar					
		Sailor with rounded edge					
	3 pc	Bertha collar	Horse shoe				
		Sailor with rounded edge on back	Notched with a cape				
	4 pc	Peter Pan collar					
		Peter Pan with trimming at outer edge					
Pointed	1 pc	Sailor with pointed edge on back	Convertible	Notched shawl collar	Turtle neck	Notched shawl collar	Wing collar
			Notched with a cape	Shawl collar with stylized point	Cowl	Shawl collar with stylized point	Shirt collar
					Mandarin		
					Shirt collar without band		

Collar styles		Collar types					
		Flat	Partial roll		Standing/Full roll		
			Simple Partial roll	Shawl collar	1 pc		2 pc
					Simple full roll	Full roll Shawl	
Pointed	1 pc	Flat collar with stylized point	Convertible				Wing collar
		Sailor with pointed edge on back	Notched with cape		Buckle collar		Shirt collar
			Notched with peak lapels		Scarf collar		
			Portrait		Edwardian		
	3 pc	Square bertha collar	Convertible		Notched with cape		Wing collar
		Flat collar with stylized point	Buckle collar				Shirt collar
			Notched with peak lapels				
			Chelsea				
			Scarf collar				
			Notched with peak lapels				
Other shapes	2 pc	Scalloped collar					
	4 pc	Petal collar					

For clarification of this typology, several collar designs are discussed below. A Peter Pan collar is a flat collar, with no stand or with limited stand, because the neckline shape of the collar matches the neckline shape of the bodice. The outer edge of peter pan collar may be rounded or scalloped and may have ruffles or trimming at the outer edge (Kopp, Rolfo, Zelin, & Gross, 1987). A Peter Pan collar can be made as two-piece or four-piece collar. The outer edge of a two-piece Peter Pan collar is shaped only at center front and has an upper and under collar. A four-piece collar is shaped at the both center front and center back and has two upper and two under collars. A Peter Pan collar can be finished with a binding or facing at the neckline.

A Bertha collar is a large cape-like flat collar. A Bertha collar can be squared or rounded at the collar outer edge (Kopp, Rolfo, Zelin, & Gross, 1987). It can be made with one upper and one under collar (i.e., two piece) or one upper and two under collars (i.e., three piece). Bertha collars can be finished with binding or facing at the neckline. A sailor collar is a large flat collar squared or rounded at the back and tapering to a 'V' at the front (Kopp, Rolfo, Zelin, & Gross, 1987). The construction of the sailor collar is similar to the Bertha collar except that the bertha collar is almost never made with one piece. The sailor collar, on the other hand, can be made with one piece, two piece, or three piece. A one piece sailor collar has only an upper collar and is finished with a binding at the outer edge. A two piece sailor collar has one upper and one under collar. A three piece sailor collar has one upper and two under collars. The front and back neckline are finished with a binding or a facing.

A convertible collar is a simple partial roll collar and can be worn open or closed. The neckline shape of the collar is partially convex and the bodice neckline is concave. This difference develops the stand and roll when the neck seam is constructed. The convertible collar can be developed as two piece or three piece with a rounded or square stylized point (Kopp, Rolfo, Zelin, & Gross, 1987). A two piece convertible collar has one upper and one under collar. A three piece convertible collar has one upper and two under collars. A convertible collar is finished with a facing at the front neckline. The back neckline is finished by turning the upper collar in at the neckline and top stitching.

A notched collar is a roll collar and is normally worn open. It consists of a lapel and a collar. The collar extends to the front of the bodice and meets the lapel, resulting in a notch (Kopp, Rolfo, Zelin, & Gross, 1987). This type of collar design requires special construction. The neckline seams are constructed first. The outer edge of the bodice and facings are sewn last. Notched collars may be made with or without a cape. The outer edge of cape may be rounded or squared. The collar is generally made of three pieces. A three piece notched collar has one upper and two under collars. The under collars are used for shaping the roll.

A shirt collar is attached to a straight or slightly shaped stand-up neckband (Kopp, Rolfo, Zelin, & Gross, 1987). The neckband may be in one piece with the collar or a separate piece with an attached collar. If the collar is made of one piece, the outer edge of collar is on fold and does not have a seam. A two piece collar has one upper and one under collar. A shirt collar is finished at the neckline by turning the upper collar in and seam stitching.

A wing collar is a two piece standing collar with a neckband. It has a stand and a roll. The outer edge of the collar has spread points (Kopp, Rolfo, Zelin, & Gross, 1987). The collar may two piece or three piece depending on whether it has a seam on the under collar at the center back. The neckline of a wing collar is finished by turning the upper collar in at the neckline. A wing collar does not have a facing at the back or front neckline.

A mandarin collar is a standing collar that extends up from the neckline. It has only a stand and no roll. This collar meets at the centerfront or at any point between the shoulder and the centerfront. A mandarin collar can have a straight or shaped collar edge (Kopp, Rolfo, Zelin, & Gross, 1987). A mandarin collar is generally made with two pieces, one upper and one under collar. The mandarin collar does not have a facing at the neckline and is finished by turning the top collar inside at the neckline and top stitching.

An Edwardian collar is a variation of the standing collar. It has a trimming at the outer edge of the normally standing collar. It is finished the same way as the standing collar.

Production Systems

A production system is defined as a set of components whose function is to convert a set of inputs into some desired output through a transformation process (Chase & Aquilano, 1992). The components can be a man, machine, equipment, or tool. A production system should, in general, allow a manufacturer to produce goods efficiently while keeping in mind the customers' needs. Both the manufacturer and the customer should benefit from the production process. The manufacturer should have monetary gains, and the customer should be able to obtain the product at a price worth the value the product holds.

Types of Production Systems

Various production systems are in use in the soft goods and hard goods industry. Each of the systems are characterized by distinctive attributes. These attributes can help identify the various systems.

Hopeman (1971) and Solinger (1988) have identified production systems based on the dimension of time factor. Production systems can be intermittent or continuous systems based on the time a workunit rests between successive workstations. This factor is directly related to the level of WIP inventory in the system. In an intermittent production system, the work unit rests temporarily in some storage area between successive workstations. Consequently the level of WIP inventory is high in an intermittent system. In continuous production systems, the workunit does not rest between successive workstations. Consequently the level of WIP inventory is zero or minimal in a continuous production system. The WIP inventory level is an attribute of a system and can be used as one of the determinants of production systems.

Solinger (1988) has also identified production systems based on the scope of workers duties and type of product flow. The scope of workers duties may be determined by the number of tasks assigned to individual operator in a system. Individual operators may be assigned single tasks or multiple tasks. The scope of workers duties is directly related to the skill of the workers. Production systems that assign single tasks to operators may not require multi-skilled workers as opposed to the systems that assign multiple tasks. Also, single task operators are limited by their skill and so cannot be used for more complex processing operations. The number of tasks assigned to individual operators in a system can be used as one of the determinants of production systems.

Production systems can be distinguished based on the type of product flow between workstations (Solinger, 1988). The products may flow either singly or in groups. The type of product flow dictates the means of transportation of workunits between workstations. Single productflow is associated with automated transfer of workunits between workstations or the handoff approach. In the handoff approach, the workunits are handed off to the next operator depending on the demand for work by the next operator. Group productflow is associated with manual transfer of bundles of workunits between workstations. The mode of transportation of workunits between workstations can be used as one of the determinants of production systems.

Kimura and Terada (1981) identify production systems based on the type of workflow. The type of workflow may be pull through or push through depending on the source of the force that drives the work through the system. The normal approach in industrial production is the push system in which piles of WIP inventory helps push the work through the system. In a pull system, the need to increase the production helps pull the work through the system. The type of workflow can be used as one of the attributes in determining a production system.

A recent approach in manufacturing is the team approach, where groups of operators function as a self-directed team (Cole, 1992; Ross, 1991; Sisselman, 1990). The production systems may be associated with interaction between operators or no interaction. The presence or absence of interaction between operators may be used as a determinant of a production system.

Based on the various attributes, production systems have been classified into several broad categories. Solinger (1988) identified two broad categories of production systems based on the scope of workers duties (number of tasks per operator), time factor (continuous systems or intermittent systems), and product flow (single or multiple flow). Solinger's (1988) classification represents systems used in the hard goods industry and very traditional apparel manufacturing such as job shop operations. Knapton (1990) broadly divided manufacturing systems in the apparel industry into traditional or dedicated systems and modular systems. The traditional or dedicated systems consist of the bundle system and PBS. Georgia Institute of Technology (1980) and Lin (1990) identified three apparel production systems that are most commonly found in the American apparel industry: (a) bundle systems, (b) progressive bundle systems, and (c) modular systems.

Bundle Systems. The bundle system is a traditional dedicated system that is normally comprised of bundles of workunits. Individual operators perform some or all of the operations on the bundle (Hannan, 1963). Traditionally individual operators perform only certain operations on all the bundles of workunits. The productflow is in groups and the workunits are transported manually by the operator himself (Lin, 1990). A bank of inventory is positioned at each machine and work flows intermittently from the storage to the operator and back to the storage after the bundles are worked on. This mode of transportation results in racks of WIP inventory (Mazziotti, 1993). The WIP inventory helps push the work through the system. The bundle system is essentially a push system. No interaction exists between the operators in a bundle system, because each operator is responsible for his own job.

Progressive Bundle System (PBS). The PBS is also referred to as an assembly line (Chase & Aquliano, 1992). In a progressive bundle system, the operations are laid out in a sequence. A group of operators work as a single unit, producing one style at a time. Progressive bundle system involves two or three work stations being worked upon for the same operation at the same time but two or more different operations/jobs of a garment are never done simultaneously in a planned synchronized manner (Solinger, 1988). Individual operators are assigned single tasks as opposed to multiple tasks in a bundle system (Mazziotti, 1993; Sisselman, 1990). The bundles of workunits are passed along singly from operator to operator. The PBS is associated with single productflow, and the workunits are transferred by means of conveyors or other automated transfer devices (Chase & Aquilano, 1992; Ross, 1991). These conveyors become storage devices which can result in moderate to high level of WIP inventory (Ross, 1991). The level of WIP inventory is controlled in a PBS by balancing the lines. The WIP inventory in a PBS is controlled to a certain extent as opposed to the level of WIP inventory in a bundle system. The inventory drives the work through the system. PBS, therefore, is a push system. Though a group of operators work on a single style at a time, no interaction exists between the operators.

Modular System. This system is also referred to as Cellular system. Modular system consists of teams of operators functioning as a single unit assembling a whole garment (Sisselman, 1990). The operators rotate to different machines as they work through the garment (Brown, 1992; Ross, 1991). The operators in a modular system can perform single or multiple tasks. The workunits are handed off to the next operator depending on the demand for work by the operator (Mazziotti, 1993). The handoff approach is associated with single product flow. The team of operators make the entire product one at a time rather than moving large masses of inventory (Ross, 1991). The workunits flow continuously through the system. This movement helps minimize the WIP inventory to a great extent (Cole, 1992).

Kron (1987) and Frank (1988) define modular manufacturing as consisting of modules or cells where each module or cell is a contained manageable work unit of people performing a measurable task. The people are self-directed and work in a team. The need to increase production helps drive the work through a modular system. Modular system is essentially a pull system (Carrere & Little, 1989). The operators are interchangeable among tasks within the group (Kron, 1987; Frank, 1988). Since the group of operators in a modular system work as a team a great deal of interaction is noticed among the operators. Modular systems encourage team work, improve quality, and increase production (Ross, 1991; Sisselman, 1990).

Carrere and Little (1989) examined eleven modular manufacturing situations. The degree of flexibility desired within a modular unit and the product characteristics dictated the level of WIP that could be accommodated. Modular manufacturing revealed benefits such as improved quality, reduction of waste, increased manufacturing flexibility, reduced turn over and absenteeism and organizational and cultural growth. Modular manufacturing also indicated a reduction of bundle or batch size, balancing of operations, pull through production and production of exact quantities of the product.

Sisselman (1990) conducted a case study of an apparel firm that reorganized its production system from the traditional progressive bundle system to the more modern modular system. During its progressive bundle stage, all the people in the plant worked in a single group and on one style at a time. The operators were thus assigned specific operations to which he/she was limited. Under the changed system, a group of six chains formed the production system, and each chain functioned as a single complete unit assembling a whole garment. Operators in the chain only assembled components to the body while the other operators worked on the less skilled operations. Although the turn cycle, from cutting to shipping and the direct and indirect costs were reduced modular manufacturing was not found to be as productive as when the work was repetitive.

Advantanges and disadvantages of the three production systems

The inherent qualities of a system enable system performance. Each system has its advantages and disadvantages. In any production system, certain elements of work are repetitive, and this affects the performance of the systems. In general, the performance is higher when the non-repetitive elements are fewer (Hodge & Canada, 1989). The time required for production is usually shorter in continuous-production system than in the intermittent production system (Hopeman, 1971).

For example, PBS with overhead conveyors (i.e., UPS) has no lifting, bending, or carrying of bundles. The garment pieces are transported to workstations by conveyor mechanisms. The transport of pieces is controlled by computer programs which minimize the waiting time for work-in-process (WIP) by more than 50% and reduce the time spent on handling and bundling (Cole, 1987; Hodge & Canada, 1989; JSN International, 1989). The work is always presented to the operator in the ideal position of work. High rest and fatigue allowances are eliminated. Operators can thus spend more time at the needle completing the task at hand at a pace not possible in a bundle situation. Results of Cock's study (1989), on simulation of line balancing indicated that PBS with conveyors can offer large savings by reducing the amount of capital tied up in work-in-process inventory.

The bundle system and PBS are considered best suited for basic products with very little style variation (Hunter, 1990; Knapton, 1990; Schoenberger, 1982; Solinger, 1988). Modular manufacturing is considered more flexible as different apparel operations can be performed by the same worker with access to multifunctional machines (Hunter, 1990; Carrere & Little, 1989; Kurt Salmon, 1988; Schonberger, 1982; The Textile Technology Clothing Corporation, 1989). The modular system can therefore produce different styles of products at the same time more easily (Ross, 1991; Sisselman, 1990).

Evaluation of System Performance

Several factors affect the performance of a production system. Evaluation of the performance of a production system should include the study of logistics in material flow, operators, efficiency and tailoribility (Shishoo, 1990). Soni and Welker (1990) suggest machine utilization, due date, and mean flow time as the criteria for evaluating system performance. Soni (1990) suggests addressing the issues of volume of product, value of the product in terms of value of material used, the flexibility and compatibility of production processes, parts to be assembled for the finished product, inspection testing and quality control, material handling and packaging, warehouse storage and production scheduling, inventory control, manufacturing system design and cost and related improvement in productivity of new or modified systems. Hodge and Canada (1989) identify net present worth, manufacturing flexibility, quality, and serviceability as being the most important attributes in selecting a sewing work station but admit that a full decision model would doubtlessly include additional attributes and an elaborate analysis.

Flexibility of Production Systems

Capability of a system refers to the system's intrinsic ability (Troxler & Blank, 1989), and flexibility is one of the determinants of capability of a system. Flexibility refers to the capability of a system to respond effectively to changing circumstances (Gerwin, 1987).

Flexibility is an adaptive response to changes or uncertainties in the environment (Gerwin, 1987); therefore, any attempt at studying the flexibility of apparel manufacturing system necessitates a close look at the uncertainties that exist in the manufacturing environment (Buzacott, 1982). Understanding the uncertain circumstances for flexibility is essential, because a wide range of circumstances could be associated with the flexibility of manufacturing systems.

The environment of a factory constitutes the internal environment and external environment. Uncertainties in the internal environment that might affect the flexibility of a system include uncertain capacity of resources, and skill of labor. In general uncertainties in the internal environment are easier to control than the uncertainties in the external environment.

Uncertainties in the external environment include variation in product mix, targeted production volumes, and availability of raw materials. Uncertainty in composition of apparel products demanded (i.e., product mix) is due to the frequent changes in style that occur in the market. Product demand changes are both short term and long term. Frequent occurrences of short term change, such as change in the part being produced at a machine, cause significant change in the performance of the system and the system has to respond with minimal loss in production and minimal cost. Long term changes in demand could be the introduction of new products into the system. Again, the system needs to be flexible enough to respond effectively to the change to produce the product with minimal change in the system and with minimal cost (Gupta & Buzacott, 1989). The uncertainty created as a result of variety in needs of the customers requires the system to be flexible to enable production of various products at the same time (Wise, 1990).

A production system is said to be flexible to style changes if it responds to frequent changes in style in an efficient manner. Lin (1990) described "frequent" in terms of number of style changes per season. Flexibility to style change is therefore considered to increase as the number of changes per season that a system can respond to increases.

A priority for apparel manufacturers is to select sewing systems that can respond to changes in the market (Hunter, 1990). A production system must be flexible enough to produce or accommodate a wide variety of products in terms of style features and to produce a selected volume efficiently within the region of economy of production.

Types of Flexibility

A wide variety of uncertainties exist in any manufacturing environment, and various types of flexibility are associated with each type of uncertainty. Gerwin (1987) has identified seven types of flexibility based on uncertainties in the manufacturing environment. Table 8 indicates the various types of flexibility that are used as a response to each type of uncertainty (Gerwin, 1987).

Table 8
Uncertainties in the manufacturing environment and the associated Flexibility required of manufacturing systems (Gerwin, 1987)

Type of Uncertainty	Flexibility
The products that will be accepted by the customers are uncertain.	**Mix flexibility:** The manufacturing system should be able to produce a number of different products at the same time.
The life cycles of products differ from one another.	**Changeover flexibility:** The system should be able to deal with addition or subtraction from the mix over time.
The attributes that customers want over time are uncertain.	**Modification flexibility:** The system should be able to deal with functional changes in the product over time.
The downtime of the machine is uncertain.	**Rerouting flexibility:** The system should be capable of undergoing a change in the operating sequence through which the product flows.
The volume demanded by the customers is uncertain.	**Volume flexibility:** The system should be adaptable to different volumes of production.
The material inputs to a manufacturing process may not meet standards. Also more than one substance or material may need to be handled for the same or different component.	**Material flexibility:** The system should have the ability to process inputs with uncontrollable variations in part dimensions.
The delivery times of raw materials are uncertain.	**Sequencing flexibility:** The system should have the ability to rearrange the way different parts are fed into the system.

Browne (1984) has identified eight types of flexibility that are similar to Gerwin (1987). In that, mix flexibility (Gerwin, 1987) is similar to product flexibility (Browne, 1984). Modification flexibility is similar to machine flexibility; material flexibility is similar to process flexibility, and sequencing flexibility is similar to operation flexibility (Brown, 1984; Gerwin, 1987). Browne (1984) also identified production flexibility which is the universe of part types that can be produced by the system; however, Gerwin (1987) does not list production flexibility as one of the types of flexibility.

