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An Empirical Investigation of Apparel Production Systems and Product Line Groups through the Use of Collar Designs

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ABSTRACT

To evaluate the right choice in production systems, apparel manufacturers, and other companies seeking production of apparel products, need input on the potential for which system can deliver the right product line to meet customer demands. This research investigates three apparel production systems (i.e., bundle, progressive bundle, modular) and five system attributes (i.e., retrieval, workflow, WPI, task per operator, interaction) within a specific product context. A questionnaire, mailed to U.S. apparel manufacturers, collected quantitative data about the three production systems, the attributes and the products manufactured on the systems. The three production systems identified in the study were effectively operationalized in the data by the five attributes. Collar designs were successfully used to represent product line groups ranging from staple to high fashion. The comparison of production systems to a specific product line group resulted in mixed findings, some in contrast to traditional assumptions, indicating a need for further investigation.

Keywords: Production, manufacturing, progressive bundle, modular, product line

Introduction

Since the mid-1970s, apparel manufacturers, and other apparel companies that contract for the production of apparel, have searched for strategies suitable to capture the increasingly elusive apparel customer while searching for ways to cut costs and deliver more product variety at a faster pace (Doeringer & Crean, 2006; Moncarz, 1992; Park & Kincade, 2011). During these decades, low-cost labor from a number of global sources was a lure that drew U.S. apparel companies to use off-shore manufacturing facilities. However, the rising costs of fuel for transportation and the demand for higher wages in many countries are causing U.S. apparel companies to re-examine their current off-shore strategies (Anonymous, 2011; Friedman, 2012).

As apparel companies consider a return to domestic production, they will be making a choice in production facilities, including production systems. These companies must hire or acquire production systems that will accommodate variations in styles, frequency in style changes, shorter lead times and smaller lot sizes. In other words, companies need production systems that will provide flexibility, speed, and cost reductions. Selection of the right production system is considered critical to market success (Anonymous, 2011; Kim & Rucker, 2005; Su, Dyer, & Gargeya, 2009).

For several reasons, companies may have difficulty finding instructive production information in order to make an optimal decision. In the *Apparel Manufacturing Handbook*, Solinger (1988) noted that confusion existed within the apparel industry about specific production systems, and stated that terms were often misused or over-generalized. Production systems, more recently introduced in the apparel industry, add further complications to this lack of clarity. Information from equipment manufacturers may be more up-to-date but is not standardized across systems and can be conflicting, confusing or incomplete ("globalEDGE[tm]," 2011; Ramanasesh & Jaikumar, 1991).

Empirical findings from academic research are also limited, and terminology about apparel manufacturing is at times confusing (Ha-Brookshire & Lu, 2010). Some production research has investigated specific systems with simulations and algorithms using mathematical data, small case studies or limited practical data (e.g., Castro, Castro, Mirón, & Martínez, 2004; Kordoghli, Saadallah, Jmali, & Liouene, 2010). Other production research has focused on broader issues of strategies (e.g., Dillard, 2000; Ko, 2001; Mackelprang & Nair, 2010), or on ways to incorporate technology into the production process (e.g., Inui, Yamada, Horiba, & Hashimoto, 2012; Kim, 2012), instead of specifics about production system structure. Although numerous apparel manufacturing studies (e.g., Lee, Kunz, Fiore, & Campbell, 2002; Lin, Kincade, & Warfield, 1994) make assumptions about production systems, few have sought to examine attributes and capabilities of various systems using industry-based data, and even fewer studies were conducted within the context of specific products.

The purpose of this study, therefore, was to provide empirical evidence for the operational definitions of production systems, within a product-specific context. The objectives of this quantitative research using U.S. manufacturing companies were: (a) to operationalize the definitions of the three apparel production systems, (b) to verify the industrial-based descriptions and examples of four product line groups, and (c) to evaluate the relationships between the apparel production systems and the product line groups. The following three research questions were proposed to meet the present study's objectives:

- Research Question 1: How do the three commonly adopted apparel production systems (i.e., bundle, progressive bundle, modular) vary according to the five attributes of (a) product or workflow, (b) method of retrieval to workstations, (c) work-in-progress (WIP) inventory, (d) number of tasks per operator, and (e) interaction between operators?
- Research Question 2: What specific apparel product examples can be used to identify the four product line groups (i.e., staple, semi-staple, fashion, high-fashion)?
- Research Question 3: What is the relationship between the three commonly adopted production systems and the four types of product line groups that are produced on each of them?

