Analysis Guidelines for Customised Orders in Apparel Chain

Ronnachai Sirovetnukul\textsuperscript{a, b*}, Parames Chutima\textsuperscript{a}, and Duangpun Kritchanchai\textsuperscript{b}

\textsuperscript{a} Department of Industrial Engineering, Chulalongkorn University, Phayathai Rd., Patumwan, Bangkok 10330, Thailand.
\textsuperscript{b} Department of Industrial Engineering, Mahidol University, Salaya, Putthamonthon, Nakornpathom 73170, Thailand.
\* Corresponding author, E-mail: egrsr@mahidol.ac.th

ABSTRACT

Over the last decade, several papers have been published the strategy of mass customisation but most of them hardly provided practical solutions. This research aims to analyse customised orders taking of parts in apparel production systems against lead-time performance. A leading-edge company of Thai apparel industry is selected to apply the underlined concept of customized producers. Attempting to develop this issue, the study first synthesizes the mass-customised apparel principle. Secondly, it examines as-is supply chain to investigate problems and the efficiency of core business processes after customers place customised orders. Thirdly, to respond product variety for competition, it proposes some apparel supply chain or apparel chain strategies under the definition of Mass Customisation (MC). Finally, this paper proposes the directions to analyse the effects of customized order in apparel production systems using simulation modelling.

Keywords: Mass Customisation, Customised orders, Supply Chain, Apparel, Simulation

1. Introduction

The textile and clothing industries have been major businesses almost in every country and have been placed as one of five fundamental industries in addition to food, automobile, information and communication technology, and tourism by Porter [1]. Especially after the free trade agreement in 2005 and Bangkok fashion, they are faced with more and more severe competition. They represent one of the largest sectors in the Thai economy in terms of Gross Domestic Product. In addition, the National Economic and Social Development Board (NESDB) of Thailand is in agreement with entering the strategy of Mass Customisation.

In this paper, the various research methodologies are classified into the qualitative approach (empirical research) and the quantitative approach to solve the problem when an apparel company wants to change the mass production policy to mass-customised order production policy producing one piece to optimal pieces an order. The study is conducted through both empirical research based on interviews with apparel companies in Thailand using Business Process Analysis in the following section of empirical findings and supply chain management and simulation modelling limited into the production process for a shirt company in Thailand next to the previous sections. Because it has a vision and a potential to become an MC producer, the reason is why that company is selected to study. Having affected by customised order, the former solves the problem of apparel chain and the latter deals with the comparative method of Mass-Produced Apparel Production Systems (MPAPS) and Mass-Customised Apparel Production Systems (MCAPS) after obvious understanding the attributes of production line types.

2. Apparel Mass Customisation

The literature survey in this research focuses on Mass Customisation. The objective of the literature survey on mass customisation is to provide a source of knowledge on the subject in which further investigation can be perfected such as Sirovetnukul et al. [2]. The literature survey investigates the current understanding of Mass Customisation across a wide range of literature from the first International Conference on Mass Customisation and Personalisation (2001). Six sets of literature have been identified, which reflect or relate to existing understanding of mass customisation: Business Strategy of Mass Customisation and Personalisation; Mass customisation and Personalisation in E-Business; Product Design for Mass Customisation; Manufacturing for Mass Customisation; Consumer Behaviour Issues; and Information Systems for Mass Customisation and Personalisation. Today enterprises need a manufacturing system that can arrange quickly to changing market conditions, provide the lowest costs, do right the first time and give customers what they want when they want it. Mass Customisation can do exactly that. Mass Customisation focuses on the entire enterprise from the order fulfillment, through flexible manufacturing, to efficient distribution systems. Some experts in MC
such as Brabazon and MacCarthy [3] advocate that MC operational strategies have not yet found abundantly and have been necessary to do research. Silveira et al. [4] merge some all MC concepts and propose eight generic levels of MC, ranging from pure customisation (individually designed products) to pure standardisation: design, fabrication, assembly, package, distribution, additional custom work, additional services, and usage. In addition, the author synthesises and expands their generic MC levels by adding the research of some papers such as Spring and Dalraymple [5] although it does not shown in this paper. In the facet of manufacturing, its progress has been divided into broad and specific aspects of mass customisation such as product design and configuration; as well as process planning and scheduling, but there are few published reports directly addressing the problem of practising mass customisation [6]. However, several companies of some industries such as Computer and Bicycle have proved that MC can be a reality, not just a pipedream. There is still much debate on how to design effective MC systems [7]. From our preliminary study, the most important reason notes why it is hard to create the generic MC model to response many industries because MC is only terminology and every solution is essential to define the obviously in-depth problem. MC is nowadays driven as a focal strategy by the NESDB of Thailand. As a result, to fulfill the prior gaps this research studies and deals with the problems of customized order in Thai apparel chain.