Ramasesh and Jaikumar (1991) have identified eleven types of flexibility after reviewing the literature. In addition to those identified by Browne (1984) and Gerwin (1987), Ramasesh and Jiakumar (1991) have identified program flexibility, material handling flexibility, and labor flexibility. Variations of labor flexibility, material flexibility, and process flexibility have been identified. Mix flexibility is a variation of process flexibility which is the capability of a production system to produce different types of products without major effort (Ramasesh & Jaikumar, 1991). The types of flexibility identified by Ramasesh and Jaikumar (1991) are more exhaustive than those identified by Browne (1984) and Gerwin (1987). The evaluation of flexibility of systems is a multi-factor decision analysis. The analysis must consider each of the types of flexibility for a more holistic evaluation of system performance.

Although flexibility of a manufacturing system is familiar to the hard goods industry, it is a relatively new concept in the apparel industry. Limited literature is available on the flexibility of apparel manufacturing systems. Three types of flexibility have been identified in the apparel industry (Hodge & Canada, 1989). Process flexibility is the capability of the system to adapt to variations in cloth characteristics. Product flexibility is the ability of a system to produce different parts (e.g., collars, pockets). Part flexibility is the capability of a system to produce different part types (e.g., different shapes of collars). Product and part flexibility are similar to the concept of mix flexibility identified by Gerwin (1987).

Of the various types of flexibility in the apparel industry, mix flexibility demands a closer look because of the nature of the apparel product and its market. The apparel market is characterized by great variation in the products demanded (AAMA, 1965). This characteristic requires mix flexibility of apparel production systems so that the system will produce a number of different products at the same time (Gerwin, 1987).

Measures for evaluating mix flexibility of production systems. Any measure of flexibility should be made with respect to the environment in which the system functions. Part size, part geometry, volume demanded, batch size, product types, and change over cost have been identified as attributes used to measure the flexibility of a manufacturing system (Ramasesh & Jaikumar, 1991; Troxler & Blank, 1989). Several measures are proposed for evaluating mix flexibility:

1. Mix flexibility can be measured by the ratio of the number of components processed by the equipment to the total number processed by the factory. This method will determine the mix flexibility of the equipment (Buzacott, 1982).

2. Mix flexibility can be measured by the number of components that can be handled by the system (Browne, 1984; Chaterjee et al., 1984, cited in Gerwin, 1987). The higher the number of components that can be handled by the system, the higher the flexibility of the system (Gerwin, 1987).

3. The range of product component characteristics handled by the system can be used to measure mix flexibility. The broader the range of component characteristics, that a system can handle, the higher the flexibility of the system (Buzacott, 1982).

Some measures are more appropriate for certain industries depending on the characteristics of the industry. If the machines are dissimilar, the ratio measure could be used, but in the apparel industry, most often, similar machines are used for different tasks. The ratio measure is inappropriate to use in the apparel industry. The number of components measure is also inappropriate for the apparel industry, because the number of components (i.e., parts) in a garment may be small, but the degree of variation between the components may be high. In this case, the measure would not be reliable. The range of component characteristics measure can be adapted to determine the mix flexibility of a system in the apparel industry. This method will be a more valid measure of mix flexibility of a system (Gerwin, 1987), because the range of component characteristics encompasses the widest variation that can occur in terms of styles of apparel. The wider the range of characteristics between parts that a system can manufacture, the higher the mix flexibility of the system.

Production Systems as Related to Products

One of the external factors affecting the performance of production systems is the type of products being produced (Buzacott, 1982). The Technical Advisory Committee of the AAMA (1965) studied the affect of style variation on manufacturing costs taking into consideration a hypothetical company producing a line of ladies tailored blouses. Style goods were found to be inherently more expensive to produce than staple goods because of product variety. If style goods replace the same quantity of staples, the efficiency lowers. As apparel products depart from staple to more complex styles, production runs are shortened.

The conventional belief is that flexible manufacturing systems are best used in low volume production (AAMA, 1965; Hunter, 1990; Mazziotti, 1993). A module, as in modular system, is considered best suited for low volumes and a greater variety of parts. An assembly line or a PBS on the other hand is considered best suited for high volumes and lower number of different parts (Chase & Aquilano, 1992). Very little empirical evidence exists to support the relationship between apparel production systems and apparel products.

CHAPTER III

Statement of problem

The changing nature of the market has resulted in an increase in the need for flexibility of manufacturing systems. The market is affected by intense competition from imports and varied requirements of customers. Manufacturing systems utilize flexibility as an adaptive measure to respond to such uncertainties in the environment (Gerwin, 1987).

This study examines the flexibility element of apparel manufacturing systems. Flexibility of production systems is an extremely broad concept. The concept of flexibility, especially mix flexibility, is relatively new in the apparel industry. Limited empirical evidence exists in this area. To fully understand a relatively new concept, a bottoms-up approach is suggested (Buzacott, 1982). Variations in different parts of a garment may be identified and aggregated to obtain the variations for an entire product. The various systems may be compared for their flexibility to the variations in the garment. This study focuses on the flexibility of production systems to variations in the types of one part of a garment (i.e., collars).

Flexibility is defined as the ability of the machine or manufacturing system or the entire factory to respond effectively to changing circumstances (Mandelbaum, 1978; Zelenovic, 1982). In general, flexibility in manufacturing can be achieved by the manufacturing process, system, or function. Flexibility of systems can be achieved by an individual machine, a group of machines, or by the entire factory. Flexibility of a system is one of the determinants of capability of a system. Capability of a system refers to the system's intrinsic ability (Troxler & Blank, 1989).

A wide variety of uncertainties exist in a manufacturing environment. Various types of flexibility are associated with each type of uncertainty (Table 8) (Gerwin, 1987). The apparel market is highly uncertain. Customers are tending toward more individualistic and one-of-a-type clothing. The market situation leads to wide variation in the demand for apparel items. Style variation is one criteria for differentiating apparel product line categories (i.e., staple, semi-staple, fashion, and high-fashion) (Johnson-Hill, 1978; Lin, Kincade, & Warfield, in press). To meet the demand for such a wide variation of products, the manufacturing system should be able to produce different products at the same time. In other words the system should have mix flexibility (Gerwin, 1987).

The statement of problem for this research is outlined in the following sections: (a) research problem, (b) objectives, (c) hypotheses, (d) assumptions, and (e) conceptual framework.

Research Problem

This study analyses the relationship between apparel production systems and style variation as revealed in the collar designs of men's and women's shirts and blouses.

Objectives

This research was designed with the following objectives:

1. To develop an instrument that can be used to determine the relationship between apparel production systems and style variation in apparel products.

2. To classify men's and women's collar designs into the four product line (i.e, staple, semi-staple, fashion, and high-fashion) categories.

3. To examine the relationship between types of apparel production systems and categories of product line represented by collar designs.

4. To analyze the relationship between size of the company (i.e., number of employees and volume of production) and apparel production systems and the corresponding product line as represented by the collar designs.

Hypotheses

Research hypothesis 1(H_1). The production systems (i.e., bundle system, PBS, and modular system) will vary with the type of product line that is produced on each of them. Bundle system will be used to produce collars from a staple product line and modular system will be used to produce collars from a fashion product line. In other words, mix flexibility to collar designs will increase progressively from bundle to PBS to modular system.

Statistical hypothesis 1. Mix flexibility of bundle system is less than PBS. The mix flexibility of PBS is less than modular system.

Research Hypothesis 2(H_2). The volume of production on a production system is related to the type of system used.

Statistical hypothesis 2. The volume of production on bundle systems will be more than the volume of production on PBS. The volume of production on PBS will be more than the volume of production on modular systems.

Research hypothesis 3(H_3). A relationship exists between size of the company (i.e., number of employees) and the production system used by the company. In general, larger companies with greater number of employees will use more advanced production systems, such as the modular production systems, than smaller companies.

Statistical hypothesis 3. Companies with more number of employees will use modular systems. Companies with moderate number of employees will use PBS or bundle system.

Research hypothesis 4(H_4). The volume of production of each product line is related to the production system used by the company. Modular systems will be used more often by large companies with larger volume of production than by small companies with smaller volume of production.

Statistical hypothesis 4. Larger companies (i.e., by the volume of production) will use modular systems. Moderately large companies will use PBS, and small companies will use bundle system.

Assumptions of the study

This research was carried out under the following assumptions:

1.The complexity in collar construction is revealed in the sketch of collar designs.

2. The product line categories differ in the complexity of construction. Staple product line is more simple in its construction than semi-staple product line. Semi-staple product line is simpler in construction than fashion product line. Fashion product line is simpler in construction compared to high-fashion product line.

3. The subjects for the Q-Sort are experts in product assembly.

4. The production managers who are respondents of the survey are conversant with apparel assembly on the shopfloor.

5. The manufacturers listed as producers of shirts and blouses manufacture the widest range of collars and adequately represent all the collars made in the textile/apparel industry.

6. The collars made on apparel products, other than men's shirts and women's blouses and shirts, are replications of the ones made in blouses and shirts.

7. The identified collar designs are representative of all the possibilities of collar designs.

CHAPTER IV

Research Method

An exploratory research was done to compare the flexibilities of three types of apparel production systems to variations in collar designs. Companies manufacturing women's blouses and shirts and men's shirts were examined. The method adopted to achieve the objectives of this research is explained in the following sections (a) research design, (b) instrument, (c) sample selection, (d) data collection, (e) data analysis, and (f) limitations.

Research Design

The survey method with mailed questionnaires was used to achieve the objectives for this research. Survey method is generally used to obtain data that come to the researcher through observation. This method implies the assumption that "a given phenomenon usually follows a common pattern or norm under similar conditions and could be observed again in the future" (Leedy, 1993, pp. 185-186). The results of survey can be generalized to the larger population if the sample represents the population. This method allows a researcher to determine the interrelations among variables (Kerlinger, 1973). Experimental method was not used for this research as it would mean tampering with real life apparel production systems and that would not be appealing to manufacturers. Case studies limit generalizability of the research to the larger population because of the sample size (Kerlinger, 1993); therefore, this method was not considered for this research .

Instrument

The instrument used to obtain the data for this research was the mailed questionnaire. The questionnaire consisted of three distinct sections: (a) Company demographics, (b) Production system(s) used by the company, and (c) Product line of the company (see Appendix C).

Company demographics

This section contained questions on: total volume of production of the company, volume of production/product line, and the number of employees. All the above questions were obtained in numerical figures by an open ended question, rather than as a range. This method enabled accurate placement of the company with respect to other companies in the sample. More powerful statistical analysis could be performed on this type of data (Coakley, C.W., personal communication, December, 1993). Also, continuous data has the flexibility of being converted to categorical data when desired.

Production Systems

This section consisted of questions related to production systems and their attributes. Questions regarding the flow of work (i.e., push or pull system), tasks per worker (i.e.,one to multiple tasks), work-in-process inventory (i.e., zero to piles of inventory), mode of transportation of workunits (i.e.,manual, brought to the employee by other means or handed off), and interaction between employees (i.e., no interaction to teamwork) were asked. Responses to these questions were tabulated to determine the primary production system used by the company (see Table 9). This method of analysis was adopted to avoid misinterpretation of the different production systems that could have occurred due to the differences in terminologies used in the literature and industry. A direct question about the production systems used by the company was asked to test the reliability of the questions related to production system attributes.

Product line of the company

This section consisted of line drawings of the collar designs that had been classified into staple, semi-staple, fashion, and high-fashion categories based on the results of Q-Sorts. The collar designs on the questionnaire were randomly arranged to avoid bias in selection of the collars. The respondents were asked to identify the collar designs that are most easily manufactured by their production systems. A direct question about the product lines that they manufacture was also

Table 9
Attributes of the three types of production systems

Production system/ Attributes	Bundle System	Progressive Bundle System	Modular System
Workflow	push	push	pull
Method of retrieval between workstations	self-help operator	brought to operator	handoff
Work-in-Process Inventory	high levels(racks of bundles	moderate levels(just enough to balance the lines)	zero/minimal
Number of tasks per operator	single task, whole garment	single task	single,multiple task or whole garment
Interaction between workers	no teamwork	no team work	teamwork

asked. This question helped test the reliability of Q-sorting that was used to categorize the collar designs into staple, semi-staple, fashion, and high-fashion product lines.

__Q-Sorts to develop instrument.__ A two-way structured Q-Sort was done to classify the collars designs into four categories of product line namely staple, semi-staple, fashion, and high-fashion. Q-Sorts "force individuals to make discriminations that they often do not make unless required to do so" (Kerlinger, 1973, p. 596). Q-Sorts help to see what is common to groups or sets of objects.

Use of Q-Sorts increased the validity of the line drawings of collar designs. A structured Q-Sort is used to rank order a set of items all of which are in one domain but are differentiated on the basis of one or more variable classifications. A one-way structured Q-Sorts is structured on the basis of one variable classification (Kerlinger, 1973). The variable that was used for classifying the collar designs was the product line. The collar designs were determined based on the type of collar-neckline attachment and the shape of outer edge of collars. Collars, in general, differ in their construction method on the basis of collar-neckline attachment and the shape of the outer edge of the collar (Smith, 1987).

Q-Sorting of collar designs into the product line categories was done in the following steps:

1. Thirty two designs of collars were identified from literature. The collar designs varied in terms of the method of construction (i.e., collar-neckline attachment and shape of outer edge of collar) used for each of them. Line-drawings of all the collar designs with different collar-neckline attachment and shape of outer edge of collar were made on separate cards. Reliability deals with the accuracy of a measure (Kerlinger, 1973; Leedy, 1993). To improve reliability of a measure instructions have to be stated clearly and unambiguously (Kerlinger, 1973). The collar type, which could not be identified in the sketch, was mentioned on the cards. An additional instruction sheet was prepared with the definitions of the collar types and product line categories. The definitions of

collar styles was not included, because collar style was assumed to be revealed in the sketch of the collar. Inclusion of the details avoided misinterpretation of the collar types by the subjects. Also, inclusion of the details improved the reliability of Q-sorts. All the collar designs were assigned numbers in a random order to avoid bias in selection.

2. Six subjects were selected to sort the collar designs into the four product line categories. The sample consisted of students, staff, and faculty in the department of Clothing and Textiles at Virginia Tech. The subjects were selected based on their knowledge of apparel production.

The subjects were provided with the stack of cards containing the line drawings of collar designs and the instruction sheet with the definitions. The stack of cards were randomly arranged to avoid bias that could have been introduced if the cards were arranged in order. The subjects were asked to sort the pictures into four categories based on the difficulty in construction.

3. Frequency distribution of collar designs (see Appendix A) was done to determine the collar designs that would be selected to represent each of the four product line categories (i.e., staple, semi-staple, fashion, and high-fashion). The collar designs selected, for use in the questionnaire, were chosen based on the following conditions:

Condition 1. The collar designs that were most frequently selected to represent the product line were picked.

Condition 2. If more than three collar designs were selected most frequently, the collar designs were selected in the order of their assigned numbers. Since the numbers were randomly assigned, selection bias was eliminated.

Condition 3. If less than three collar designs were selected most frequently, the next most frequently occuring collar designs were picked and condition 1 and 2 were applied.

4. Twelve collar designs, three for each of the four product line categories, were thus selected to be used in the questionnaire.

Content Validity and Readability

A pilot test was conducted to test the content validity and readability of the instrument. Content validity indicates the representativeness of the content of a measuring instrument (Kerlinger, 1973; Leedy, 1993). The questionnaires were distributed to the production personnel of a medium sized manufacturer of ladies apparel. The subjects were asked to examine the instrument for clarity and adequacy of terminology. Based on the feedback from the pilot test, revisions were made to the questionnaire before mailing it to the manufacturers. The pilot test of the questionnaire indicated the need to ask the primary production system used by the company, rather than just the production systems. The questions related to the attributes of the production systems were also directed to the primary production system. The pilot test was used to test the clarity of the terms used to describe the collar types. The pilot test results indicated that no definitions were required to clarify the collar types.

Sample selection

The procedure used for selecting the product sample and subject sample is explained in the following sections: (a) product sample and (b) subject sample.

Product Sample

For a comprehensive study of the relationship between apparel production systems and degree of style variation in apparel products, all the apparel products with all the variations would have to be included. Innumerable variations exist among apparel products and to include each one of them would be beyond the scope of this study.

To begin examination of this topic, one product type with variations in one area of the garment was selected. An upper body garment with a collar was investigated. This area of the garment was selected for various reasons:

1. Making and attaching the collar to the neckline is one of the more difficult operations in the assembly of a garment during production. This operation requires better skills and manipulation to produce a better quality product (Smith, 1987; Y.B. Nayak, personal communication, March,1992).

2. The collar area attracts the first attention in a garment when worn. This reason makes the collar attachment area in a garment one of the top-priority areas for inspection by quality control personnel. Good quality garment construction is said to be revealed in a finished collar (Hertal, personal communication, March, 1992; Lawrence & Yurick, 1977).

3. Collar attachment is one of the few operations in apparel assembly that is amenable to automation (Brown, 1992). Automation tends to reduce the flexibility of a production system (Hutchinson & Sinha, 1989; U.S. Office of Technological Assessment, 1987).

4. Additional time is required for designing collar, making collar patterns, and cutting collars. Extra fabric is required for collars. For these reasons collar-making adds substantially to the cost of the garment (Stamper, Sharp, & Donnell, 1986).

Subject Sample

Manufacturers listed in SIC 2321, men's and boys' shirts, and SIC 2331, women's, misses, and juniors blouses and shirts, categories constituted the population for this study. These categories were selected, because the collars made in the two categories were considered to represent all the collars made in the apparel industry. A stratified, proportionate, random sample of 200 manufacturers was selected out of a population of 1523 manufacturers in the two categories(Dun and Bradstreet, personal communication, December, 1993). Sixty-eight manufacturers were selected from SIC 2321 and 132 manufacturers were selected form SIC 2331. The proportions were based on the population of manufacturers in each category. The list was purchased from Dun and Bradstreet. Dun and Bradstreet maintains records of small and large manufacturing business establishments. Random selection from this list would avoid any bias that could have resulted from including companies based on their size. The list is made by compiling information obtained from reporters on the field, from the Department of Commerce, business principals, newspapers, postal service, and court proceedings. The list is considered to be current as the records are updated daily. Out of the purchased list of 200 manufacturers, 23 had to be eliminated at the first stage, since manufacturing was not done at the facility listed. The sample for mailing contained 177 companies.