Review of Literature

Although the apparel industry may focus on the consumer-centered product development process and retail strategies to meet consumer demand, the apparel production system is at the heart of any cut-and-sew operation. The production system, as the core of a manufacturing enterprise, forms a significant capital investment for any company (Heim & Compton, 1992; Jacobs, Chase, & Aquilano, 2008). As apparel companies face the demands of the future, capital investments becomes a serious financial issue (Cooper, 2010).

Types of Apparel Production Systems

A production system is comprised of attributes with the function to transform inputs into desired and predicted outputs (Jacobs et al., 2008). The attributes can be human labor, machines or tools. For the apparel industry, the production system is defined as "an integration of material handling, production processes, personnel, and equipment" (Vijayalakshmi, 2009, para. 9). Solinger (1988) proposes that these attributes or dimensions be used in defining a production system. He proposed three attributes: the continuity of work flow, the range of workers' duties or tasks, and the amount of work moved from each station. Lin , Kincade, and Warfield (1995) described production attributes as layout of equipment, requirement of operators, and method of fabric movement. With the increased emphasis on team work, interaction of operators is important (Mazziotti, 1995; Oliver, Kincade, & Albrecht, 1994). In synthesis of the literature, five attributes were noted in common: work flow, method of retrieval, work-in-process (WIP), number of tasks per operator, and interaction between operators. In combination of attributes, an adequate production system should manufacture goods efficiently and effectively with outputs of the production system that satisfy the target customer.

In the apparel industry, the most basic apparel production system is the whole garment system. This system involves one operator who sews all cut pieces into the final apparel product (Babu, 2006; Solinger, 1988). Although commonly used by traditional tailors and haute couture seamstresses, this system is labor intensive, low in productivity and rarely seen in modern mass production facilities. In contrast, most companies use one or more variations of the section or subassembly system, similar to assembly line production in other manufacturing industries. The product is manufactured section by section with the component units sewn together at the end of the manufacturing process. The most commonly identified section systems are categorized into the following systems: bundle, progressive bundle, and modular (Lin et al., 1995; Lin, Moore, Kincade, & Avery, 2002; Oliver et al., 1994; Solinger, 1988).

The bundle system is a dedicated system comprised cut parts, tied into bundles, to complete one or more sections of an apparel product (Oliver et al., 1994; Vijayalakshmi, 2009). Because of equipment restrictions and operator training, many production facilities using the bundle system make only one category of apparel (e.g., jackets, bathing suits, shirts). In denoting the attributes of the system, an individual operator performs some or all of the operations on the bundles of cut parts, which are retrieved and transported manually by a runner (see Table 1). A stack of bundles is positioned at each machine, and work flows intermittently from the storage to the operator and back to the storage (Lin et al., 1995). The bundle system is sometimes denoted as the conventional bundle system to differentiate it from other section systems, such as the progressive bundle system. Because of the layout and method of retrieval, work-in-progress (WIP) is anticipated to be at high levels and interaction between operators is very low.

Table 1. Predicted Attributes of the Three Commonly Adopted Production Systems

System Attributes	Production Systems		
	Bundle	Progressive Bundle	Modular
Workflow	Push	Push	Pull
Method of retrieval to workstations	Brought to operator or self-retrieved from general storage	Brought to operator from operator by cart or conveyor	Hand off
Work-in-process (WPI) inventory	High levels (racks or carts of bundles)	Moderate levels (enough to balance the lines)	Zero to minimal
Number of tasks per operator	Single task or whole garment	Single task	Single to multiple tasks
Interaction between operators	No teamwork	No teamwork	Teamwork

In the apparel industry, the progressive bundle system is sometimes abbreviated as PBS. It is also called a push system because bundles are pushed between each operator's station and down the production line (Oliver et al., 1994). The progressive bundle system is more sequential in layout of production steps than the conventional bundle system, and bundles are retrieved from one operator to the next by carts or conveyor, instead of an intermittent return trip to storage (see Table 1). Individual operators perform only one or a few operations on each cut piece within the bundle before the bundle progresses (Glock & Kunz, 2005; Solinger, 1988). WIP is anticipated to be at high levels and interaction between operators is usually low.