2.1 Apparel Customised Order

Although clothes are a basic need of the customers providing comfort and hygiene, it also depends greatly upon customers’ personalities and preferences. The general premise comes from the fact that customers expect different value from various clothes. Therefore the manufacturer has to provide the clothes with obvious attributes or features in order to respond to the customers’ value. There are many factors that a customer can choose over clothes. These features are body size (grade size or customised size); gender (ladies’ wear, men’s wear or children’s wear); age; design, style or model (formal wear, casual wear or sportswear); material; colour or pattern (monogram and logo); accessory (embroidery, printing and etc.); and finishing. Each clothing company must be aware of selecting these features as its unique characteristics. Clothes can be considered as basic products and short-live or fashion products. The basic products have distinct cycles in their selling over the years, which follow the seasonal changes. For the fashion products, the rate of change in customer needs and demands are very high in this industry. Products tend not to be repeatable and customers tend not to have repeatable demand. What is fashionable today may not stay in the market for more than 6 months. However, this research gives an interesting view on how variety under basic and fashion products has developed in the garment sector. According to a study Kurt Salmon Associates [8] conducted for [TC], a leader in research and development and education for the sewn products industry, Mass Customisation can be positioned into three categories. Each of them responds to individual customers’ desire. These three levels are:

- **Personalisation**: The customer orders mass-produced products, which are then personalised according their request. For example, a consumer can order a tennis shirt with his/her initials in a specified colour.
- **Fit**: Customer’s measurements are incorporated into the initial garment manufacturing process, and the items are manufactured individually to satisfy those specifications. The client may later come back for a fitting and more tailoring.
- **Design**: The customer participates, more conveniently with means of electronics, in the design and/or colouring of the individually manufactured garment that includes the elements of personalisation and fit.

The customised order may mean uncertainty demand reciprocally that many characteristics of products above make the uncertainty demand happen.

2.2 MC Apparel Production Process

The apparel, which is in the last downstream of textile production, is processed through several stages respectively, i.e., cutting, embroidery or printing, sewing, and finishing. There have been a lot of approaches from many authors to achieve MC. As the preceding section, three main ways are adopted in process, i.e., postponement, cut-to-fit, and design. Postponement is a powerful method that provides customisation to the customers, particularly in the level of personalisation. Two examples of companies who use postponement approach are Benetton that emphasises on colour and Kikomo that is flexible on colour and pattern. Pursuing mass customisation, the pattern is based on a standard body of the target customer. The standard size is adjusted to fit individual consumer specifications depending upon those companies that define sizes and dimensions. Therefore, standard sizes seem to be part of postponement. Design options are composed of standard and new options that
the latter is determined costly. In execution, it currently provides the consumer any flexibility to
internet with manufacturer and retailer’s designs based on standard processes and sizing, with standard
options in style, style detail, colour, and fabric. Moving at a higher level, several authors have
mentioned about the nuances of mass customisation practices through cut-to-fit customisation in the
garment industry. Co-Design may offer the same range of choices as designed options with the
addition of personal fit and support by a design manager.
MC might be an expensive proposition but to add more experience with the manufacturing
technology and to develop good management, these costs will decline. Todays in mass customisation
practices, the apparel industry as the soft goods industry limits the customised extent of the product
market to reduce costs. The custom owner prescribes a limited number of style variations and size
ranges. However, following problems need to be resolved for the full implementation of MC toward
consumers.

Under the production process there are many constraints understood and considered clearly.
For instance, the informal, casual or standard shirt requires less specialised competence and high
quality than fashion shirts. Subsequently, both basic, casual and fashion products should be filled in the
gap of what system and attributes they are produced under the mass-customised definition.