Data Collection

Questionnaires were mailed to the owners/CEOs of the selected 177 apparel manufacturing firms. Self-addressed, stamped envelopes were included for returning the questionnaires. The initial mailing packet also included a cover letter (see Appendix B) mentioning the purpose of the research. The company owners/CEOs were asked to direct the questionnaires to the production managers. Four weeks were allotted for return of the questionnaires. An executive summary of the results was offered as an incentive for returning the questionnaires. To maintain confidentiality of the apparel manufacturers and monitor the return list, numbers were assigned to each of the manufacturers. The return envelopes were numbered before the actual mailing. Post cards (see Appendix D) were mailed a week later to serve as a reminder/thank-you. The questionnaire was separated from the cover letter and the envelope before data analysis to maintain confidentiality of respondents. After four weeks, telephone calls were made to increase the response rate. Phone calls were made at random to non-participants to improve the reliability of the sample.

Data analysis

The variables under study were: (a) production systems, (b) size of the company in terms of number of employees, (c) size of the company in terms of volume of production, and (d) the product line manufactured by the company.

Production systems

The primary production system for each company was determined by the sum of the weights assigned to each of the attributes. Weights were assigned to the attributes that define the production systems. More weight was assigned to the attributes that are more important in defining the systems. Lower weight was assigned to attributes that were less important in defining the systems.

The number of tasks and the method of retrieval of the cut parts were assigned a higher weight since the three production systems differ distinctly in these two attributes. These attributes were identified as Level 1. The type of work-flow, levels of work-in-process inventory, and the presence/absence of interaction between workers were assigned a lower weight since two of the three systems distinctly differ in these three attributes but the third system could be defined by either of the two alternatives. These attributes were identified as Level 2. For example, in bundle system and in a true PBS, no interaction takes place between the workers, but in a modular system the work is based on the interaction between workers (i.e., team approach). If a company has the same Level 1 attributes, it was considered as that system under which the two attributes occurred. On the other hand, if the two Level 1 attributes did not belong to the same group, the Level 2 attributes were considered. If two of the three Level 2 attributes coincided with either one of Level 1 attributes, the company was considered to use the production system corresponding with the two similar Level 2 attributes. Production systems were thus obtained as categorical data.

<u>**Product line of the company**</u>

The product line of a company was identified as staple, semi-staple, fashion, or high-fashion based on the collar design(s) selected by the manufacturers. The product lines were assigned values from one to four progressively from staple to high-fashion product line. This procedure was adopted since the product lines differed in their degree of complexity. Staple product line was considered to be least complex and thereby carried a value of one, while high-fashion product line was considered to be most complex and thereby carried a value of four. The difference between the values of the product line categories was used to determine the degree of complexity of the product line. For example, the difference between staple and semi-staple product line is one, which means that the semi-staple product line is more complex than staple product line by one degree. On the other hand, the difference in values between staple and fashion product line is two, which means that the fashion product line is more complex than staple product line by two degrees.

Values were assigned to each collar design based on the product line it represented. The sum of all the values of all the collar designs that were selected by the company determined the position of the company on the product line continuum. The product line continuum thus ranged from a minimum of one to a maximum of 30.0. Companies placed between 1.0 and 4.0 on the product line continuum were considered as producing staple product line. Within the product line, the companies having a value of less than 3.0 were considered to produce more staple product line than companies with values greater than 3.0 but less than 4.0. The companies with a product line value of more than three but less than 4.0

were considered to produce product lines tending to be more semi-staple. Similarly, a value of 7.0 was considered to be the maximum value for a semi-staple product line. A value of 10.0 was considered to be the maximum value for fashion product line, and a value of 30.0 was considered to be the maximum value for a high-fashion product line. Thus, product line values for the companies were obtained as continuous data. The product line values were recorded as continuous data, since a clear distinction cannot be made between the complexities of the product lines.

Size of the company

Size of the companies was identified by the number of employees and volume of units produced per week. The size of the companies was recorded as continuous data which is statistically more informative. This type of data can be converted to categorical data when required. Also, more powerful statistical tests can be performed on continuous data (Coakley, C.W., personal communication, December, 1993).

Statistical Tests

The type of statistical tests used for each hypothesis is explained below:

Hypothesis 1

Apparel production systems was used as categorical data and the product line categories was used as continuous data for this hypothesis. Analysis of

Variance (ANOVA) was performed to determine if mix flexibility of apparel production systems (i.e., product line types) increases from Bundle to PBS to Modular system.

Hypothesis 2

The type of production system was used as categorical data and size of the company (i.e., number of employees) was used as continuous data to test this hypothesis. ANOVA was administered to determine the relationship between size of the company (i.e., number of employees) and the production system used by the company.

Hypothesis 3

The type of production system was used as categorical data and the size of the company (i.e. the volume of production) was used as continuous data. ANOVA was administered to determine the relationship between the volume of production and the production system used by the company.

Limitations of the Study

Like all research, this study had certain limitations:

1. This study was limited to one part of a product which is the collars of men's and women's uppergarments (i.e., men's shirts and women's shirts & blouses).

2. Only SIC 2321 and 2331 have been included in this study. Workshirts and night shirts and women's dresses that might have collars are not included in this study.

3. This study is limited to garments made from textile fabrics, those that involve cutting and sewing operations.

CHAPTER V

Results and Discussion

This study examined some of the important variables in the apparel production environment and the interaction between them. The important variables analyzed were product line manufactured by the company and the production system used to manufacture the product line.

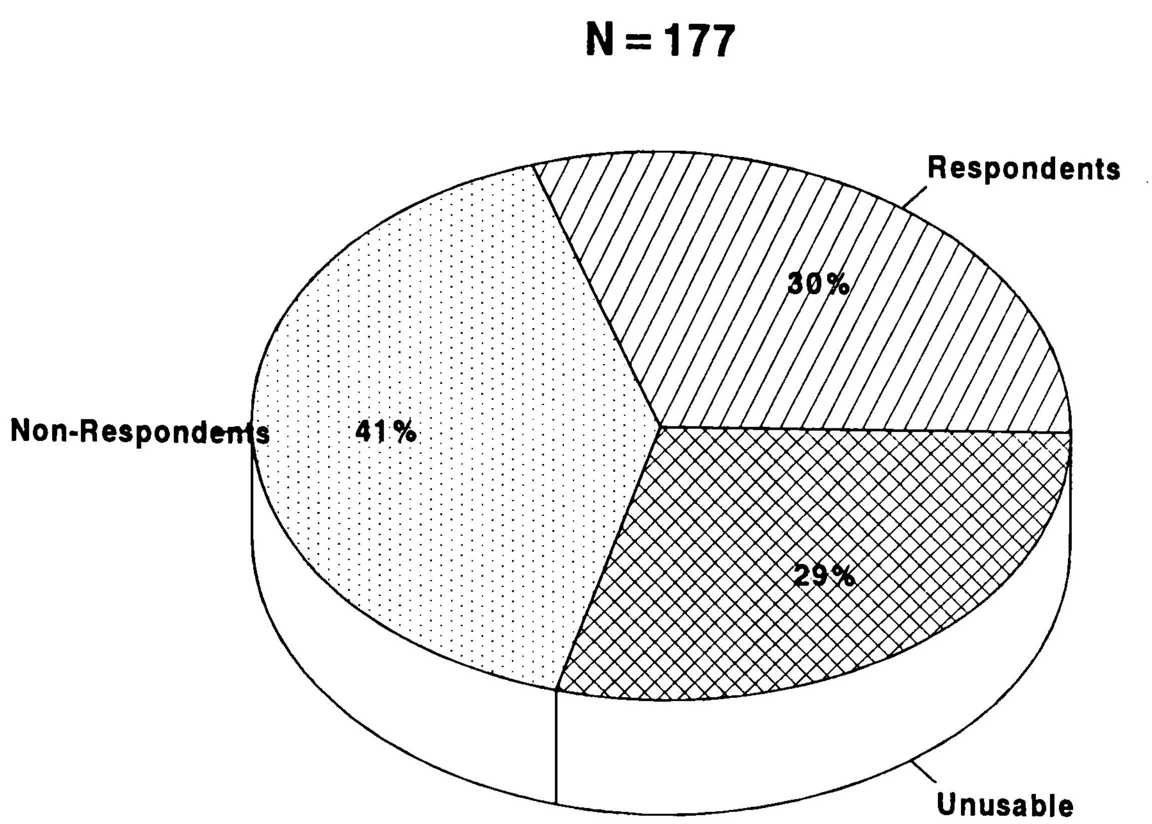
The results of this study are presented in the following sections (a) response rate of the survey, (b) company demographics, (c) production system, (d) product line, (e) production system-product line relationship, (f) production system-volume of production relationship, and (g) production system-size of company relationship.

Response Rate of the Survey

The sample selected for this research constituted 13% of the population of manufacturers producing men's and women's blouses and shirts. Twenty-one completed questionnaires were received by the end of four weeks of data collection with an initial response rate of 15%. Fifteen questionnaires were returned due to wrong addresses, the companies going out of business, or the companies having moved without leaving a forwarding address. Telephone interviews were made in the fifth week of data collection to increase the response rate.

Forty companies had to be eliminated from the sample, because they had gone out of business, had disconnected numbers, or did not fall under the criteria set for this research (i.e., manufacturers of upper body garments). Wrong numbers were verified through directory assistance. Companies in these groups constituted the unusable portion of the sample. In all, 53 companies responded to the survey. All the remaining manufacturers were contacted a minimum of three times. Those manufacturers who were busy and refused to be interviewed were included in the non-respondent portion of the sample. Figure 3 indicates the proportion of responses, non-respondents, and wrong numbers. Exclusion of the unusable portion of the sample resulted in an adjusted response rate of 39%. The response rate increased phenomenally by 24% with the follow-up telephone interviews. Increase in response rate with telephone interviews is in confirmation with Ko's findings (1993).

The general characteristics of the non-respondents was investigated. Their characteristics were found to be similar to that of the respondents. This enhanced the reliability of the sample. Any bias in the results due to sampling error was thus discounted.



RETURN RATE FOR THE SURVEY

Figure 3

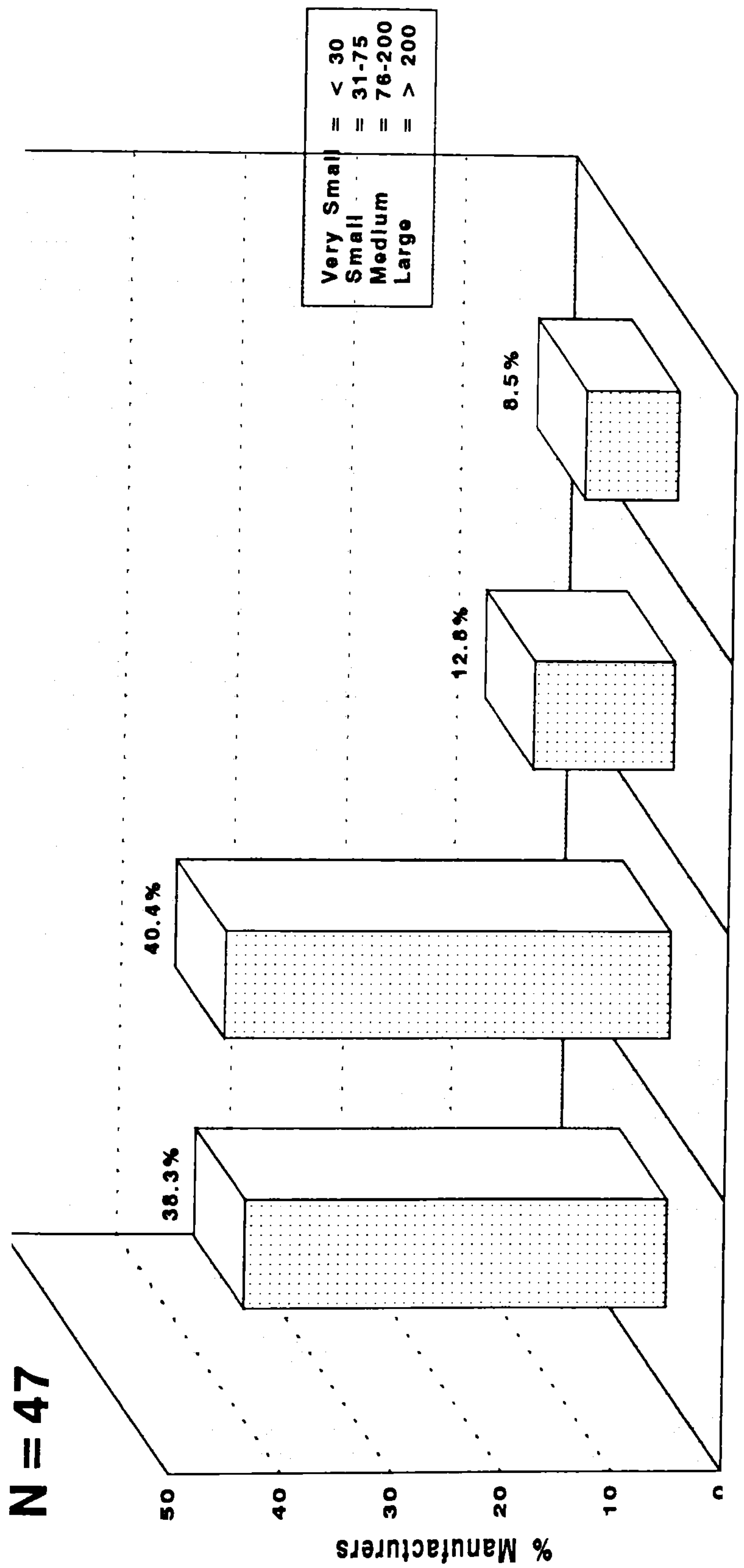
Company Demographics

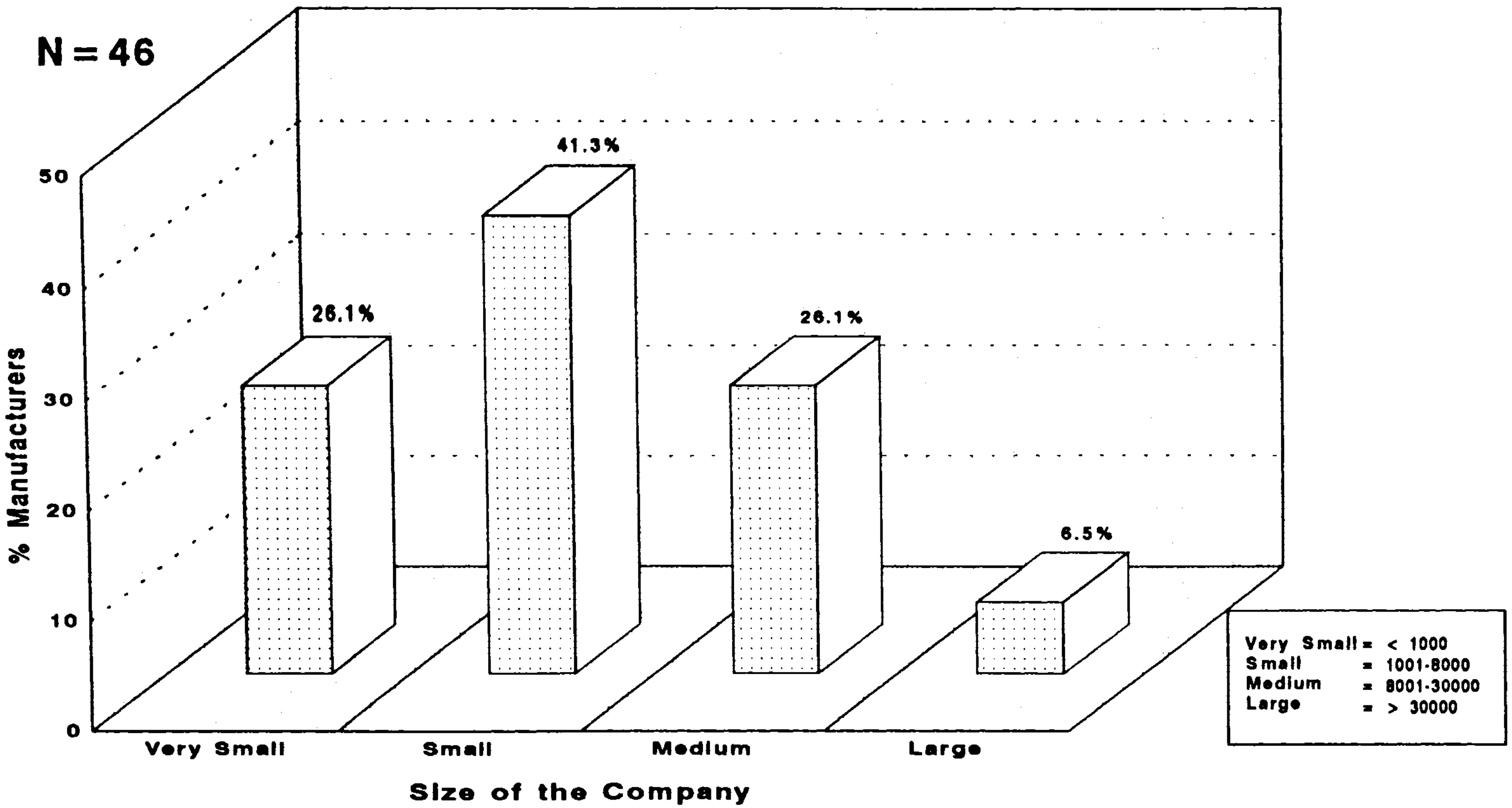
Size of the Companies

The size of the companies was determined based on the number of operators and the total volume of production of the company. The size of the companies in the sample varied widely both in terms of the number of employees and the total volume of production. Figures 4 and 5 illustrate the size breakdown of companies based on the number of employees and the total volume of production. Based on the number of employees, most of the companies in the sample ranged from very small to small. Based on the volume of production, most of the companies ranged from very small to medium. This profile parallels the size range of all U.S. apparel manufacturers (Dickerson, 1991; Ziemke, & Adams, 1990). This profile further supports the reliability of the sample.

Product Categories

The sample for this study was selected, based on product categories, from the SIC classification of manufactured products. The categories selected were men's shirts and women's blouses and shirts. The original sample of 200 manufacturers consisted of 66% women's and 34% men's wear category of producers. The returned sample of 53 respondents indicated production of women's wear (79.2%), men's wear (47.2%) and children's wear (35.8%). The proportion of women's wear manufacturers to men's wear manufacturers in the


N = 47
Very Small = < 30
Small = 31-75
Medium = 76-200
Large = > 200
38.3%
40.4%
12.8%
8.5%
% Manufacturers
50
40
30
20
10
0



SIZE BREAKDOWN OF COMPANIES
BY VOLUME OF PRODUCTION

Figure 5

adjusted sample was found to be greater than the proportion of manufacturers inthe actual sample. This change could be attributed to the fact that some manufacturers produce both men's and women's wear (26.9%), and they reported both of the categories.