The modular system, although dating from the 1980s, is one of the newest production systems in the apparel industry. This system is also called a team or cellular system. The system consists of teams of operators functioning as a single unit, assembling a whole apparel product (see Table 1). The operators rotate across several machines as they assemble or sew the cut pieces into an apparel product (Dillard, 2000; Lin et al., 2002). The team makes the entire product, one apparel item at a time, rather than moving large bundles of cut parts through the system (Abend, 1999; Mazziotti, 1995). Thus, this system should have low levels of WIP and high level of interaction between operators. Since the inception of the system, many variations of the modular system are promoted or have been marketed by various sewing machine manufacturers (e.g., Juki, Toyota).

Although definitions for the three most common production systems are often similar in the literature, these definitions tend to be generalized in content resulting in continued confusion with terminology. Solinger (1998) noted that the progressive bundle system is one of the most commonly misused terms in the study of apparel production systems. For example, the progressive bundle system is characterized as synchronistic (Babu, 2006), in-line (Castro, Castro, Mirón, & Martínez, 2004), or batch organized (Lin et al., 1994), with each term giving subtly variance to the system's attributes. Adding further confusion is the kanban technique that is considered either an attribute of the progressive bundle system or a separate system (Oliver et al., 1994).

Further confusion exists over the use of the term, unit production system or UPS. Some authors discuss this as a mechanical system or a method of work retrieval (Babu, 2006; Kincade & Gibson, 2010), while other sources propose this system as a fourth production system (Textile/Clothing Technology Corp ([TC]^2), 2005; Vijayalakshmi, 2009). UPS can be known by the brand name of Eton, the company that developed the overhead conveyor for moving fabric from one operator's station to the next station. Brand names of modular systems can also be confusing to researchers. For example, the Just-in-Time systems, the Toyota Sewing System, and Quick Response System by Juki are company specific production systems exhibiting aspects of the modular system (Lin et al., 1994).

Although researchers (e.g., Dillard, 2000; Lin et al., 2002) and industry specialists (e.g., Babu, 2005; [TC]^2, 2005) have named specific apparel manufacturing systems, no empirical research was found that examined the terms with current practices performed in the industry. As various companies market their brand-specific production systems, confusion will continue to compound regarding the terms for the production systems.

Product Line Groups

Product line groups have their origins in product classification practices. Traditionally, manufacturers and their products were classified by the Standard Industrial Code (SIC) for U.S. government purposes and measures of economic growth (e.g., contributions to taxes, numbers for employment). This code, in existence since the 1930s, was replaced in 1997 by the North American Industry Classification System (NAICS; U.S. Census Bureau, 2001). Apparel manufacturing is listed primarily under NAICS 31. Although enumerated to several digits, the NAICS codes provide only broad categories of apparel products such as dresses, shirts, and trousers yet do not provide information about style or other characteristics of apparel products.

In contrast to federal and industrial codes, product or merchandise classifications can provide more detailed characteristics of the apparel product. The American Apparel Manufacturers Association (AAMA) created a classification that introduced the idea of style change as a variable (AAMA Technical Advisory Committee, 1965). This system was refined by Johnson-Hill (1978), Glock and Kunz (2005), and Kincade and Gibson (2010). This revised product line classification organizes apparel products according to the following three attributes: degree of style change, frequency of style change, and volume of production.

Based on the degree of style changes from season to season, products can be described as being basic, semi-basic, various styles or highly varied style. Product lines carrying basic products change little in style (e.g., classic styles) while product lines carrying products with great style variety (e.g., fashion forward) have extensive style variation. When considering frequency of style change, product lines can be categorized into staple, semi-staple, fashion or high-fashion, based on the degree of variation among them (Johnson-Hill, 1978). The frequency of style change can range from zero or one change per season to more than six changes per season. Volume of production per style per season can range from mass production or high volume per style to very low volume per style (Lin et al., 1994). The two product line characteristics of style change, frequency, generally coincide with each other and with the volume of production. The result of these intersections is the following four product line groups: staple, basic and high volume; semi-staple, semi-basic and moderate volume; fashion, various styles and moderate volume; and high-fashion, highly varied styles and small volume. With the assumed coordination among product line attributes, these four product line groups are labeled as staple, semi-staple, fashion, and high-fashion (see Table 2).