2.3 Limitations for Mass-Customised Apparel

Due to a lot of definitions of MC apparel in many ways, this research determines its obvious
boundary before developing into the next state. The mass-customised apparel order defines the
production of specified optional products and their volumes determined by a manufacturer. They
consist of additional features more than existing standard options and no repeat orders. In addition to
supporting of the goal of the MC definition, Lin et al. [9] report that almost all of the respondents or
companies tended to give high scores to all four of the dimensions or output measures (quality, cost,
time and flexibility) of manufacturing strategy that the results of means and deviations of all
dimensions are very similar. It became evident that all four dimensions are of general importance to
mass-customised apparel. To achieve them, companies need to look into the entire supply chain.
However, at the beginning stage this research only focuses on the lead time of apparel production
systems.

3. Empirical findings and Supply Chain Management

Before the research is narrowed down into one company selected, the background and
empirical findings of MC in Thai apparel industry are surveyed and concluded. Seven Thai apparel
companies surveyed are the make-to-order and make-to-forecast manufacturers. Their customers range
from a well-known company such as Nike and Tommy or even independent shops (retailers). These
garment companies produce various styles of men’s wear, ladies’ wear and children’s wear from the
basic wear to high fashion dresses with a number of accessories. About 3-6 months before starting a
new season, their customers will make an order and provide specifications in detail. Each order is
another choice from the degree of customisation. The design process is hardly conducted by these
companies even though they are a leading garment company in Thailand. Few companies in Thailand
make design clothes by themselves. Most companies lack their own brand names. After that, the
garment manufacturers start to order a lot of materials needed for the production. At present, the
forecast orders are decided by customers. The companies’ chief materials are dyed fabric, which some
orders from owned textile companies and accessories, which may be either imported or produced by
themselves. Getting more than 85 percent efficiency of fabric utilisation (with human working), those
companies spend an extra two hours of labour doing it. The production processes, which include
cutting, printing, embroidering, sewing, and finishing, depend on labour intensive. There are many
inspections in each stage of production since fabric check. Most of finished garments are shipped by
due-dated time approximately 90-120 days from picking up an order. Approximately the sixty to ninety
percent is exported to the overseas market. Communication or co-ordination between each department
is not connected. In other words, supply chain has still been imperfect, for example, long leadtime
affecting from long dyed fabric and/or transferred accessories. Long waiting periods are becoming
increasingly unacceptable and there is at least as much pressure to reduce leadtime as to reduce costs.
Most companies are also currently squeezed to be MC. However, their production needs to employ
both MTO and MTS to be survival in competition. Based on the business process analysis, the current
situations, named As-Is and the supply chain improvement, named To-Be are studied in the following
section.
3.1 As-Is
3.1.1 Apparel supply chain
Supply chain management, as a new industrial-wider management strategy, has become solution for improving competitiveness. For the overview of textile industry, the supply chain of textile consists of four business units, i.e., yarning, fabrication, dyeing and apparel. Likewise the chain of apparel is distributed to the supply network; production process (factory); and customer order/delivery process (distribution). In other words, the process of customer order and production might be named the order fulfillment process by Kritchanchai and Wasusri [10]. To understand the apparel supply chain or apparel chain, at the first stage many small, medium, and large (SML) companies faced on long leadtime and their products are identified to map business processes. Subsequently factors and supply chain strategies leading to lead-time reduction are conducted. After surveying, most apparel companies are nowadays classified as a make-to-order producer since their products such as shirts are fashion but some have still produced repeated or make-to-stock products such as T-shirts and basic uniforms.

Supply network
There are two policies in the apparel chain: Make-to-Stock (MTS) and Make-to-Order (MTO). The MTS policy is allocated for a wide range of raw materials and accessory types. On the contrary, a small variety of them employ the MTO policy. Those companies schedule by the combination of first-in-first-out and due-dated strategy to reserve the capacity of production and supplier for customers’ satisfaction. Although any customer has reserved its capacity for a time period, its capacity can be released to others unless raw materials and accessories arrive on time.

Production process
The typical production process of seven apparel companies can be divided into the stage of design, grading and marking, fabric cut, assembly (seam), and inspection packing. More detailed findings suggest that product variety most likely took place in:
- Stage 1: Design. This stage is obviously where product variety begins. Designer will prepare numerous styles of garment. Some basic styles may require less time while more complex styles may take longer.
- Stage 2: Grading and Marking. In this stage incoming materials are marked according to pattern. Product variety is due to the design, style of the apparel product and the use of different types of material, e.g. cotton jersey (for T-shirt), silk, etc. Processing times may vary depending on the style and material types such as Chess pattern.
- Stage 3: Cutting. In this stage, materials are cut into different pieces according to the mark. This is a process conducted manually. Changes from one type of product to another means that the cutting staff need to inspect the marks, get different tools. Thus, a certain period of setup activities may occur when it is different.
- Stage 4: Assembly (Sewing). Different pieces of a garment are sewn to create a finished apparel.
- Stage 5: Packaging. Different customers may require specific packaging
  Linking to the solution of customised order in depth, the production process would be in the following section in part of the simulation model.