Most of the women's wear manufacturers in the sample produce upper body garments such as blouses. Most of the men's wear producers manufacture shirts (i.e., sports and dress shirts). The manufacturers of children's wear mostly produce girls' wear. Table 10 indicates the frequency and percentage of respondents based on the product categories manufactured by them.

Table 10
Product Categories manufactured by the Respondents.

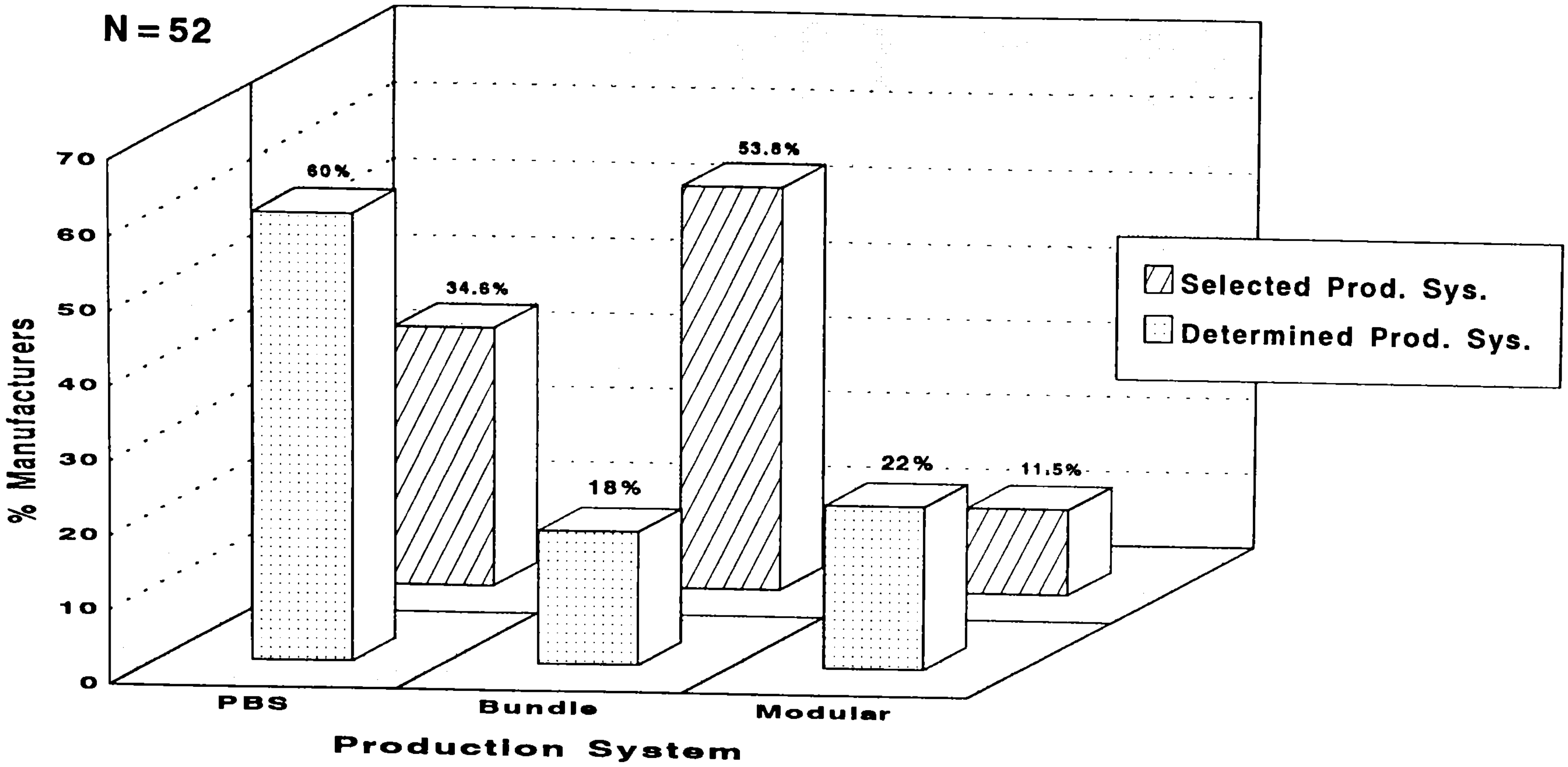
Product Category	Frequency n	Percent %
Women's Wear	42	80.8
Blouses	31	59.6
Skirts	26	50.0
Pants	21	40.4
Dresses	21	40.4
Jackets	13	25.0
Coats	5	9.4
Under Garments	2	3.8
Others	7	13.5
Men's Wear	24	47.2
Dress Shirts	6	13.2
Sports Shirts	18	34.6
Jackets	5	9.4
Coats	0	0
Trousers	3	5.8
Underwear	0	0
Others	8	19.8
Children's Wear	19	36.5
Boys	9	17.3
Girls	14	26.9
Infants	6	11.5
Others	5	9.6

N=52

Production Systems

The three production systems selected for this study included bundle system, PBS, and modular system. Great inconsistency exists in the terminologies used in the apparel industry and literature (Gerwin, 1987; Gupta & Buzacott, 1989; Ramasesh & Jaikumar, 1991). To overcome the inconsistency, attributes that characterize the three production systems were selected from literature. The attributes identified were type of workflow, mode of transportation of workunits between workstations, the number of tasks per operator, level of WIP inventory, and interaction between workers (Hopeman, 1971; Kimura & Terada, 1981; Solinger, 1988). Definitions were provided for each of the attributes for clarity in terminology.

The production system used by the company was determined by aggregating the weights assigned to each of the attributes and was designated as the determined production system. A direct question, as to the system being used, indicated the type of production system that the manufacturers thought they were using and was designated as the selected production system. Figure 6 indicates the rate at which the various systems both determined and selected system were represented in the sample. According to the system determined based on the attributes, PBS was found to be used by most (60%) while bundle system and modular system had lower usage with 18% and 22% respectively. In the selected system, most of the manufacturers use bundle system (53.8%) and very few use



PRODUCTION SYSTEM USAGE

Figure 6

modular (11.5%) system. The results obtained for selected production system is consistent with the findings of Lin, 1990. A simple chi square test indicated a significant relation between the determined production system and the selected production system (χ^2 [4, N=50] =19.541, p=.001). This confirms the reliability of the method used to determine the system. The difference that is noticed between determined and selected production system is not significant and may be attributed to the inconsistency in terminologies between the industry and literature.

To further check the reliability of the definition of determined production system, the relationship between individual attributes and the determined system was evaluated. The significance of the attributes in determining the production system in use was tested using a simple chi square test. The level of significance was set at a probability of .05.

WIP Inventory

The bundle and PB system have been classified as intermittent systems (Solinger, 1988). Modular systems have been classified as continuous systems. Intermittent systems consists of WIP inventory that remains stationary between successive workstations (Solinger, 1988) while continuous systems have zero/minimal WIP inventory. Modular systems have been defined as consisting of zero/minimal WIP inventory (Ross, 1991). Significant associations were found between apparel production systems and the level of WIP inventory for each of the systems in this sample (determined production system, χ^2 [4, N=49] =22.674, p=.000; selected production system, χ^2 [4, N=49] =48.327, p=.000). More than 50% of the cells had less than the minimum values and so the test was repeated for bundle and PBS only. Fisher's exact test indicated a significant relation between the two variables (p=.001). This result indicates the reliability of the three levels of WIP inventory that was used for the three systems.

The frequencies and percentages of the WIP inventory levels of the three production systems is shown in Table 11. All bundle system users reported high levels of WIP inventory (100%). This finding is consistent with the theoretical concept of WIP inventory levels in for the three systems. Most of the PBS and modular system users reported having moderate levels of WIP inventory (PBS 53.33%; modular system 50%). High levels of WIP inventory was noticed most in PBS (56%) compared to bundle system and modular system. Only modular system had a zero inventory level (100%). This finding suggests that zero inventory level is probably possible only in modular system and that bundle system almost always involves high levels of WIP inventory.

Table 11
WIP of the Determined Production Systems.

Level of WIP		Determined Production System			Total
		PBS	Bundle	Modular	
High	n	9	14	2	25
	%	18.37	28.57	4.08	51.02
	Row %	36.00	56.00	8.00	
	Col %	100.00	46.67	20.00	
Moderate		0	16	5	21
		0.00	32.65	10.20	42.86
		0.00	76.19	23.81	
		0.00	53.33	50.00	
Low		0	0	3	3
		0.00	0.00	6.12	6.12
		0.00	0.00	100.00	
		0.00	0.00	30.00	
Total	n	9	30	10	49
	%	18.37	61.22	20.41	100.00

Workflow

The type of workflow in any production system is either push or pull depending on what drives the work through the system (Kimura & Terada, 1981). A significant relationship was found between the production system and the type of workflow in the case of both determined and selected production systems (determined production system, χ^2 [2, N=48] =10.640, p=.005; selected production system, χ^2 [2, N=48] =16.538, p=.000). This finding suggests the reliability of the two types of workflow as a contributing factor in determining the type of system. Table 12 indicates the frequency and percentage of determined production systems with the associated workflow.

Table 12
Work Flow in the three Determined Production Systems.

Level of Work Flow		Determined Production System			Total
		PBS	Bundle	Modular	
Push through	n % Row % Col %	6 12.50 15.00 66.67	29 60.42 72.50 96.67	5 10.42 12.50 55.56	40 83.33
Pull through		3 6.25 37.50 33.33	1 2.08 12.50 3.33	4 8.33 50.00 44.44	8 16.67
Total	n %	9 18.75	30 62.50	9 18.75	48 100.00

Most of the manufacturers reported a push workflow (83.33%) and very few manufacturers reported a pull workflow on their systems. This finding could be attributed to the fact that very few manufacturers used modular system which has been associated with pull workflow. Most of the bundle system (66.67%) and PBS (96.7%) indicated push workflow. This finding is consistent with findings in literature that indicate a push workflow in traditional manufacturing systems (Carrere & Little, 1989). The type of workflow is directly related to the WIP inventory between the workstations. High levels of WIP is said to be the motive to push the work through the system; however, modular system users reported pull and push workflow almost equally. This finding could be attributed partly to the inconsistency in terminology used in the industry. Also a better representation of modular system users would probably have revealed more obvious differences in the type of workflow for modular system. Of the very few manufacturers who adopted the pull workflow, most of them were modular system users (50%). This finding is consistent with the findings of Carrere and Little (1989). In a pull workflow, a need to increase the production helps pull the work through the system.

Mode of transportation of workunits

The type of product flow is dictated by the method of retrieval or mode of transportation of workunits between workstations (Solinger, 1988). The mode of transportation between workstations is one of the more important attributes that characterize apparel production systems. Significant association was noticed between the determined production systems and the mode of transportation of workunits between workstations but not for the selected production system (determined production system χ^2 [4, $\underline{N}$=49] =28.756, p=.000; selected production system χ^2 [4, $\underline{N}$=49] =3.848, p=.427). The chi square test was not considered valid due to under representation of modular system users. To improve the validity of the test, bundle system and PBS only were tested for the relation. Significant relation was found between the systems and the mode of transportation of workunits between workstations (χ^2 [2, N=45] =20.019, p=.000).

Table 13 indicates the frequency and percentage of the various means of transportation of workunits found in the determined production systems. Most of the manufacturers using bundle system indicated that the operator himself carries

Table 13
Mode of Transfer of Workunits
in the Determined Production Systems.

Mode of Transfer of Workunits		Determined Production System			Total
		PBS	Bundle	Modular	
Self-Help Operator	n % Row % Col %	7 14.29 53.85 77.78	2 4.08 15.38 6.67	2 8.16 30.77 40.00	13 26.53
Transport by other means		2 4.08 6.25 22.22	27 55.10 84.38 90.00	3 6.12 9.38 30.00	32 65.31
Handed off		0 0.00 0.00 0.00	1 2.04 25.00 3.33	3 6.12 75.00 30.00	4 8.16
Total	n %	9 18.37	30 61.22	10 20.41	49 100.00

the workunits to the workstation (77.78%). This finding is consistent with the theoretical definitions put forward by Hannan (1963). Most of the PB system users indicated transportation of workunits by other means of transportation (e.g., conveyors or material handlers). This finding confirms the theoretical definitions of PBS in literature (Chase & Aquilano, 1992; Ross, 1991). Transportation by other means increases the time spent on actual sewing operation and helps improve productivity (Hodge & Canada, 1989).

Within modular system, the three modes of transportation of workunits were noticed almost equally. Across the systems, handoff approach for retrieval of workunits was most commonly found in modular system (75%). This finding indicates that this mode of transportation is a characteristic feature of modular systems and not bundle or PB systems. In the modular system, the workflow is continuous and the workunits do not remain stationary at any moment during processing (Solinger, 1988). The workunits are handed off to the next operator when the operator is ready to work on the oncoming workunit. Transportation by other methods such as conveyors was noticed most in PBS (84.38%). This finding is consistent with the definition of the PBS in the literature (Sisselman, 1990).

Lack of significant association between the selected production system and the mode of transportation between workunits may be attributed to the finding that most of the selected bundle system users (71.43%) reported transportation of workunits by other than manual means. This finding is contrary to the findings of the mode of transportation for determined production systems This finding could be attributed to the increased awareness among apparel manufacturers about the unproductivity of the time spent on non-value added repetitive tasks. Manual transportation is probably being replaced by automated devices to overcome this problem (Cole, 1987; Hodge & Canada, 1989; JSN International, 1989).

The number of tasks per operator

The number of tasks assigned to each operator have been identified as being different in each of the three production systems. Significant association was found between apparel production systems and the number of tasks assigned to each operator (determined production system, χ^2 [4, N=50] =47.928, p=.000; selected production system, χ^2 [4, N=50] =23.508, p=.000). Majority of the manufacturers (78%) reported assigning single tasks to an individual operator and the operator does not make the entire garment. This finding is consistent with the classification of PBS as a section production system rather than a whole garment production system by Solinger (1988). This finding could be attributed to the over representation of PBS in which operators work on single tasks and do not make the entire garment.

Table 14 indicates the frequency and percentage of the production systems with the associated number of tasks per operator. Most of the bundle system users (77.78%) reported assigning single tasks to operators, and the operator does not make the entire garment unlike the definition of bundle system by Hannan (1963). In a traditional bundle system, operators perform multiple tasks and sometimes may make the entire garment. All the PBS users (100%) reported assigning single tasks and the operator does not make the entire garment. This finding is consistent with the theoretical definition of PBS (Sisselman, 1990; Solinger, 1988). This finding suggests that manufacturers are increasingly adopting the latter approach to overcome the problem of locating multiskilled operators. Assigning single tasks to individual operators reduces the need for multi-skilled operators (Maziotti, 1993). This finding is consistent with the theoretical definition of PBS (Sisselman, 1990; Solinger, 1988). The operations are laid out in a sequence and work flows from one operator to the next in a progression.

Table 14
Number of Tasks per Operator in the Determined Production Systems.

Tasks		Determined Production System			Total
		PBS	Bundle	Modular	
Multiple	n % Row % Col %	2 4.00 100.00 22.22	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 4.00
Single		7 14.00 17.95 77.78	30 60.00 76.92 100.00	2 4.00 5.13 18.18	39 78.00
Single or Multiple		0 0.00 0.00 0.00	0 0.00 0.00 0.00	9 18.00 100.00 81.82	9 18.00
Total	n %	9 18	30 60.00	11 22.00	50 100.00

In a modular system most of the manufacturers (81.82%) reported assigning single or multiple tasks depending on the work demanded by the next operator. This finding is a direct consequence of the handoff approach as reported earlier. The results are consistent with the theoretical concept of handoff approach in modular manufacturing (Ross, 1991).

Interaction between operators

One of the characteristic features of modular system is the team approach to manufacturing (Carrere & Little, 1989; Cole, 1992). A great degree of interaction exists between operators in a modular system. Simple chi square tests were performed to determine the relationship between production system and interaction between operators in the sample. Significant association was found between production system and interaction between workers (determined production system, χ^2 [4, N=50] =13.992, p=.007; selected production system, χ^2 [4, N=50] =12.731, p=.013). The chi square tests were not considered valid due to under representation of modular systems, but the frequencies and percentages in Table 15 indicate that in determined production systems, most of the modular system users (81.82%) reported interaction among operators. Correspondingly most of the bundle system (55.56%) and PBS users (70%) indicated no interaction among the operators. An interesting finding was the relatively high degree of interaction among operators in a PBS. This finding is not consistent with the theoretical definition of PBS. This finding suggests that manufacturers are incorporating team work in PBS.

The chi square test was repeated for determined bundle system and PBS to determine the relation between traditional systems and interaction among workers. Fisher's exact test indicated no significant relation between the production system and interaction between workers (χ^2 [1, N=45] =0.512,

$p=.474$). These findings are consistent with the theoretical concepts of teamwork in the three systems. The high degree of significance between the production systems and the attributes indicate the reliability of the attributes in determining the system. The attributes of one system could be incorporated into other production systems, based on the company's objectives, to improve their effectiveness. Table 16 is an overview of the significance of attributes with respect to the determined and selected production systems. The variable, determined production system was used in hypotheses testing.

Table 15
Degree of Interaction among operators in Determined Production System.

Degree of Interaction		Determined Production System			Total
		PBS	Bundle	Modular	
Interaction	n	4	9	9	22
	%	8.00	18.00	18.00	44.00
	Row %	18.18	40.91	40.91	
	Col %	44.44	30.00	81.82	
No Interaction		5	21	1	27
		10.00	42.00	2.00	54
		18.52	77.78	3.70	
		55.56	70.00	9.09	
Total	n	9	30	11	50
	%	18.00	60.00	22.00	100.00

Table 16
Level of significance of System Attributes and Production System.

Production System		System Attributes				
		WIP	Work Flow	Mode of Transfer	No. of Tasks	Team Work
Determined	χ^2	22.67	10.64	28.76	47.93	13.99
	prob.	0.00	0.01	0.00	0.00	0.01
Selected	χ^2	48.3	16.5	3.9	23.5	12.7
	prob.	0.00	0.00	0.43	0.00	0.01

For hypotheses testing, only the determined production system was used because relation between determined and selected production systems was significant and linear.