According to Johnson-Hill (1978), these four product line groups can be applied to a specific product and allow for changes in style and complexity of the product as an indication of the degree of flexibility needed for the production run. Although Lin et al. (1994), Johnson-Hill (1978), and AAMA (1965) provide some examples of product style variations, the product line groups are not operationalized for specific products.

Table 2. Product Line Groups with Attribute Descriptions

Product Line Groups	Product Line Group Descriptors		
	Degree of Style Change	Frequency of Style Change	Volume of Production
Staple	Basic	Staple (0-1 change/season)	High volume (mass production)
Semi-Staple	Semi-basic	Semi-staple (2-3 changes/season)	Moderate volume
Fashion	Various styles	Fashion (4-5 changes/season)	Moderately low volume
High Fashion	Highly varied styles	High fashion (> 6 changes/season)	Very low volume per style

Apparel Production Systems in Relationship to Product Line Groups

The context for apparel production system selection would be the product line group because most manufacturers specialize in the cut-and-sew of specific products (e.g., jeans, tailored jackets, shirts and blouses, sweat shirts). This product specific situation is evident in any Google search for apparel manufacturers. For example, websites, such as the *Apparel Manufacturer Search Engine* at http://www.apparelmanufacturer.com/, reveal a list of products that are the first sort of any apparel manufacturer search.

A generally held assumption in trade literature, and in some academic literature, is that apparel production systems vary in flexibility for product line variance and are appropriate for certain product line groups. The conjecture is that systems, such as bundle and progressive bundle, are more static and appropriate for basic or staple lines and that fashion or high-fashion lines are best handled with a modular system (e.g., Babu, 2006; King, Hodgson, Little, Carrere, & Benjamin, 2001; Solinger, 1988). This assumption is similar to hypotheses proposed by Kim and Rucker (2005) and by Lin, et al. (1995), but was not supported by their research on outsourcing or productivity, respectively. Other sources (e.g., Oliver et al., 1994; Vijayalakshmi, 2009) provide apparel companies with advantages and disadvantages of these systems, but no research was found that evaluated the systems within the context of specific products.

Method

To meet the objectives of the study, the researchers utilized a quantitative research approach and surveyed U.S. apparel manufacturers about their production systems and the product lines that they produce. A paper-and-pencil questionnaire was developed from previous research instruments and refined through a pilot study.

Sample – Product Category and Manufacturing Companies

The product chosen for the study was the collar design of shirts and blouses. The collar area is an important feature of a shirt or blouse because it attracts the first attention in an apparel item when worn (Coffin, 1998). The U.S. government categorizes the manufacturers of these two products separately although the average consumer may not differentiate between shirts and blouses. Because of the similarities in construction, the two products were considered as one product line, and responses from manufacturers of either product were put into the single database.

Shirts and blouses were chosen after extensive discussion with apparel production personnel. General agreement among industry personnel is that attaching a collar to a shirt or blouse is one of the most difficult operations in the assembly of an apparel product (Beazly & Bond, 2003; Coffin, 1998). This operation requires better skills and manipulation to produce a better quality product, and the collar attachment becomes a top-priority for quality inspection (Brown & Rice, 2001). In addition, collar production is one of the few operations in apparel production that is amenable to automation.

The subjects chosen for the study were U.S. apparel manufacturers with NAICS codes of 315211, 315212, 315223, and 313232 (previously SIC 2321, 2331, and 2361), which include men's and boys' shirt and women's and girls' blouse manufacturers. A stratified, proportionate, random sample of 200 manufacturers was selected from a list purchased from Dun and Bradstreet. The proportions were based on the population of the manufacturers in each category. The final sample for mailing contained 177 companies because additional investigation revealed that 23 companies were not manufacturers. This finding is consistent with the nomenclature problems noted by Ha-Brookshire and Lu (2010).