Customer order/delivery process
The finished products will be shipped to the customer that may be a distributor and a retailer but not an end customer. Nevertheless, the term ‘customer’ getting customised order refers to the end customer, that is to say, the consumer or user of the customised apparel.

3.1.2 Analysis from observations of seven companies into MC levels
There is one reason to support selection seven Thai companies to study because they show all levels that respond levels of MC although some levels do not found in the real situation. Their customers are a well-known company and independent shops as retailers. From interviewing in companies represented Thai small, medium and large (SML) companies throughout operational systems, this industry needs workers for every process. Most SML manufacturers are often blamed as the weak link of the apparel supply chain after mapping an as-is model by tracking an order from customer order until placed order. It is found that most apparel manufacturers are not currently able to provide quick response replenishment. From surveying, all companies are almost completely an original equipment manufacturer. Few companies launch to put forward to be an original design manufacturer except for a company (named X), or even other levels of MC. All of them are part of the
internal (back end) processes, but there are no companies in this industry to launch by linking into the external (front end) MC processes or the product catalogue; design-to-order and assembly-to-order. It is interesting to study how to step towards both of them. In brief, there are three kinds of apparel industry from surveying seven Thai companies: Mass-produced products (more than 70% firms); Tailored-made products including one-piece production; and Catalogue products that it is remarkable catalogue products of shirts have not been found but an idea is only spawned.

3. To-Be

When product variety comes into the chain, those companies recognize that it is essential to find out the way to manage but no recipe make a correction until now. Nonetheless, the problem solutions of apparel chain are put forward in this section. A future system or to-be model should be proposed to eliminate long leadtime and other relevant problems such as raw material sourcing, information management, production planning and inventory control, quality, and performance measurement. Before doing mass-customised apparel, a firm needs to assess its readiness from a designed checklist by Sirovetnukul et al. [11] to reduce preliminary problems.

To achieve MC, many companies are shifting their supply chain policy from MTS to MTO when a customised order gets into supply chain. There are several popular supply chain strategies or drivers to deal with the challenge of mass-customised apparel. They are divided into customised products and processes. On the one hand, modular customization, dimensional customization and adjustment customization are drivers for customised products. Modular customization reduces the variety of components while offering a greater range of end unique products. Modular product design supports a way to provide variety and speed, thereby, enhancing the customization responsiveness. Modularity in the product design facilitates flexible manufacturing systems for low cost customization through fast set-ups. Dimensional customization refers to permanent dimensional change such as cutting-to-fit or tailoring. This way of customizing can be performed automatically by computer numerical control equipment such as single ply cutting for apparel. The machines can be controlled by programs which can be changed instantly providing a high flexibility for the manufacturing process. Automatic pattern adjustment, automatic marker making and automatic fabric cutting help dimensional customization for apparel. Adjustable Customisation provides the ability of the product to be customised by adjusting the features. Adjustments can be manual such as an adjustable cloth wriststrap set. An advantage in this customization is that it can still be mass-produced without having to forecast choices, build in many versions of variety of products. The companies have also tried to use the adjustable customization technique to customize apparel. For example, user control manual adjustment can be a waistband adjustment of a pant using the band-button attachment. On the other hand, other principles to customised processes are postponement and standardisation. Postponement consists of differentiating a product on the latest possible point at the supply network. This point is called customer order decoupling point, once it sets the point where the process is decoupled from mass production to customised production. Standardisation is a mass customisation technique that provides the product flexibility for the production system. Standardisation of parts and materials is an important prerequisite for the build-to-order and MC which will simplify product development efforts, lower costs of parts, material and overheads, simplify supply chain management, improve availability and deliveries of materials, improve serviceability, fast response, easy material management and reduce manufacturing complexity [12]. The standardisation strategy for apparel need to be addressed in a different way than other products as there is a fashion element involved in the product itself. For example, instead of allowing the customer to customise the style and placement of a monogram in unlimited ways, the manufacturer can offer few styles and places of the main style so that customised manufacturing can be simplified. Standardisation can be done in relation to sewing thread (to limit thread type for shirts with appropriate colours), fabric and colour (to limit fabric type and colour), feature types (to limit collar and cuff style options) and fit (to limit loose or fit). Ultimately, it is necessary to study these existing techniques further whether they can used and how they can be expanded further in apparel industry.