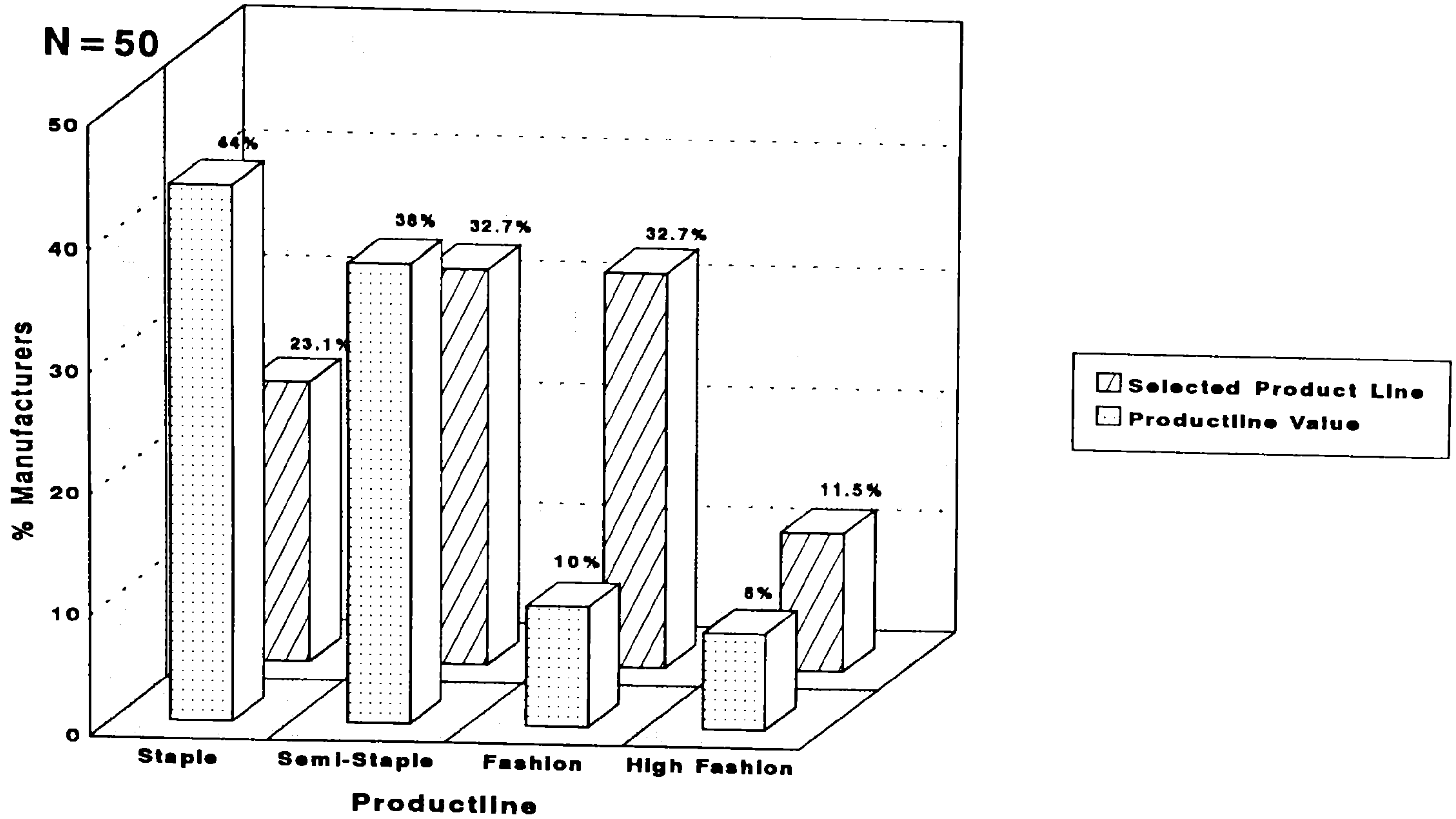
Product line

The product line of a company was determined based on the collar designs that the company manufactures. The collar designs were previously selected and categorized, by Q-sorts, into product lines (see Appendix A). Collar designs classified as staple and semi-staple product line were in general simpler in construction. The collar designs that were classified as fashion and high-fashion product line were more complex in construction. This finding is consistent with the product line description by (Hill, 1978). Table 17 indicates the frequencies and percentage of manufacturers producing the various collar designs. Most manufacturers produced collars from the staple/semi-staple product line. The pointed convertible collar was produced by most manufacturers (60%) followed by the mandarin collar (56%) and pointed shirt collar (48%). Fashion/high-fashion collars were produced by the least number of manufacturers. The scarf collar (10%) and chelsea collar (12%) from the high-fashion product line were produced by the least number of manufacturers. Values were assigned to each product line and the corresponding collar design as designated in Chapter IV. The sum of scores for all the collar designs manufactured by a company is referred to as the product line value.

Figure 7 indicates the product lines manufactured by the companies. The product line selected by the company is compared with the product line value determined by the collar designs manufactured.

Table 17
Frequency Distribution of the Product line Categories Based on Collar Designs.

	Product line											
	Staple			Semi-Staple			Fashion			High Fashion		
Collar Designs by numbers	**6**	**8**	**10**	**4**	**9**	**12**	**1**	**2**	**7**	**3**	**5**	**11**
n	28	24	9	17	30	11	6	10	5	6	3	5
%	56	48	18	34	60	22	12	20	10	12	6	10
Product line %			81.33			72.33			28			18.67



PRODUCT LINES MANUFACTURED BY
THE COMPANIES

Figure 7

Collars in the staple product line was produced by most (44%) of the manufacturers, followed by the semi-staple product line (38%). Fashion and high-fashion collars was produced by the least number of manufacturers (fashion, 10%; high-fashion, 8%). The Student-Newman-Keuls analysis of variance test was performed to determine the relation between product line value and the selected product line. Significant association was found between the selected production system and the selected product line (F [3, 48] =3.18, p=.0322).

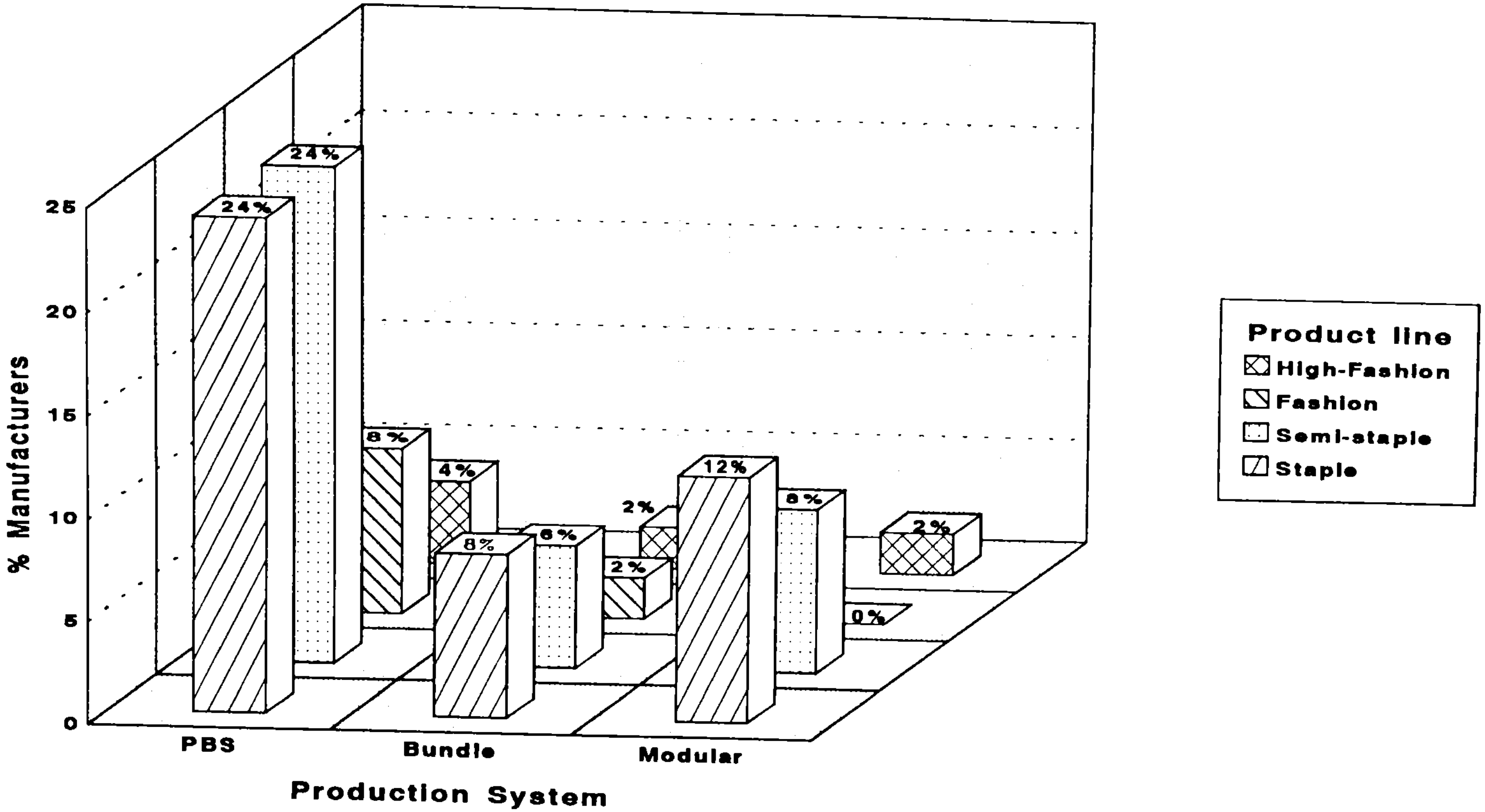
For testing of the hypotheses, both the measures of the product line variable were used (i.e., selected product line and the product line value). This procedure of testing was adopted because the analysis of variance tests revealed a significant relation between the two variables, but the relation was not linear.

Production System and Product line Relationship

The main objective of this research was to compare the flexibility of three types of apparel production systems to variations in collar designs. It was hypothesized on theoretical grounds that modular system would be more flexible than PBS and PBS would be more flexible than bundle system (H_1). For hypothesis testing, the following combination of variables were tested: determined production system and product line value; and determined production system and selected product line.

First, the three production systems were compared for their product line value which is the summation of all the collar design scores. Analysis of variance procedure was used to test this hypothesis. The Student-Newman-Keuls test revealed no significant relation between the determined production system and the calculated product line value (F [2, 47] =0.27, p=.7640). Hypothesis 1 (H_1) was not confirmed with this sample. This finding may be due to type II error that could have occurred because of the small sample size.

For further validation, a simple chi square test was performed with the determined production system and the selected product line. A significant relation was found between the two variables (χ^2 [6, N=50] =14.816, p=.022). The chi square test was not considered valid due to under representation by bundle and modular systems. To improve the validity of the test, staple and semi-staple product lines were combined in one group and the fashion and high-fashion product lines were combined in another group. Results of the test indicate a significant association between the determined production system and the selected product line (χ^2 [2, N=50] =8.186, p=.017). This result indicates that a relation exists between production systems and product line categories, but a more balanced sample may be needed for further confirmation of this hypothesis. Figure 8 illustrates the different production systems with the associated product lines.



PRODUCT LINES MANUFACTURED
ON THE THREE PRODUCTION SYSTEMS

Figure 8

A difference in the results between the two measures of product line may be attributed to the misinterpretation of product line terms despite the definitions. Fashion product line, for example, may have been interpreted as a product line that is being produced more recently rather than a product line that consists of more frequent changes in styles. Some of the manufacturers selected fashion product line though they produced more staple collar designs.

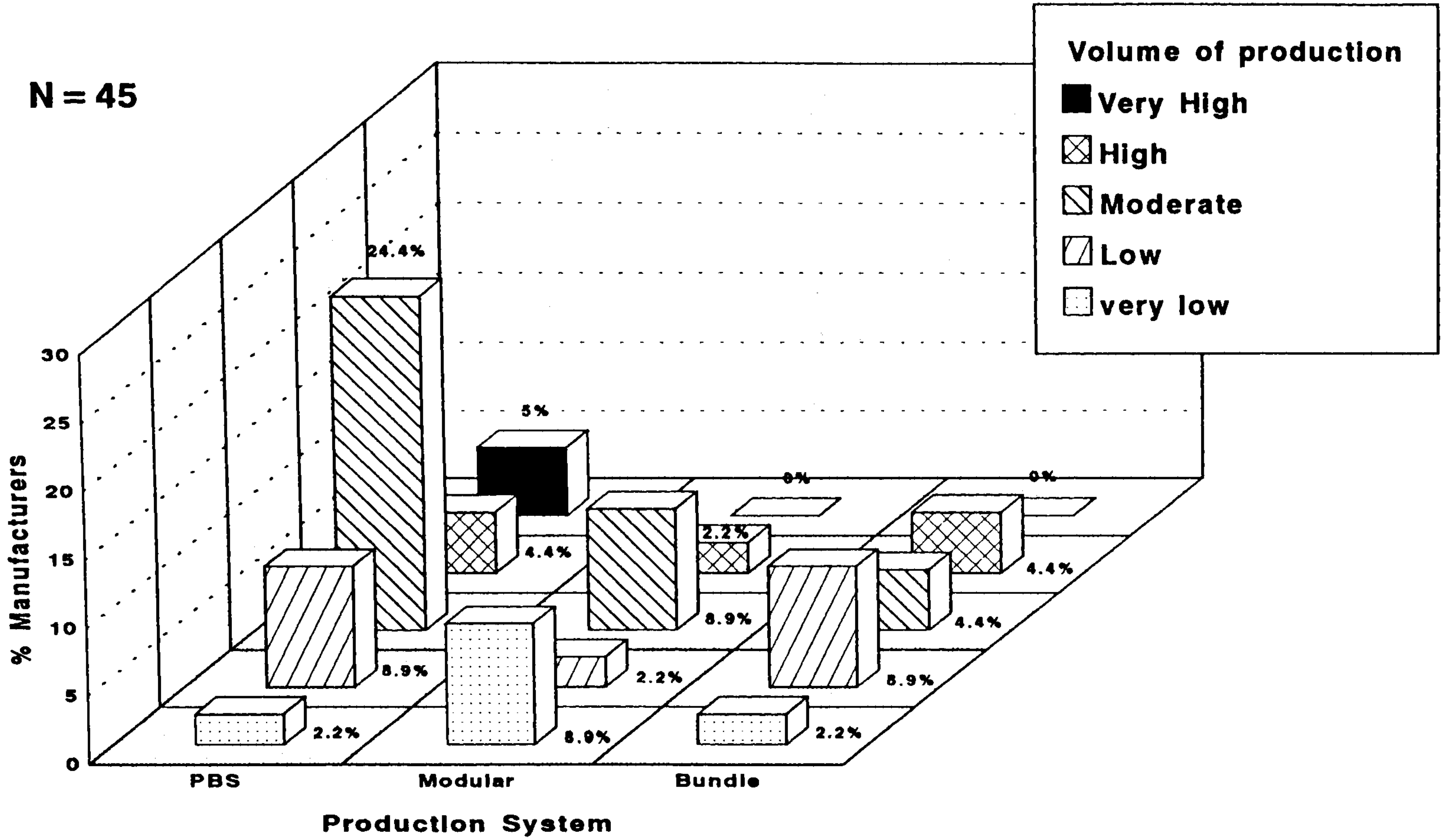
Frequency distribution of determined production systems and the associated product line values indicate that PBS was most used for all product line categories. This finding could be attributed to the over representation of PBS in the sample. Within the system, bundle system was most used for staple product line (8%). This finding is consistent with the theoretical concept of the flexibility of bundle system (Hunter, 1990; Johnson-Hill, 1978; Knapton, 1990; Schoenberger, 1982; Solinger, 1988). Staple collars are simpler in construction with very little variation in styles. Very little variation in styles does not require the system to be very flexible to style variation. Bundle system was used to a very small extent for fashion (2%) and high-fashion product line (2%). PBS was most used for both staple (24%) and semi-staple (24%) product line compared to high-fashion product line (4%). Semi-staple product line consists of more variation between styles compared to staple product line (Johnson-Hill, 1978). PBS could be considered more flexible than bundle system due to its ability to accommodate more style variations. This finding is consistent with the findings in literature.

An interesting finding was that modular system was most used to produce staple product line (12%) and was least used for fashion product line (0%). This finding is contrary to the expected results. Modular system was hypothesized as having the ability to produce greater style variation as found in fashion/high-fashion product line (Carrere & Little, 1989; Hunter, 1990; Johnson-Hill, 1978; Kurt Salmon, 1988; Ross, 1991; Schoenberger, 1982; Sisselman, 1990) compared to bundle system and PBS (i.e., a higher degree of flexibility). This result could be attributed largely to the under representation of modular system. On the other hand, modular system may not be as flexible as theorized in the literature.

A significant association between the selected and determined production system and between selected and calculated product line value confirmed the reliability of responses to the questionnaire. Comparison of the flexibility of the three production systems was limited due to the under representation of modular and bundle system users.