Instrument

This paper-and-pencil questionnaire contained three sections: production systems, product line groups, and company demographics. Demographic information was collected to provide a profile of the responding apparel companies. The company demographics collected information about volume of production for the company, volume of production per product line, number of employees, as well as types of products the companies manufactured. A pilot study of the questionnaire was conducted to improve validity and reliability. The participants in the pilot study were production personnel in a medium-sized manufacturer of women's wear and not part of the final sample. These personnel verified that the wording and use of terms in the questionnaire were accurate for industry use.

Apparel production systems

The section of the questionnaire for the production systems included: (a) one question asking the respondents to self-select the name of their primary production system (i.e., bundle, progressive bundle, modular) and (b) five questions to address production system attributes (e.g., WIP inventory, interaction between operators). The manager's response to the primary production system question was named the self-selected system. The three systems offered in the self-selection question were chosen as the most frequently used in the literature.

The five production system attributes were: (a) product or workflow, (b) method of retrieval to workstations, (c) amount of work-in-process (WIP) inventory, (d) number of tasks per operator or scope of workers' duties, and (e) interaction between operators. These questions provided data for the variable called the determined production system and were used to operationalize industry-based definitions for each system. The five questions and their associated levels (see Table 1) were developed from a span of sources including Lin et al. (1995), Mazziotti (1993), Oliver et al. (1994), Solinger (1988), and Vijayalakshmi (2009), which increased content validity for the items.

Workflow was identified as the push created by WIP or the pull generated by a draw force that moved the work further into the system (Glock & Kunz, 2005; Oliver et al., 1994; Vijayalakshmi, 2009). Method of retrieval explains how the cut parts are brought to the operator. This varies from a runner retrieving parts from a central location to cut parts being delivered from operator to operator by carts or conveyors (Solinger, 1988). One of the most commonly agreed upon characteristic of the modular system is that the parts, in single, are passed to the next operator by hand (i.e., handoff; Dillard, 2000; Mazziotti, 1993; Vijayalakshmi, 2009). The WIP, number of tasks, and interaction between operators can vary from limited to extensive (Oliver et al., 1994; Vijayalakshmi, 2009).

Product line groups

For data on product line groups, the questionnaire had a single question for the manufacturers to select the primary product line that was produced by the production plant. The four product line groups were listed with a brief explanation of each line group. For example, staple was listed with the definition as follows: basic garment styles with long and continuous production runs (at most 1 style change/season; see Table 2). These descriptors were adapted from textbook descriptions and previous research (e.g., Glock & Kunz, 2005; Lin et al., 1994). Results from this question were used as the selected product line variable.

For the second measure of product line groups, the respondents to the questionnaire reviewed the 12 collar designs, representing the four product line groups, and were asked to identify designs that were most easily manufactured in their primary system in their plant. The aggregate of their responses became the variable, product line value.

To prepare initially for the questionnaire, 32 collar designs were identified based on the type of collar-neckline attachment and the shape of the outer edge of the collar. Collars in general differ in their construction method on the basis of these two characteristics (Beazly & Bond, 2003; Brown & Rice, 2001; Calasibetta, 1988; Coffin, 1998). The design styles included the simple styles of a mandarin collar and a flat, rounded-edge collar to more complex styles such as a scarf collar with overlapping tie-ends and a complex wing collar with band.

To select and classify collar designs into the four product line groups for use in the questionnaire, a two-way structured Q-sort method was employed. The Q-sort method can be used to determine what is common within groups and different between groups, based on one or more variable criteria (Malhotra, 2010). Line drawings of the 32 collar designs were made on separate cards. An instruction sheet with definitions of collar designs and the four product line groups was also provided to the Q-sort participants. Inclusions of definitions and construction details avoided misinterpretation of the collar designs and improved reliability of the outcome. All collar designs were assigned numbers in a random order to avoid bias in selection. Six subjects with extensive sewing or apparel production experience were selected to participate and sort the collar designs into the four product line groups.

Based on the Q-sort, the frequency distribution of the 32 collar designs was used to determine the designs selected to represent each of the four product line groups. Three conditions were used to determine the designs chosen. First, the collar designs that were most frequently selected to represent the product line group were picked. Second, if more than three designs were identified for one group, the collar designs were selected in the order of their assigned numbers. With this selection step, random assignment selection bias was reduced. If less than three designs were selected most frequently, the next most frequently occurring design was picked.