Moving from the qualitative problem to the quantitative problem, the problem solutions for customized garments on apparel production systems are illustrated in the simulation section.

4. Simulation Method

4.1 Nature of the simulation study

A simulation study may be aimed at evaluating system performance under various possible values of the relevant parameters or at obtaining the best policy to be applied in a system under the study. Based on this framework and several papers simulating in operations and practice, the
simulation model developed in this study is also be classified into dynamic, stochastic, and discrete, called Discrete Event Simulation (DES) [13]. This research selects to study and run customised demand into apparel production systems because Reiner and Trcka [14] pointed out that an analysis of a supply chain must be very specific.

4.2 Problem formulation

Findings from the empirical study involving seven apparel companies in Thailand show that in general Thai apparel companies produce in a traditional mass production systems or the progressive bundle. These findings are used to develop the MC model that in particular represents a generic MC apparel production system. This problem cuts part of the supply network and production or the order fulfillment process of Kritchanchai and Wasusri [10] to study and focus on the direction of MC. The aim of this section is to investigate all possible characteristic on the apparel production systems. So far, no company in Thailand has applied MC system that can be used as a benchmark. Therefore a model is designed to represent a plausible MC apparel system. The best method to do this is by developing a hypothetical simulation model. This is the main justification for the use of simulation model in this study. However, the MP system will be modelled, completed and compared to achieve the objective of the study on the sample shirt company. The first model represents the current apparel production system, called the base case or MPAPS model. The second model is an intriguing MC apparel production system, called the improvement or MCAPS model. Several experiments will be done to compare and move from the current mass production system to the new mass customization system. In the following section, the development of simulation model will be described.

4.3 Simulation Modelling

4.3.1 Input Parameters

In a traditional mass production system, a mass-produced apparel order is generated in certain batches, i.e., each order could have a quantity (volumes) of more than one thousand pieces per day as the planned production rate but the actual production rate is produced at the rate less than a few hundred pieces per day. In another way volumes of each customised order assumed and generated in the pattern of casual and fashion should be produced at the rate less than three hundred pieces and twenty pieces respectively from interviewing although each order should be unique for the ideal MC concept [12]. A mass-customised apparel order, related to the allocation of raw materials and component parts, is the combination of mass-produced styles and customised features at the assembly point, i.e., Construction; Emblems, Logos, Prints and Photos; Monograms; and Decorated Stitching. Its characteristics shown in Table 1 are composed of style types, frequency of style change, and volumes of an order.

### Table 1. Characteristics of a mass-customised apparel order

<table>
<thead>
<tr>
<th>Style Variations</th>
<th>Style change</th>
<th>Volumes / an order (varied sizes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. New</td>
<td>1 - 2 weeks</td>
<td>Minimum 1 piece</td>
</tr>
<tr>
<td>2. Standardised</td>
<td>1 - 6 months</td>
<td>30 pieces (less than 30 plus a surcharge)</td>
</tr>
<tr>
<td>(e.g. construction)</td>
<td>&gt; 6 months</td>
<td>Maximum 4,000 pieces</td>
</tr>
</tbody>
</table>

Furthermore, the processing time is a variable depending on the complexity of the product. To reflect this, it is possible that processing time for each order in each stage of production vary according to a certain distribution or is assumed to be a constant. MCAPS is developed to represent a generic apparel production system in case of MC; consequently, some quantitative real data cannot be used in the simulation. A reference set of input data is normally established to develop a reference state against which the results of the experiments can be benchmarked [15].