Production System and Volume of Production Relationship

The volume of production on a modular system was hypothesized (H_2) on theoretical grounds to be less than that on PBS and bundle systems. This hypothesis was not confirmed with the sample. Student-Newman-Keuls analysis of variance test indicated no significant relation between the two variables (determined production system, F [2, 42] $=1.87$, $p=.1668$). Figure 9 illustrates the



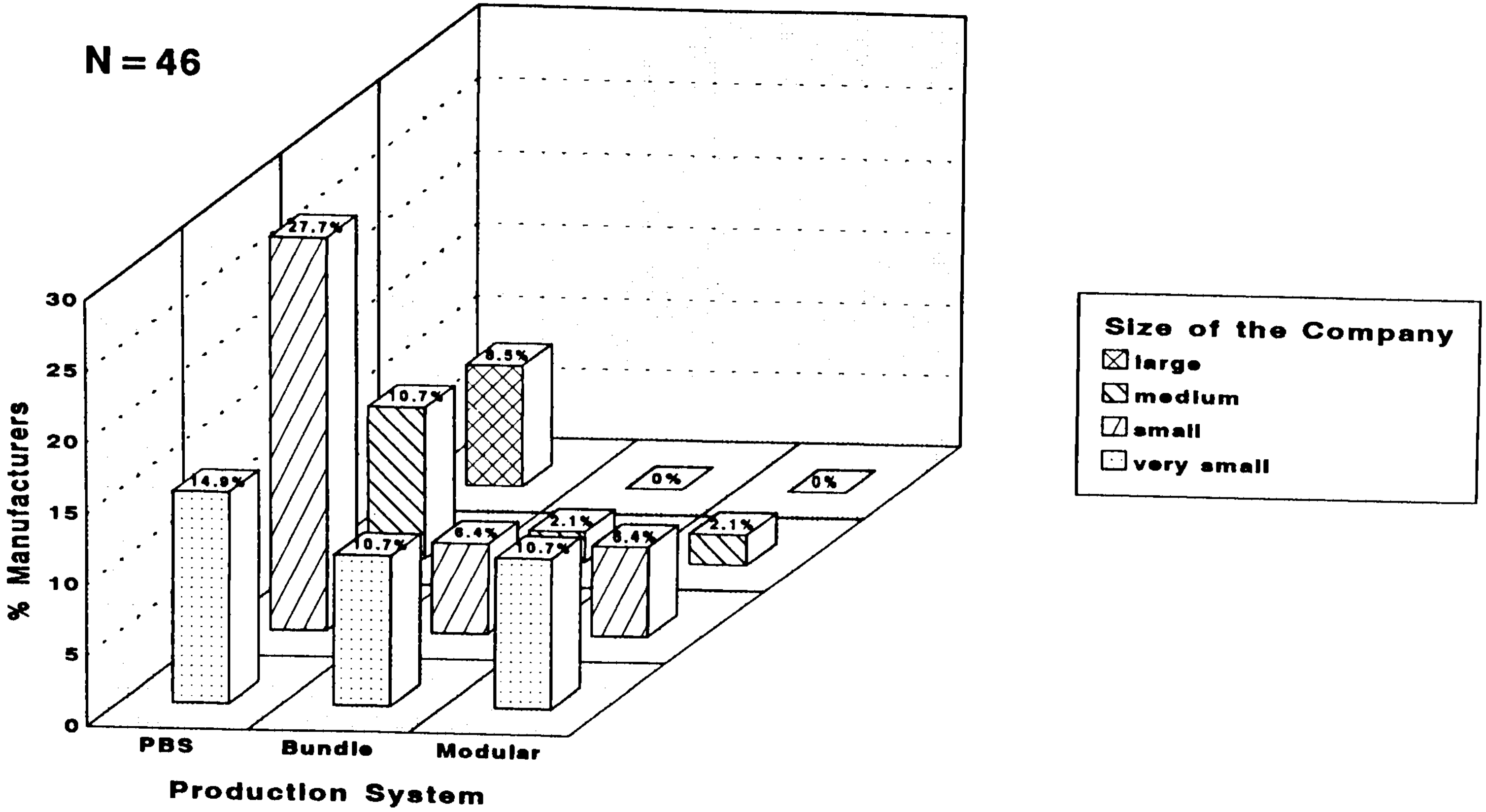
VOLUME OF PRODUCTION
ON THE THREE SYSTEMS

Figure 9

volume of production on the primary system. Comparison of the three systems indicated that modular system was most used for very low production which is consistent with the findings in literature (Ross, 1991). Very low volume of production is associated with custom production and high degree of variation (Johnson-Hill, 1978), but all three systems were found to be equally used (11%) for very low and low volume of production. PBS was used the most for moderate and high/very high volumes (33.4%) compared to bundle system (8.8%) and modular system (11.1%). Within the system, PBS was used most for moderate volume of production (24.4%) followed by low volume (8.9%). This result is consistent with the theoretical concepts found in literature. Bundle system was used most for low volume production (8.9%). Modular system was used most for very low (8.9%) and moderate volumes of production (8.9%). Bundle system was least used for high and very high volumes of production. This finding is contrary to the theoretical concepts that claim bundle system to be used for high volume or bulk production. Modular systems were least used for very-high volumes of production. This finding is consistent with the theoretical definitions of modular manufacturing where the system is said to be used for more customized production.

Production System and Size of the Company

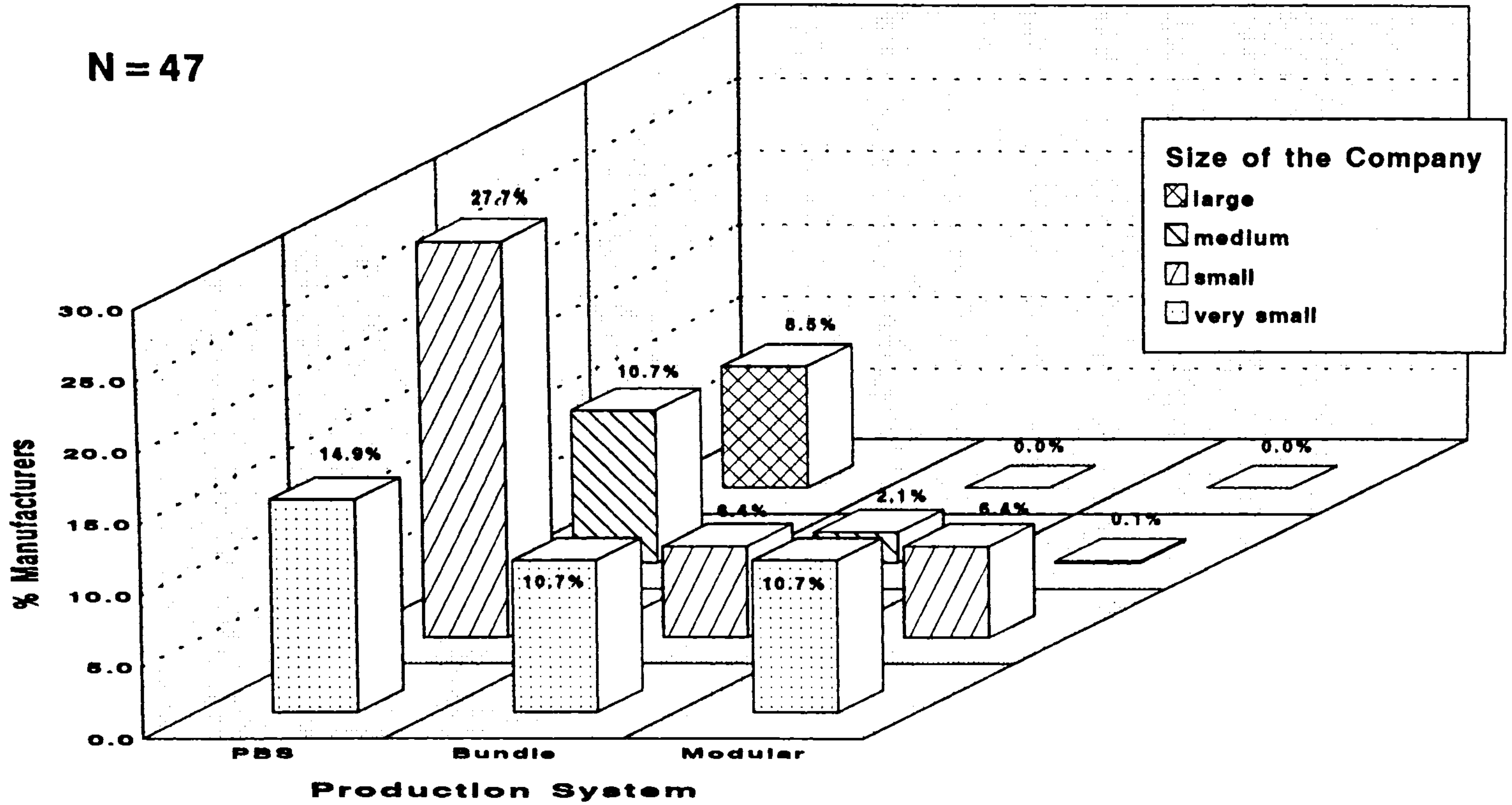
The size of the company was determined based on the number of employees and the total volume of production of the company. A relation was hypothesized (H_3) to exist between the determined production system and the size of the company by number of employees. The Student-Newman-Keuls analysis of variance test indicated no significant relation between the two variables (F [2, 44] $= 1.59$, $p = .2152$). Hypothesis, H_3, therefore could not be confirmed with this sample. This finding is interesting in the light of the fact that larger companies continue to use traditional production systems as seen in Figure 10. Claims in literature, that many companies are adopting advanced production systems as a fad, may not be true (Cole, 1992). Figure 10 indicates that PBS was used most often irrespective of the size of the company; however, comparison within the system indicated that modular system was most used by small companies (10.7%). Within the system, PBS was used most by small companies (27.7%), and within the system, bundle system, was most used by very small companies (10.7%). This finding is not consistent with the literature that advanced production systems like modular system are generally used by large companies. This finding may probably be due to the inadequate representation of large companies in the sample.



PRODUCTION SYSTEM USAGE
BY SIZE OF COMPANY (no. of employees)

Figure 10

Relation between production system and size of a company was tested with the volume of production as an indicator of the size of the company (H_4). H_4 was tested with the Student-Newman-Keuls analysis of variance procedure. No significant relation was noticed between the size of the company, by volume of production, and the system that is adopted by the company (F [2, 43] =0.54, p=.5841). Figure 11 illustrates the systems used by companies of different sizes in terms of volume of production. Usage of PBS was found to be used more than bundle system and modular system irrespective of the size of the company. This finding could be attributed to the inadequate representation of modular system in the sample. Bundle system was most used by very small companies, and PBS was used most by small companies. These findings are similar to the results obtained for size of company in terms of the number of employees. This finding confirms the finding that larger companies do not necessarily use more advanced production systems.



PRODUCTION SYSTEM USAGE
BY SIZE OF COMPANY (vol. of prod.)

Figure 11

CHAPTER VI

Summary, Conclusions, Implications, and Suggestions

Production and efficiency of apparel production systems have been examined, but, finer aspects of manufacturing, such as flexibility, have been neglected in the apparel industry. With the fast-changing nature of the apparel market, apparel manufacturers must begin adopting strategies for increased flexibility, simultaneously improving productivity and efficiency (Soni, 1990).

The capability of a system is the system's intrinsic ability (Troxler & Blank, 1989), and flexibility is one of the determinants of capability of a system. Flexibility refers to the capability of a system to respond effectively to uncertain circumstances (Gerwin, 1987); therefore, any attempt at studying the flexibility of apparel manufacturing system necessitates a close look at the uncertainties that exist in the manufacturing environment (Buzacott, 1982). A production system is said to be flexible to style changes if it responds to frequent changes in style in an efficient manner. A production system must be flexible enough to produce or accommodate a wide variety of products in terms of style features and to produce a selected volume efficiently within the region of economy of production.

The purpose of this research was to analyze flexibility at the basic level, by examining one aspect of flexibility (i.e., mix flexibility) and one part of a garment (i.e., collars). Starting at the basic level facilitates defining and operationalizing of terms and concepts.

This study was designed to examine the relationship between apparel production systems and product line categories. An objective of this study was to determine the production systems used by the company and the product line manufactured by the company. The information obtained was used to compare the flexibility of three types of apparel production systems.

Summary and Conclusions

This study analyses the relationship between apparel production systems and style variation as revealed in the collar designs of men's and women's shirts and blouses. The objectives of this research were achieved by the survey method. Mailed questionnaires were used to obtain the data. The survey instrument contained three sections (i.e., company demographics, production systems and product line of the company). Q-Sorts were done to select the collar designs that represent the product line categories. Thirty two collar designs were identified for the initial Q-Sorting. From the Q-Sorts twelve collar designs (i.e., three for each product line) were selected to represent the product line categories in the instrument. The instrument was pilot tested for content validity and reliability.

The questionnaires were mailed to a stratified, proportionate, random sample of 177 apparel manufacturers in the United States. Fifty-two responses were received with a response rate of 39%. The respondents represented manufacturers producing men's and women's shirts and blouses. Values were assigned to each collar based on its product line. The values of the collar designs manufactured by a company were summed to obtain the product line of the company. Questions were asked about the five production system attributes and responses were aggregated to obtain the production system for the company. Analysis of variance (ANOVA) and chi square tests were performed to analyze the data.

Company Demographics

A majority of the companies in the sample ranged from very small to medium with less than 100 employees and volume of production of less than 30,000 units per week. The sample consisted of producers of women's wear(79.2%), producers of men's wear (47.2%), and producers of children's wear (35.8%). This finding is consistent with the general profile of all U.S. apparel manufacturers (Dickerson, 1991).

Production Systems

The three production systems selected for this study were bundle system, PBS, and modular system. Most of the respondents used PBS, followed by modular system, and bundle system. The production system used by a company was determined based on five attributes identified from literature (i.e., Work flow, mode of transportation, WIP inventory, number of tasks, and interaction between workers).

Significant associations were found between the production system attributes and the production system used by the company. Bundle system was found to have high levels of WIP inventory. The level of WIP inventory is directly related to the type of workflow adopted by the company. Consequently, most of the bundle system users reported adopting the push workflow where piles of WIP inventory causes to push the work through the system. Most of the manufacturers using bundle systems reported assigning single tasks to individual operators although in traditional bundle system operators are sometimes assigned multiple tasks where they make the entire garment. The workunits in a bundle system were reported to be transported manually between workstations. Some of the findings indicated transportation of workunits by other means. This change could occur, because manufacturers are beginning to increase automation for more repetitive and non-value added tasks like material handling. No interaction was found among bundle system users which indicates the absence of team approach to manufacturing. These findings confirm the classification of bundle system as the traditional manufacturing system defined by Knapton (1990).

Most of the PBS users reported moderate WIP inventory levels that were just enough to balance the lines, and push workflow was most reported by PBS users. Most of the PBS users reported assigning single tasks to an individual operator, and the operator does not make the entire garment. The need for multi-skilled operators is minimized. The workunits in PBS were found to be transported more by automatic transfer devices rather than manually. As reported earlier, this mode of transportation helps improve productivity. PBS users also reported no interaction among operators. These findings confirm the classification of PBS as a traditional system similar to the bundle system (Knapton, 1990).

Modular system attributes were dissimilar when compared to the bundle system and PBS. Modular system users were found to have zero WIP inventory and pull type of workflow. In a pull workflow, the need to increase production helps pull the work through the system rather than high levels of WIP inventory that helps push the work through the system (Kimura & Terada, 1989). Individual operators in a modular system are assigned multiple tasks depending on the demand for work by the next operator. This feature of modular system confirms the system's classification as a continuous rather than an intermittent system (Carrere & Little, 1989). The team approach to manufacturing was reported only by modular system users. This finding coincides with Knapton's (1990) classification of modular system as being different from the more traditional bundle and PB systems.

Product Line

The product line of a company was determined based on the collar designs that the company manufactures. The collar designs were previously selected and categorized, by Q-sorts, into four product lines (i.e., staple, semi-staple, fashion, and high-fashion [see Appendix A]). Collar designs classified as staple and semi-staple product line were in general simpler in construction. The collar designs that were classified as fashion and high-fashion product line appeared to be more complex in construction. Values were assigned to each product line and the corresponding collar design. The sum of scores for all the collar designs manufactured by a company was referred to as the product line value. Significant associations were noticed between the product line selected by the companies and the product line determined by the collar designs. Most manufacturers produced collars from the staple/semi-staple product line. Fashion/high-fashion collars were produced by the least number of manufacturers.

Production System and Product Line Relationship

Modular system was hypothesized (H_1) to be more flexible than PBS and that PBS would be more flexible than bundle system. Flexibility was measured by the range of characteristics of part types (i.e., product line based on collar designs) that a system can manufacture. For this hypothesis (i.e., H_1), the three production systems were compared for their selected product line and for their product line value, which is the summation of all the collar design scores. Analysis of variance test confirmed this hypothesis with the determined production system and the selected product line. PBS was found to be most flexible followed by modular system and bundle system.

When analysis was done using product line value instead of selected product line, chi square test failed to confirm this hypothesis. The difference in the relationship of production system with selected product line and the product line value may be attributed to the fact that the relationship between product line value and selected product line was not a completely linear relationship. Some manufacturers who selected more fashion product line produced more staple collars. These staple collars may be considered more fashionable today as the consumers are opting for more simple lines for fashion items.

Production System and Volume of Production

The type of production system and the volume of production were Hypothesized (H_2) to be positively related. Comparison of the three systems for their volume of production indicated that bundle system was most used for low volume production, PBS was used most for moderate and high volumes, followed by modular system that was most used for very low volume of production. Analysis of variance test did not confirm the relationship between the two variables. High volume of production is generally associated with more staple products with very little style variation (Johnson-Hill, 1978; Lin, Kincade, & Warfield, in press). Very low volumes are associated with custom production and high degree of style variation (Johnson-Hill, 1978; Lin, Kincade, & Warfield, in press). The volume of production on bundle system is not consistent with literature.

Production System and Size of the Company

The type of production system and the size of company (i.e., number of employees [H_3] and the total volume of production of the company [H_4]) were hypothesized to be related. Although bundle system was used most by small companies, PBS was used by small to medium sized companies, and modular system was most used by small companies, the analysis of variance tests did not confirm these hypotheses. The use of modular system by small companies is not consistent with literature (Cole, 1992). This finding may be attributed to the fact that other variables are affecting selection of production systems. Smaller companies are more adaptable to new situations and may be adopting advanced manufacturing systems more easily compared to larger companies (Cole, 1992; Ko, 1993).

Implications

The results of this study could be used for subsequent research on flexibility of apparel manufacturing systems. The five system attributes that were identified may be used reliably for determining the production systems used by a company. This procedure would help identify systems when evaluated in subsequent research.

The procedure adopted for determining the product line of a company was partially successful in determining the product line. With additional study, this procedure may be used for determining the product line based on style variation in garment parts. A classification system may be developed for research in the apparel industry based on the criteria set forth in this study (i.e., construction features and look of a garment). Quantifying these variables will help improve the validity of statistics in research related to production systems and product lines.

Suggestions

The suggestions for this research include:

1. The sample size for the Q-Sorts may be increased to improve the reliability of categorization of collar designs into product lines.

2. This research can be repeated with a larger sample and including more modular system users to reexamine some of the hypotheses that could not be confirmed in this study.

3. A similar study could be done using computer simulation where the flexibility of production systems could be determined taking into consideration all the factors that influence or affect system performance.

4. The results of this study could be used to determine the mix flexibility of apparel manufacturing systems. Other types of flexibility could be determined by their underlying parameters and the aggregate flexibility of an apparel manufacturing system calculated. The flexibility attribute is input to a multi-criterion decision making problem. Flexibility will provide the additional competitive edge in meeting the evergrowing challenges of varying product design (Soni, 1990).

5. The flexibilities of other manufacturing systems can be determined and compared to identify the most flexible manufacturing system. The measures of flexibility can be used by decision makers in support of choosing a manufacturing system for specific products lines.

6. Research could also be done to determine the relationship between quality of the apparel product and flexibility of the manufacturing system. Research can be done to determine how much flexibility was lost or gained as a result of improvement in quality. Flexibilities of different systems performing the

same task can be compared. The uncertainties that are controlled and adapted to, and the strategies used for controlling and adapting can also be studied. Ultimately, this research could lead to a comprehensive analysis of the flexible factory, as it adapts to uncertainty.