From these frequencies, the final 12 collar designs were identified for use in the questionnaire, with each product line group containing three designs. The collar designs classified as staple (e.g., mandarin collar) and semi-staple (e.g., convertible collar) were visually simple in structure and construction. The designs classified, as fashion (e.g., sailor collar) or high-fashion (e.g., scarf collar), were visually complex in construction. In the questionnaire, the collar designs were randomly arranged to avoid bias in selection of the collars.

Data Collection Procedure

Following Dillman's (2000) Total Design Method, questionnaires were mailed to the owners or top management personnel of the apparel manufacturing companies selected for this study. After four weeks of data collection and a fifth week of follow-up phone calls, a total of 40 companies were eliminated from the sample because they had gone out of business, had disconnected numbers, or did not fall under the criteria of manufacturing shirts and blouses. Fifty-three usable questionnaires from the eligible apparel manufacturers resulted in a response rate of 30%. Non-respondents were telephoned, and demographics of their companies (e.g., plant size, products produced) were verified. Demographics for the non-respondents' companies were similar to the company demographics for respondents. This similarity was important because company demographics are often related to operational differences (Kincade, 1995; Ko, 2001), and the finding lends support to the idea that limited bias was introduced through non-response.

Data Analysis

Production systems

Operationalization of the production system by its attributes (RQ1) was evaluated by comparing the two measures of the production system variable (i.e., self-selected and determined) with each attribute. The self-selected system was a single question. The determined production system variable was formed by aggregating the weights assigned to each of the attributes. Pearson's *chi*-square tests were used to compare the self-selected system to the determined system, and to compare the two system variables to the attributes.

Product line groups

Identification of the product line groups (RQ2) for shirts and blouses was evaluated by comparing two measures of product line groups (i.e., selected product line, product line value). The measures were as follows: (a) a direct question asking for a selection of the company's primary product line (i.e., selected product line) and (b) a question asking for the selection of all collar styles most likely produced at that company (i.e., product line value). A respondent could select from one or more of the 12 collar designs. To form the product line value, the collar designs, representing the product line groups, were assigned numbers (i.e., staple [1] to high-fashion [4]) based on the decisions from the Q-sort. The values for the collar designs, chosen by the respondents, were summed for each manufacturer and were used as the product line value for that respondent. Using the ratings for the designs, the product line value for each respondent had a potential ranking of 1 to 48. The resulting variable represented the position of the company on the product line continuum ranging from staple to high-fashion. This technique mirrored the classification structure for products recommended by Lin et al. (1994). Comparison of the selected product line variable to the product line value variable was evaluated with Student-Newman-Keuls analysis of variance test.

Production systems in relationship to product line groups

The comparison of the production system to the product line group (RQ3) was conducted using the comparisons between the determined production system and the selected product line and the determined production system and the product line value. The Student-Newman-Keuls test and the *chi*-square test were used for this examination.

Findings and Discussion

Of the 53 usable responses, most companies were categorized as small apparel manufacturers based on the number of employees and were rated very small to medium based on volume of production. The primary product for manufacture was noted as blouses (women's wear companies), shirts (men's wear companies) and blouses or dresses (children's wear companies), which confirmed the accuracy of the database. As an additional profile of the database, the respondents consisted of 79.2% women's wear manufacturers, 47.2%

men's wear manufacturers and 35.8% children's wear manufacturers. Children's wear included products for girls and boys as well as children's wear not specified by gender. The numbers do not add to 100 percent because the question allowed manufacturers to select more than one response.

Production Systems

The first research question was set to clarify and operationalize the terms used to identify and describe apparel production systems. The analysis examined the relationship between the three most commonly used apparel production systems and the attributes frequently associated with these systems. This analysis is based on the assumption that apparel production systems vary according to the attributes of (a) product or workflow, (b) method of retrieval to workstations, (c) WIP inventory, (d) number of tasks per operator, and (e) interaction between operators.