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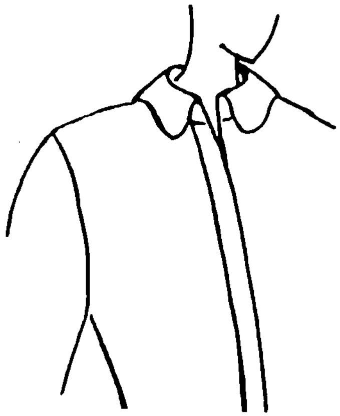
APPENDICES

APPENDIX A

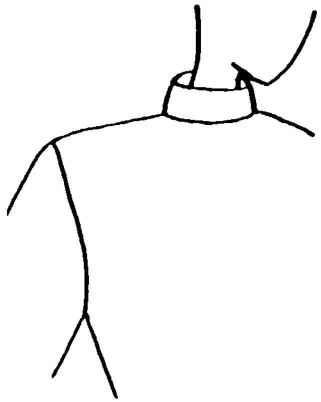
Collar Designs selected to represent the Product lines

STAPLE PRODUCT LINE



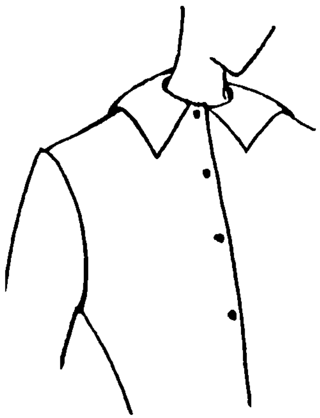
Shirt Collar with rounded edge

Shirt Collar with pointed edge



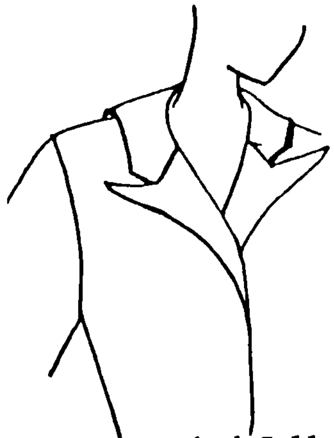
Mandarin Collar

SEMI-STAPLE PRODUCT LINE



Convertible Collar

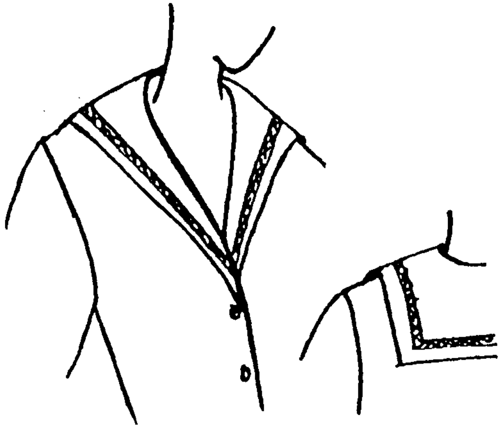
Shawl Collar with pointed notches



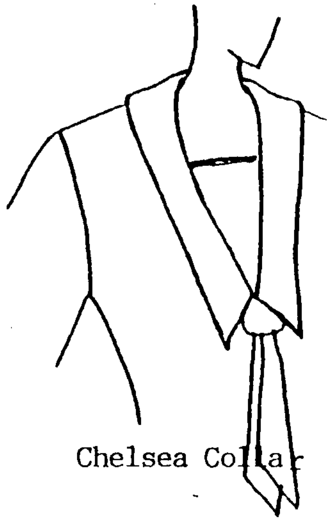
Notched Collar with pointed lapels

FASHION PRODUCT LINE

Simple Shawl collar



Sailor collar

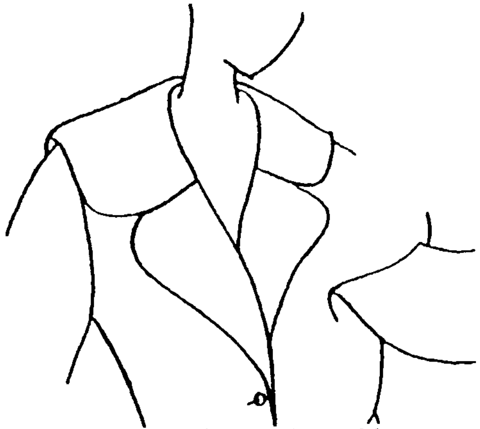


Chelsea Collar

HIGH-FASHION PRODUCT LINE

Scarf Collar

Wing Collar



Rounded notch collar
with a cape

APPENDIX B
Cover letter for the questionnaire

Plant Manager
Company
Street Address
City, State, zip code
Date

SALUTATION:

The apparel industry has recently seen an upsurge in the need for technical information and analysis. As part of my thesis I am asking you to contribute to this information. You and your plant will benefit from the results by receiving an executive summary of this study.

The enclosed survey asks about the production systems you use and the type of products you manufacture. The questionnaire can be completed in less than 10 minutes. The answers to the questions will remain confidential. Only the investigator will have access to the data. So we are not asking for exact figures. You are free to omit any question on the survey.

The study is carefully designed so that individual firms cannot be identified. There are no identification numbers or individual ink. I will not be able to identify the survey because the envelops and the letter will be separated from the survey before reaching me.

I realize your time is important, but the success of this important study will depend on your response. Please return the completed survey by (date). If you wish to receive an executive summary of the study, please indicate this on the back of the envelope. The results will be mailed to you within the next few months. If you have any questions about this research, please contact Dr. Doris Kincade at (703) 231-7637. If you have questions about the conduct of this research please contact Dr. Ernest Stout, Research Division at (703) 231-6077. The study has been approved by the university IRB.

Thank you very much,
Sincerely,

Durga
Graduate Student,
Dept of Clothing & Textiles
VPI & SU

I have read the letter and understand the conditions of the survey.

____
signature

Please return this letter with the survey.

APPENDIX C
Questionnaire for Apparel Manufacturers

SECTION I: PRODUCTS [Please check all that apply (√)]

1. Do you produce women's wear? ( )Yes ( )No

   If so what kind?
   ( )blouses ( )skirts ( )pants
   ( )dresses ( )jackets ( )coats
   ( )undergarments ( )others (specify) __________

2. Do you produce men's wear? ( )Yes ( )No

   If so what kind?
   ( )dress shirts ( )sports shirts ( )jackets
   ( )coats ( )trousers ( )underwear
   ( )others (specify) __________

3. Do you produce children's wear? ( )Yes ( )No

   If so what kind?
   ( )boys ( )girls ( )infants
   ( )others (specify) __________

4. Given below is a list of collar designs. Circle the collar designs that are manufactured most <u>easily</u> by your primary production system.

(1) (2) (3) (4)

(5) (6) (7) (8)

(9) (10) (11) (12)

5. What product line(s) does your company manufacture?
[Check all that apply. Please read the definitions before you check the answer(s)]

( ) staple - basic garment styles with long and continuous production runs (atmost 1 style change/season)
( ) semi-staple - basic garment styles with some changes in styles (2-3 style changes/season)
( ) fashion - varied styles with frequent changes in the styles (4-6 style changes/season)
( ) high-fashion - highly varied styles with rapid changes (>6 style changes/season)

6. What is the primary product line that your company manufactures?
( )staple ( )semi-staple ( )fashion ( )high-fashion

7. Did your company at any time refuse to produce an order?
( )Yes ( )No

If yes, what are the reasons [check all that apply]
( ) did not have the capacity to produce a large order
( ) did not have the machines to produce the required styles
( ) operators were not appropriately skilled
( ) it was not cost effective to produce the required styles because of the operations and system that we have
( ) other ______________________

SECTION II: COMPANY DEMOGRAPHICS [please give as accurate an answer as possible]

1. How many operators (sewing machine and assistant operators) does your company employ?
________no. of oprs.

2. What is the total volume of production of your company? __________pcs/week

3. What is the volume of production for each of the product line that you manufacture?
Staple _________pcs/week Semi-Staple __________pcs/week
Fashion _________pcs/week High-Fashion __________pcs/week

SECTION III: PRODUCTION SYSTEMS [please circle the most appropriate answer(s)]

1. What are the production system(s) used by your company?
[Circle all that apply. Please read the definitions before you circle the answer(s)]

(1) **bundle system**-comprises of bundles of workunits and each operator performs one operation on all the units or, produces the entire product.
(2) **progressive bundle system**-comprises of workunits that are passed along singly from operator to operator. Each operator works only on one set of operations and does not make the entire product.
(3) **modular system**-comprises of teams of operators producing one garment at a time. The operators rotate to different machines as they work through the garment.
(4) other ______________________

2. What is the primary production system used by your company?
[please check only one answer]
( )bundle ( )progressive bundle ( )modular ( )other

Circle the ONE most appropriate answer. Please read the definitions before you check the answer.

3. What is the type of workflow adopted for the primary production system in your company?

(1) **Push system** - Piles of work-in-process inventory helps push the work through the system.
(2) **Pull system** - A need to increase the output helps pull the work through the system.
(3) other ________________________________

2. How are the cut parts/sub-assembled parts brought to the operator in your primary production system?

(1) the operator himself carries the cut parts to the workstation
(2) cut parts/in-process parts are brought to the workstation by other means
(3) the cut parts/in-process parts are handedoff to the next operator
(4) other ________________________________

3. How many tasks at a time are assigned to one operator in your primary production system?

(1) multiple tasks and one operator may make the whole garment
(2) single task and one operator does not make the whole garment
(3) single, multiple, or whole garment depending on the demand of work for next operator
(4) other ________________________________

4. How much work-in-process inventory do you have in the sewing lines in your primary production system?
(1) more than one rack of bundles
(2) just enough to balance the lines
(3) zero inventory
(4) other ________________

5. What kind of interaction exists between the operators in your primary production system?

(1) interaction among a group of operators
(2) no interaction and individual operators perform their own job
(3) other ________________

7. What type of product line(s) do you manufacture on your primary production system?
( ) staple ( ) semi-staple ( ) fashion ( ) high-fashion

8. What volume of products is manufactured on your primary production system?
____________pcs/week

9. What were the criteria for selecting the primary production system that you are currently using? **(check all that apply)**

( ) suitable to the product line we manufacture
( ) flexible, in that the system can produce any style that we want to produce
( ) least expensive
( ) easy to maintain
( ) is traditionally used in the apparel industry
( ) other

THANK YOU!

APPENDIX D
Follow-up Postcard

Dear Mr./Ms.xxxx

April 12 1994

Over a week ago you received a questionnaire from VPI & SU asking about your apparel production and operation. I will be using your responses to profile the apparel industry and to examine its future competitive position.

If you have already returned the completed questionnaire, please accept my sincere thanks. If not, I request you to take 10 minutes and complete it today. Your responses are of utmost importance for our research. For the results to be generalized to the American apparel industry, it is important that your firm be included. If you have not received it, please do call me as soon as you can and I will have one mailed to you immediately.

I'm extremely thankful for your co-operation and enthusiastically look forward to receiving your responses.

Sincerely,

Kanakadurga
(703) 951-3998

SUPPLEMENT

Manuscript for publication in The International Journal of Manufacturing Systems

Introduction

The U.S. apparel market is fast changing and offers a challenge that few other consumer products offer to marketeers and manufacturers alike. The American apparel market is characterized by increasing number of imports, an individualistic consumer, and fast turns in fashion. Current trends in the apparel market indicate greater variations in styles, frequent changes in styles, shorter lead times and smaller lot sizes (Hodge & Canada, 1989; U.S. Office of Technological Assessment, 1987). In a world of ever changing fashions, more and more apparel manufacturers are adopting strategies suitable to capture the growing apparel market while keeping in mind the customers' individualistic needs. With foreign producers often using low cost labor and maintaining a competitive price for their goods, the U.S. manufacturers will have to take a closer look at their manufacturing strategies and management techniques to remain competitive(Soni, 1990).

Changes in the market caused by changing fashions and seasonality leads to a wide variation in the styles of apparel items demanded. This situation affects the styles of apparel products that are to be produced and influences the assembly operations during manufacturing (Lin, Kincade, & Warfield, in press). With more consumers tending towards one-of-a-kind clothing, manufacturing systems need to be highly flexible to enable customized production with shorter production runs, while still maintaining the economy of production (Sisselman, 1990). A system that is highly flexible can respond more easily to demand than a system with little flexibility (Hodge & Canada, 1989).

Background

Planning should be the basis for all future managerial activities. Planning establishes the guidelines and actions that must be taken to meet the company's objectives and goals (Evans, Anderson, Sweeney, & Williams, 1984). A company's decision making process is influenced by a number of factors like economic conditions, government regulation, competition, and technology (Troxler & Blank, 1989).

Production systems are one of the major components of production in an organization and constitute a major portion of the company's investment (Evans, Anderson, Sweeney, & Williams, 1984). Selecting the right production system assumes great importance since investors would want a system worth the investment. Production systems have to be evaluated to help companies make informed choice of production systems. The purpose of this study was to develop an instrument which could accurately measure the production system manufactured by a company.

Production Systems

A production system is defined as a set of components whose function is to convert a set of inputs into some desired output through a transformation process (Chase & Aquilano, 1992). The components can be a man, machine, equipment, or tool. A production system should, in general, allow a manufacturer to produce goods efficiently while keeping in mind the customers' needs. Both the manufacturer and the customer should benefit from the production process. The manufacturer should have monetary gains, and the customer should be able to obtain the product at a price worth the value the product holds.

Types of Production Systems

Various production systems are in use in the soft goods and hard goods industry. Each of the systems are characterized by distinctive attributes. These attributes can help identify the various systems.

Hopeman (1971) and Solinger (1988) have identified production systems based on the dimension of time factor. Production systems can be intermittent or continuous systems based on the time a workunit rests between successive workstations. This factor is directly related to the level of WIP inventory in the system.

Solinger (1988) has also identified production systems based on the scope of workers duties and type of product flow. The scope of workers duties may be determined by the number of tasks assigned to individual operator in a system.

Individual operators may be assigned single tasks or multiple tasks. The scope of workers duties is directly related to the skill of the workers. Production systems that assign single tasks to operators may not require multi-skilled workers as opposed to the systems that assign multiple tasks.

Production systems can be distinguished based on the type of product flow between workstations (Solinger, 1988). The products may flow either singly or in groups. The type of product flow dictates the means of transportation of workunits between workstations. Single productflow is associated with automated transfer of workunits between workstations or the handoff approach.

Kimura and Terada (1981) identified production systems based on the type of workflow. The type of workflow may be "pull through" or "push through" depending on the source of the force that drives the work through the system. The normal approach in industrial production is the push system in which piles of work-in-process (WIP) inventory help push the work through the system. In a pull system, the need to increase the production helps pull the work through the system.

A recent approach in manufacturing is the team approach, where groups of operators function as a self-directed team (Cole, 1992; Sisselman, 1990). The production systems may be associated with interaction between operators or no interaction. The presence or absence of interaction between operators may be used as a determinant of a production system.

Based on the various attributes, production systems have classified into several broad categories (Solinger, 1988).

Bundle Systems. The bundle system is a traditional dedicated system that is normally comprised of bundles of workunits. Individual operators perform some or all of the operations on the bundle (Hannan, 1963). Traditionally, individual operators perform only certain operations on all the bundles of workunits. The productflow is in groups, and the workunits are transported manually by the operator himself (Lin, 1990). A bank of inventory is positioned at each machine and work flows intermittently from the storage to the operator and back to the storage after the bundles are worked on. This mode of transportation results in racks of WIP inventory (Mazziotti, 1993). The WIP inventory helps push the work through the system. The bundle system is essentially a push system. No interaction exists between the operators in a bundle system, because each operator is responsible for his own job.

Progressive Bundle System (PBS). The PBS is also referred to as an assembly line (Chase & Aquliano, 1992). In a progressive bundle system, the operations are laid out in a sequence. A group of operators work as a single unit, producing one style at a time. Progressive bundle system involves two or three work stations being worked upon for the same operation at the same time but two or more different operations/jobs of a garment are never done simultaneously in a planned synchronized manner (Solinger, 1988). Individual operators are assigned single tasks as opposed to multiple tasks in a bundle system (Mazziotti, 1993; Sisselman, 1990). The bundles of workunits are passed along singly from operator to operator. The PBS is associated with single productflow, and the workunits are transferred by means of conveyors or other automated transfer devices (Chase & Aquilano, 1992; Ross, 1991). These conveyors become storage devices which can result in moderate to high levels of WIP inventory (Ross, 1991). The level of WIP inventory is controlled in a PBS by balancing the lines. The WIP inventory in a PBS is controlled to a certain extent, as opposed to the level of WIP inventory in a bundle system. The inventory drives the work through the system; therefore, PBS is a push system. Though a group of operators work on a single style at a time, no interaction exists between the operators.

Modular System. This system is also referred to as Cellular system (Ross, 1991). Modular system consists of teams of operators functioning as a single unit assembling a whole garment (Sisselman, 1990). The operators rotate to different machines as they work through the garment (Brown, 1992; Ross, 1991). The operators in a modular system can perform single or multiple tasks. The workunits are handed off to the next operator depending on the demand for work by the operator (Mazziotti, 1993). The handoff approach is associated with single productflow. The team of operators make the entire product one at a time rather than moving large masses of inventory (Ross, 1991). The workunits flow continuously through the system. This helps minimize the WIP inventory to a great extent (Cole, 1992).

Kron (1987) and Frank (1988) define modular manufacturing as consisting of modules or cells where each module or cell is a contained manageable work unit of people performing a measurable task. The people are self-directed and work in a team. The need to increase production helps drive the work through a modular system. Modular system is essentially a pull system (Carrere & Little, 1989). The operators are interchangeable among tasks within the group (Kron, 1987; Frank, 1988). Since the group of operators in a modular system work as a team a great deal of interaction is noticed among the operators. Modular systems encourage team work, improve quality, and increase production (Ross, 1991; Sisselman, 1990).

Related Research

Carrere and Little (1989) examined eleven modular manufacturing situations. The degree of flexibility desired within a modular unit and the product characteristics dictated the level of WIP that could be accommodated. Modular manufacturing revealed benefits such as improved quality, reduction of waste, increased manufacturing flexibility, reduced turn over and absenteeism and organizational and cultural growth. Modular manufacturing also indicated a reduction of bundle or batch size, balancing of operations, pull through production, and production of exact quantities of the product.

Sisselman (1990) conducted a case study of an apparel firm that reorganized its production system from the traditional progressive bundle system to the more modern modular system. During its progressive bundle stage, all the people in the plant worked in a single group and on one style at a time. The operators were thus assigned specific operations to which he/she was limited. Under the changed system, a group of six chains formed the production system, and each chain functioned as a single complete unit assembling a whole garment. Operators in the chain only assembled components to the body while the other operators worked on the less skilled operations. Although the turn cycle, from cutting to shipping and the direct and indirect costs were reduced modular manufacturing was not found to be as productive as when the work was repetitive.

Objectives

This research was designed with the following objectives:

1.To develop an instrument that can be used to quantify the apparel production system variable.

2. To classify production systems into three categories.

Research Design

The survey method with mailed questionnaires was used to achieve the objectives for this research. The results of survey can be generalized to the larger population if the sample represents the population and also allows a researcher to determine the interrelations among variables (Kerlinger, 1973).

Instrument

The instrument used to obtain the data for this research was the mailed questionnaire. The questionnaire consisted of questions related to production system(s) attributes of the company. Questions regarding the flow of work (i.e., push or pull system), tasks per worker (i.e., one to multiple tasks), work-in-process inventory (i.e., zero to piles of inventory), mode of transportation of workunits (i.e., manual, brought to the employee by other means or handed off), and interaction between employees (i.e., no interaction to teamwork) were asked. Responses to these questions were tabulated to determine the primary production system used by the company (see Table 1).

Table 1
Attributes of the three production systems

Production system/ Attributes	Bundle System	Progressive Bundle System	Modular System
Workflow	push	push	pull
Method of retrieval between workstations	self-help operator	brought to operator	handoff
Work-in-Process Inventory	high levels(racks of bundles	moderate levels(just enough to balance the lines)	zero/minimal
Number of tasks per operator	single task, whole garment	single task	single,multiple task or whole garment
Interaction between workers	no teamwork	no team work	teamwork

Sample selection

Manufacturers listed in SIC 2321, men's and boys' shirts, and SIC 2331, women's, misses, and juniors blouses and shirts categories, were the population for this study. A stratified, proportionate, random sample of 200 manufacturers was selected out of a population of 1523 manufacturers in the two categories (Dun and Bradstreet, personal communication, December, 1993). Sixty eight manufacturers were selected from SIC 2321, and 132 manufacturers were selected form SIC 2331. The proportions were based on the population of manufacturers in each category. The list is considered to be current as the records are updated daily. Out of the list of 200 manufacturers, 23 had to be eliminated at the first stage, since manufacturing was not done at the facility listed. The sample for mailing contained 177 companies.

Data Collection

Questionnaires were mailed to the owners/CEOs of the selected 177 apparel manufacturing firms. Self-addressed, stamped envelopes were included for returning the questionnaires. The initial mailing packet also included a cover letter mentioning the purpose of the research. The company owners/CEOs were asked to direct the questionnaires to the production managers. Postcards and telephone calls were sent to increase the response rate. Phone calls were made at random to non-participants to evaluate the reliability of the sample.

Data analysis

The three production systems selected for this study included bundle system, PBS, and modular system. Great inconsistency exists in the terminologies used in the apparel industry and literature (Gerwin, 1987; Gupta & Buzacott, 1989; Ramasesh & Jaikumar, 1991). To overcome the inconsistency, attributes that characterize the three production systems were selected from literature. The attributes identified were type of workflow, mode of transportation of workunits between workstations, the number of tasks per operator, level of WIP inventory, and interaction between workers (Hopeman, 1971; Kimura & Terada, 1981; Solinger, 1988). Definitions were provided for each of the attributes for clarity in terminology.

Weights were assigned to the attributes that define the production systems. More weight was assigned to the attributes that are more important in defining the systems. Lower weight was assigned to attributes that less important in defining the systems. The production system used by the company was determined by aggregating the weights assigned to each of the attributes and was designated as the determined production system. A direct question, as to the system being used, indicated the type of production system that the manufacturers thought they were using and was designated as the selected production system.

Chi square tests were used to test the relationship between the selected and determined systems and between the selected system and each attribute.

Results and Discussion

A majority of the companies in the sample ranged from very small to medium with less than 100 employees and volume of production of less than 30,000 units per week. The sample consisted of 79.2% women's wear producers, 47.2% men's wear producers, and 35.8% children's wear producers. This finding is consistent with the general profile of all U.S. apparel manufacturers (Dickerson, 1991).

This study examined one of the important variables in the apparel production environment: production systems and the attributes of production systems.

Production Systems

A simple chi square test indicated a significant relation between the determined production system and the selected production system (χ^2 [df=4] =19.541, p=.001). This confirms the reliability of the method used to determine the system. The results obtained for selected production system is consistent with the findings of Lin (1990).

To further check the reliability of the definition of determined production system, the relationship between individual attributes and both the determined and selected production system was evaluated. The significance of the attributes in determining the production system in use was tested using a simple chi square test. The level of significance was set at a probability of 0.05.

WIP Inventory. The bundle and PB system have been classified as intermittent systems (Solinger, 1988). Modular systems have been classified as continuous systems. Intermittent systems consists of WIP inventory that remains stationary between successive workstations (Solinger, 1988) while continuous systems have zero/minimal WIP inventory. Modular systems have been defined as consisting of zero/minimal WIP inventory (Ross, 1991). Significant associations were found between apparel production systems and the level of WIP inventory for each of the systems in this sample (determined production system, χ^2 [df=4] =22.674, p=.000; selected production system, χ^2 [df=4] =48.327, p=.000)., More than 50% of the cells had less than the minimum values; therefore, the test was repeated for bundle and PBS only. Fisher's exact test indicated a significant relation between the two variables (p=.001). This result indicates the reliability of the three levels of WIP inventory that was used for the three systems.

The frequencies and percentages of the WIP inventory levels of the three production systems is shown in Table 2.

Table 2
WIP of the Determined Production Systems.

Level of WIP		Determined Production System: PBS	Bundle	Modular	Total
High	n	9	14	2	25
	%	18.37	28.57	4.08	51.02
	Row %	36.00	56.00	8.00	
	Col %	100.00	46.67	20.00	
Moderate		0	16	5	21
		0.00	32.65	10.20	42.86
		0.00	76.19	23.81	
		0.00	53.33	50.00	
Low		0	0	3	3
		0.00	0.00	6.12	6.12
		0.00	0.00	100.00	
		0.00	0.00	30.00	
Total	n	9	30	10	49
	%	18.37	61.22	20.41	100.00

All bundle system users reported high levels of WIP inventory (100%). This finding is consistent with the theoretical concept of WIP inventory levels for the three systems. Most of the PBS and modular system users reported having moderate levels of WIP inventory (PBS 53.33%; modular system 50%). High levels of WIP inventory was noticed most in PBS (56%) compared to bundle system and modular system. Only modular system had a zero inventory level (100%). This finding suggests that zero inventory level is probably possible only in modular system and that bundle system almost always involves high levels of WIP inventory.

Workflow. The type of workflow in any production system is either push or pull depending on what drives the work through the system (Kimura & Terada, 1981). A significant relationship was found between the production system and the type of workflow in the case of both determined and selected production systems (determined production system, χ^2 [df=2] =10.640, p=.005; selected production system, χ^2 [df=2] =16.538, p=.000). This finding suggests the reliability of the two types of workflow as a contributing factor in determining the type of system. Table 3 indicates the frequency and percentage of determined production systems with the associated workflow.

Table 3
Work Flow in the three Determined Production Systems.

Level of Work Flow		Determined Production System			Total
		PBS	Bundle	Modular	
Push through	n	6	29	5	40
	%	12.50	60.42	10.42	83.33
	Row %	15.00	72.50	12.50	
	Col %	66.67	96.67	55.56	
Pull through		3	1	4	8
		6.25	2.08	8.33	16.67
		37.50	12.50	50.00	
		33.33	3.33	44.44	
Total	n	9	30	9	48
	%	18.75	62.50	18.75	100.00

Most of the manufacturers reported a push workflow (83.33%) and very few manufacturers reported a pull workflow on their systems. This finding could be attributed to the fact that very few manufacturers used modular system which has been associated with pull workflow. Most of the bundle system (66.67%) and PBS (96.7%) indicated push workflow. This finding is consistent with findings in literature that indicate a push workflow in traditional manufacturing systems (Carrere & Little, 1989). The type of workflow is directly related to the WIP inventory between the workstations. High levels of WIP is said to be the motive to push the work through the system; however, modular system users reported pull and push workflow almost equally. This finding could be attributed partly to the inconsistency in terminology used in the industry. Also a better representation of modular system users may have revealed more obvious differences in the type of workflow for modular system. Of the very few manufacturers who adopted the pull workflow, most of them were modular system users (50%). This finding is consistent with the findings of Carrere and Little (1989). In a pull workflow, a need to increase the production helps pull the work through the system.

Mode of transportation of workunits. The type of product flow is dictated by the method of retrieval or mode of transportation of workunits between workstations (Solinger, 1988). The mode of transportation between workstations is one the more important attributes that characterize apparel production systems. Significant association was noticed between the determined production systems and the mode of transportation of workunits between workstations but not for the selected production system (determined production system χ^2 [df=4] =28.756, p=0.000; selected production system χ^2 [df=4] =3.848, p=.427). The chi square test was not considered valid due to under representation of modular system users. To improve the validity of the test, bundle system and PBS only were tested for the relation. Significant relation was found between the determined systems and the mode of transportation of workunits between workstations (χ^2 [df=2] =20.019, p=0.000).

Table 4 indicates the frequency and percentage of the various means of transportation of workunits found in the determined production systems. Most of the manufacturers using bundle system indicated that the operator himself carries

Table 4
Mode of Transfer of Workunits
in the three Determined Production Systems.

Mode of Transfer of Workunits		Determined Production System: PBS	Bundle	Modular	Total
Self-Help Operator	n	7	2	2	13
	%	14.29	4.08	8.16	26.53
	Row %	53.85	15.38	30.77	
	Col %	77.78	6.67	40.00	
Transport by other means		2	27	3	32
		4.08	55.10	6.12	65.31
		6.25	84.38	9.38	
		22.22	90.00	30.00	
Handed off		0	1	3	4
		0.00	2.04	6.12	8.16
		0.00	25.00	75.00	
		0.00	3.33	30.00	
Total	n	9	30	10	49
	%	18.37	61.22	20.41	100.00

the workunits to the workstation (77.78%). This finding is consistent with the theoretical definitions put forward by Hannan (1963). Most of the PB system users indicated transportation of workunits by other means of transportation (e.g., conveyors or material handlers). This finding confirms the theoretical definitions of PBS in literature (Ross, 1991; Chase & Aquilano, 1992). Transportation by other means increases the time spent on actual sewing operation and helps improve productivity (Hodge & Canada, 1989).

Within in modular system, the three modes of transportation of workunits were noticed almost equally. Across the systems, handoff approach for retrieval of workunits was most commonly found in modular system (75%). This finding indicates that this mode of transportation is a characteristic feature of modular systems and not bundle or PB systems. In the modular system, the workflow is continuous and the workunits do not remain stationary at any moment during processing (Solinger, 1988). The workunits are handed off to the next operator when the operator is ready to work on the oncoming workunit. Transportation by other methods such as conveyors was noticed most in PBS (84.38%). This finding is consistent with the definition of the PBS in the literature (Sisselman, 1990).

Lack of significant association between the selected production system and the mode of transportation between workunits may be attributed to the finding that most of the selected bundle system users (71.43%) reported transportation of workunits by other than manual means. This finding is contrary to the findings of the mode of transportation for determined production systems This finding could be attributed to the increased awareness among apparel manufacturers about the unproductivity of the time spent on non-value added repetitive tasks. Manual transportation is probably being replaced by automated devices to overcome this problem (Hodge & Canada, 1989; JSN International, 1989; Cole, 1987).

The number of tasks per operator. The number of tasks assigned to each operator have been identified as being different in each of the three production systems. Significant association was found between apparel production systems and the number of tasks assigned to each operator (determined production system, χ^2 [df=4] =47.928, p=.000; selected production system, χ^2 [df=4] =23.508, p=.000). Majority of the manufacturers (78%) reported assigning single tasks to an individual operator, and the operator does not make the entire garment. This finding is consistent with the classification of PBS as a section production system rather than a whole garment production system by Solinger (1988). This finding could be attributed to the over representation of PBS in which operators work on single tasks and do not make the entire garment.

Table 5 indicates the frequency and percentage of the production systems with the associated number of tasks per operator. Most of the bundle system users (77.78%) reported assigning single tasks to operators, and the operator does not make the entire garment unlike the definition of bs by Hannan (1963). In a traditional bundle system operators perform multiple tasks and sometimes may make the entire garment. All the PBS users (100%) reported assigning single tasks, and the operator does not make the entire garment. This finding suggests that manufacturers are increasingly adopting the latter approach to overcome the problem of locating multiskilled operators. Assigning single tasks to individual operators reduces the need for multi-skilled operators (Maziotti, 1993)). This finding is consistent with the theoretical definition of PBS (Solinger, 1988; Sisselman, 1990). The operations are laid out in a sequence and work flows from one operator to the next in a progression.

Table 5
Number of Tasks per Operator in the three Determined Production Systems.

Tasks		Determined Production System			Total
		PBS	Bundle	Modular	
Multiple	n % Row % Col %	2 4.00 100.00 22.22	0 0.00 0.00 0.00	0 0.00 0.00 0.00	2 4.00
Single		7 14.00 17.95 77.78	30 60.00 76.92 100.00	2 4.00 5.13 18.18	39 78.00
Single or Multiple		0 0.00 0.00 0.00	0 0.00 0.00 0.00	9 18.00 100.00 81.82	9 18.00
Total	n %	9 18	30 60.00	11 22.00	50 100.00

In a modular system most of the manufacturers (81.82%) reported assigning single or multiple tasks depending on the work demanded by the next operator. This finding is a direct consequence of the handoff approach as reported earlier. The results are consistent with the theoretical concept of handoff approach in modular manufacturing (Ross, 1991).

Interaction between operators. One of the characteristic features of modular system is the team approach to manufacturing (Carrere & Little, 1989; Cole, 1992). A great degree of interaction exists between operators in a modular system. Simple chi square tests were performed to determine the relationship between production system and interaction between operators in the sample. Significant association was found between production system and interaction between workers (determined production system, χ^2 [df=4] =13.992, p=.007; selected production system, χ^2 [df=4] =12.731, p=.013). The chi square tests were not considered valid due to under representation of modular systems, but the frequencies and percentages in Table 6 indicate that for determined production systems, most of the modular system users (81.82%) reported interaction among operators. Correspondingly most of the bundle system (55.56%) and PBS users (70%) indicated no interaction among the operators. An interesting finding was the relatively high degree of interaction among operators in a PBS. This finding is not consistent with the theoretical definition of PBS. This finding suggests that manufacturers are incorporating team work in PBS.

The chi square test was repeated for determined bundle system and PBS to determine the relation between traditional systems and interaction among workers. Fisher's exact test indicated no significant relation between the production system and interaction between workers χ^2 [df=1] =0.512, p=0.474). These findings are consistent with the theoretical concepts of teamwork in the three systems. The high degree of significance between the production systems and the attributes indicate the reliability of the attributes in determining the system; however, attributes of one system could be incorporated into other production systems, based on the company's objectives, to improve their effectiveness. Table 7 is an overview of the significance of attributes with respect to the determined and selected production systems.

Table 6
Degree of Interaction in the Determined Production System.

Degree of Interaction		Determined Production System			Total
		PBS	Bundle	Modular	
Interaction	n % Row % Col %	4 8.00 18.18 44.44	9 18.00 40.91 30.00	9 18.00 40.91 81.82	22 44.00
No Interaction		5 10.00 18.52 55.56	21 42.00 77.78 70.00	1 2.00 3.70 9.09	27 54
Total	n %	9 18.00	30 60.00	11 22.00	50 100.00

Table 7
Relationship Between System Attributes and Production System.

Production System		System Attributes				
		WIP	Work Flow	Mode of Transfer	No. of Tasks	Team Work
Determined	χ^2	22.67	10.64	28.76	47.93	13.99
	prob.	0.00	0.01	0.00	0.00	0.01
Selected	χ^2	48.3	16.5	3.9	23.5	12.7
	prob.	0.00	0.00	0.43	0.00	0.01

Conclusions

The three production systems selected for this study were bundle system, PBS, and modular system. The production system used by a company was determined based on five attributes identified from literature (i.e., work flow, mode of transportation, WIP inventory, number of tasks, and interaction between workers).

Most of the respondents used PBS, followed by modular system, and bundle system. Significant associations were found between the production system attributes and the production system used by the company. Bundle system was found to have high levels of WIP inventory. The level of WIP inventory is directly related to the type of workflow adopted by the company. Consequently most of the bundle system users reported adopting the push workflow where piles of WIP inventory causes to push the work through the system. Most of the manufacturers reported assigning single tasks to individual operators, and the operator does not make the entire garment, although in traditional bundle system operators are sometimes assigned multiple tasks where they make the entire garment. The workunits in a bundle system were reported to be transported manually between workstations. Although some of the results indicated transportation of workunits by other means which implies that manufacturers are beginning to increase automation for more repetitive tasks like material handling. No interaction was noticed among bundle system users indicating the absence of the more recent concept of team approach to manufacturing. This confirms the classification of bundle system as a traditional manufacturing system by Knapton (1990).

Most of the PBS users reported moderate WIP inventory levels that was just enough to balance the lines. Consequently push workflow was most reported by PBS users. Most of the PBS users reported assigning single tasks to an individual operator, and the operator does not make the entire garment. The need for multi-skilled operators is, therefore, minimized. The workunits in PBS were found to be transported more by automatic transfer devices rather than manually. As reported earlier, this mode of transportation helps improve productivity. PBS users also reported no interaction among operators, which confirms the classification of PBS as a traditional system along side bundle system (Knapton, 1990).

Modular system constituted system attributes that more unique in nature compared to the bundle system and PBS. Modular system users were found to have zero WIP inventory. Consequently, pull type of workflow was most reported by the manufacturers. In a pull workflow the need to increase production helps pull the work through the system rather than high levels of WIP inventory that helps push the work through the system. Individual operators in a modular system are assigned multiple tasks depending on the demand for work by the next operator. This feature of modular system confirms the system's classification as a continuous rather than an intermittent system where the workunits rest between successive workstations before being worked upon. The modern team approach to manufacturing was noticed only among modular system users. This confirms Knapton's (1990) classification of modular system as being different from the more traditional bundle and PB systems.

Implications

The results of this study could be used for subsequent research on flexibility of apparel manufacturing systems. The five system attributes that were identified may be used reliably for determining the production systems used by a company. This procedure would help evaluate systems for subsequent research related to production systems. Quantifying this variable will help perform more valid statistics in research related to production systems.

Suggestions

The suggestions for this research include:

1. This research can be repeated with a larger sample and more modular systems users to confirm some the hypotheses that could not be confirmed in this study.

2. A similar study could be carried using computer simulation where the flexibility of production systems could be determined along with the factors that influence or affect the system performance.

3. The results of this study could be used to determine the flexibility of apparel manufacturing systems. Similarly other types of flexibility could also be determined by their underlying parameters and the aggregate flexibility of an apparel manufacturing system calculated.

5. The flexibilities of different manufacturing systems can be determined and compared to identify the most flexible manufacturing system. The measures of flexibility can be used by decision makers in support of choosing a manufacturing system, and products to produce.

8. The measures of flexibility can be used by decision makers in support of choosing a manufacturing system, and products to produce.

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