Two variables were used to represent the production systems. The self-selected system was chosen by the manufacturers in self-identification, and the determined system was calculated by aggregating the weights assigned to each of the attributes. When asked to self-select their primary production system, the respondents selected the systems as follows: bundle (53.8%), progressive bundle (34.6%), and modular (11.5%). In comparison for the determined system, the progressive bundle system was used by 60% of the respondents, while bundle and modular systems were 18% and 22%, respectively. A *chi*-square test indicated a statistically significant relationship between the self-selected production system and the determined production system ($\chi^2[4, N = 5] = 19.54$, $p = .001$). Although some differences did occur between the self-selected system and the determined system in raw percentages of use, the statistical finding does confirm the reliability of the aggregated attribute method used to define or describe each of the three production systems. The findings are similar to systems usage as noted by Lin et al. (1994).

To further examine the accuracy of the attributes used as operational definitions for the three production systems, comparisons were made between the self-selected system and determined system and each attribute. A statistically significant relationship was found between the self-selected system and four of the five attributes (workflow, $\chi^2(2, N = 48) = 16.54$, $p < .001$; WPI, $\chi^2(4, N = 49) = 48.33$, $p < .001$; task per operator, $\chi^2(4, N = 50) = 23.51$, $p < .001$; interaction $\chi^2(4, N = 50) = 12.73$, $p = .013$). The only nonsignificant relationship was between the self-selected system and the method of retrieval (method of retrieval, $\chi^2(4, N = 49) = 3.85$, $p = .427$). When the modular system was removed the bundle and progressive bundle systems were significantly related ($\chi^2[2, N = 45] = 20.02$, $p < .001$). For the determined system, all five attributes were significantly related to the system variable (workflow, $\chi^2(2, N = 48) =10.64$, $p = .005$; method of retrieval, $\chi^2(4, N = 49) = 28.76$, $p < .001$; WPI, $\chi^2(4, N = 49) = 22.67$, $p < .001$; task per operator, $\chi^2(4, N = 50) = 47.93$, $p < .001$; interaction, $\chi^2(4, N = 50) = 13.99$, $p = .007$). The findings provided support for RQ1. The three systems identified in the study could be accurately operationalized by the attributes.

With exception of method of retrieval for the modular system, the relationships for each attribute level and the system were as predicted in Table 1. In terms of workflow, both the bundle and progressive bundle systems were related to the push flow, and modular was related to the pull flow. This supports the use of the attributes by Dillard (2000), Glock and Kunz (2005), and Lin et al. (1994). The handoff method and the low level of WIP were identified significantly with the modular production system in support of the team-based system described by Dillard (2000) and Oliver et al. (1994). Limited to no interaction was found in the bundle or progressive bundle system, as described by Sollinger (1998), whereas a higher level of interaction was associated with the modular system. Because of the significant relationships between the self-selected production system and the determined production system and the determined production system and the attributes, the determined production system measure was used in the examination of the RQ3.

Product Line Groups

The second research question probed the assumption that specific examples of apparel products could be identified for the four product line groups. The product line group selected by respondents was as follows: staple (23.1%), semi-staple (32.7%), fashion (32.7%), and high-fashion (11.5%). When the selected product line group, as identified by the direct question, was compared to the product line value, a statistically significant and positive association was found ($F[3, 48] = 3.18$, $p = .032$). The product line group that the respondents selected for their company was significantly related to the collar designs, representing the product line groups, as identified by the product line value. This finding provided support for RQ2. Because of the exploratory nature of this finding, both variables, the selected product line and the product line value, were used as proxies for the product line group in investigating RQ3.

Production Systems in Relationship to Product Line Groups

The third research question queried if the three commonly adopted production systems (i.e., bundle, progressive bundle, modular) would vary with the type of product line that is produced on each of the production systems. The determined production system and the selected product line were found to be significantly related ($X^2[5, N = 56] = 14.82$, $p = .022$). However, the relationship between the determined production systems and the product line value was not statistically significant ($F[2, 47] = 0.27$, $p = .764$). In other words, the findings are split for the response to RQ3 and provide only partial support for the assertion that production systems are closely related to product lines.

In a qualitative examination of the data, the modular production system was used by a number of manufacturers who selected the staple product line as their primary product line, and the modular system was not used by any of the manufacturers who selected the fashion product line. This finding is in contrast to the general trade and academic recommendations that modular production lines are best used for fashion or high-fashion products because of the flexibility inherent in the cross-training of employees in a modular production system (Castro, Castro, Mirón, & Martínez, 2004; King et al., 2001). One possible interpretation of this conflicting finding is that the benefits of the modular production system (e.g., low levels of inventory, higher attention to quality) can be desirable for any product line and not just with fashion goods. This idea extends the findings of Lin et al. (1995) that both staple and high fashion goods are produced on modular systems because the current study was product specific with a range of fashion levels within the product line groups.

Conclusions and Implications

Industry specialists and researchers have indicated that confusion exists with the terminology regarding apparel production systems, and current apparel literature does not provide industry-based and empirically examined definitions for the three most common production systems (i.e., bundle, progressive bundle, modular). This study, therefore, aimed to fill this void in the apparel literature by investigating attributes for these three production systems. Using data collected from U.S. apparel manufacturers, industry-utilized attributes for all three systems were operationalized and confirmed in this study. As anticipated from the review of literature, the bundle and progressive bundle systems were affirmed to have high levels of WIP and limited interaction between operators, whereas modular systems were identified as having a high level of operator interaction and a low level of WIP. The modular system was confirmed as having a pull workflow in contrast to the push workflow of the bundle and progressive bundle systems. In future research, these attributes may be used to further examine other characteristics of the three production systems and strategies related to their use.

In addition, the attributes associated with each system were examined within a specific product context, collar designs of shirts for men's and boy's wear and blouse for women's and misses' wear. The use of collar designs to designate the variance in product line differences ranging from staple to high-fashion was supported through the Q-sort method as well as the comparison of the responses for the selected product line and the product line value. This data collection method and the finding can be useful to academic researchers who want to examine production operations within a specific product context. Product sketches can be used as proxies for actual products when conducting apparel manufacturing research. Additional product categories could be tested through these methods to provide further nomenclature and research tools for academia.

The comparison of the production systems to the product line groups resulted in mixed findings. One reason for these mixed results may be attributed to the common assumption that each production system has an appropriate product line. Both trade (e.g., Vijayalakshmi, 2009) and academic literature (e.g., Lin et al., 1994) have reported that the modular system is most suitable for high-fashion product lines and the bundle and progressive bundle systems are for staple product lines or mass production. As the findings demonstrate, the modular system may be used for multiple types of product lines, including the basic product line group. Apparel manufacturers and other apparel companies seeking new facilities for production should examine the outcomes they wish to achieve. Selection should not be based on the assumption that a specific system is right for a specific product category (e.g., bundle system is best for staple goods), instead other variables may be more important in system selection. For example, Dillard (2000) and Castro, Castro, Mirón, and Martínez (2004) recommend examining operator skills, management styles, and available training when considering a modular or team-based system. Researchers should also not succumb to pre-existing general assumptions about systems and examine system attributes instead of system names.

Further research is needed to examine the reasons for the differences found between generally accepted positions on the best choices of apparel production systems for varied product line groups using a balanced sample with higher usage of the modular system. For example, the assumed exclusive use of a modular system for high fashion product categories can be further examined in future research studies, possibly using case studies or computer-generated analysis. Despite the researchers' efforts to use a stratified, proportionate, random sampling technique, the number of respondents using modular systems was low in this sample and could have an effect on the findings. As newer facilities are being constructed in many locations in the world, the opportunity to make industry-based comparisons between progressive bundle and modular systems may be present. In addition, the use of designs of other apparel product items could be implemented in a future research study to re-examine the idea of product line groups represented by product designs.

Additional variables of financial measures and time-to-market factors can be added to future research studies to determine their impact on selection of production systems. Costs, in measures of money, time and resources, are concerns of domestic manufacturers who must operate competitively in a global market. Measuring operations and outputs of production systems with these additional variables, both individually and in their interrelations with getting the right product to the right customer, can provide information to assist domestic manufacturers in making choices about the right production system. Domestic manufacturers have obvious cost advantages of proximity to market and possibly other intangible advantages of location. These factors could be considered in a trade-off analysis with costs of facilities, labor, and productivity. Quality, rework and product development are also concerns of developing and shipping the right product. Future research can expand the scope of the current study to investigate the pre- and post-production systems, which must integrate seamlessly with the selected production system.

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