4.3.2 Decision parameters (Simulation Environment)

The Make-Through system (or craft manufacturing) in which a highly skilled operator makes one garment for entire processes at a time. This system is required in custom clothing that is lower productivity and higher costs than mass-produced production. That illustration is a reason why other characteristics of different apparel production systems, named sewing systems are described and compared. From surveying the apparel industry spread over the entire U.S. [9], many variations of old and new systems have been defined and named with an array of terms, i.e., Straight Line (SL), Bundle System (BS), Progressive Bundle System (PBS), Transporter System (TS), Unit Production System (UPS), and Modular Production System (MPS). Various classifications of sewing systems have been designed to meet the variety of production needs for last decade. There are a few papers comparing some attributes with a pair or a couple of sewing systems. To succeed the target of extending MPAPS
and flexible specialization apparel production system in approach to MCAPS, the attributes which are significant for the classification of the entire apparel production systems need to be studied and identified. Those parameters must be decision variables that a company can manipulate. The relationship between some attributes and all sewing systems is exemplified in Table 2. Those factors have an influence to decision parameters in simulation. However, there is a paper [9] helping us cut off some systems. Introduction of new styles into the production environment is noted that producers have at least three choices of sewing systems (BS, PBS, MPS, and other sewing systems), available to produce garments. The gap of that paper does not refer which the sewing system is the best due to lack of the relationships among style types, sewing systems and dimensions of strategy at the same time but compared with an individual couple. It is not reasonable to conclude that PBS and MPS is representative for MP and MC respectively, but MPAPS and MCAPS should be refined from discovering all previous attributes. Finally, it is not easy to build both of them because there are differences of apparel production system definitions that have not been clearly specified in the same direction, but their results is likely to illustrate what happen if customised orders run into these systems.

Table 2. Comparisons of attributes of apparel production systems

<table>
<thead>
<tr>
<th>Attributes</th>
<th>SL</th>
<th>BS</th>
<th>PBS</th>
<th>PBC</th>
<th>TS</th>
<th>UPS</th>
<th>MPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Style type</td>
<td>One style</td>
<td>-</td>
<td>-</td>
<td>Various styles</td>
<td>Small size products</td>
<td>One style</td>
<td>Various styles</td>
</tr>
<tr>
<td>Volume</td>
<td>Low (Craft)</td>
<td>Large (MP)</td>
<td>Large (MP)</td>
<td>-</td>
<td>-</td>
<td>Large (MP)</td>
<td>Low and Medium</td>
</tr>
<tr>
<td>Team/Number of Operators</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20-40 without team 15-20 with team</td>
<td>7-15</td>
<td></td>
</tr>
<tr>
<td>Batch size (Product unit)</td>
<td>Single 1</td>
<td>Large (L)</td>
<td>L &amp; Various 30-50</td>
<td>L &amp; various</td>
<td>-</td>
<td>A few 1-3</td>
<td>I for stand 2-5 for sit</td>
</tr>
<tr>
<td>WIP</td>
<td>Very low</td>
<td>High</td>
<td>High</td>
<td>High (need extra space)</td>
<td>High</td>
<td>Lower than BS or No WIP</td>
<td>Very low</td>
</tr>
<tr>
<td>Number of tasks per an operator</td>
<td>-</td>
<td>One operation 1</td>
<td>One operation 1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Multi tasks and multi M/C</td>
</tr>
<tr>
<td>Machine Capability</td>
<td>No Extra M/C</td>
<td>-</td>
<td>-</td>
<td>Group of similar M/C interchanged</td>
<td>-</td>
<td>Spare M/C</td>
<td>Small cluster of M/C and special feature</td>
</tr>
</tbody>
</table>

4.3.3 Output Parameters

Time such as lead time, waiting time and idle time is considered to be an output performance measure that is one important core of four MC apparel performance measures, that is, time, quality, cost and flexibility [2,9]. However, other effects of customised orders, work-in-progress (WIP), machine and operator utilization, and production rate are also measured.

4.3.4 Scope of the study

There are four limitations that are preliminarily determined in the part of simulation modelling. First, the mass-customised men’s shirt order is defined by the combination of features but not from individual end user. Secondly, additional features are selected to study on both construction and ornamental stitching only. Thirdly, production scheduling cannot be optimized due to customised orders scheduled by customer’s production order as the first-in-first-out policy. Finally, raw materials and accessories are regularly delivered on time.
4.4 Simulation Experiments

Several sets of experiments will be conducted. These sets of experiments illustrate the difference between MPAPS and MCAPS while customized orders and decision parameters under apparel production systems are varied. The validation of the possibility of simulated production has been tested by comparing model’s output to the real data of an apparel firm that produces men’s business, casual and fashion shirts.

4.5 Experimental Results

The results from the simulation study will explain obviously what are the characteristics of MPAPS and MCAPS, illustrated in Table 3.

Table 3. Finding Results of Generic Simulation Model Development for MPAPS and MCAPS

<table>
<thead>
<tr>
<th>Group of PV (Customised order)</th>
<th>Attributes of Apparel Production Systems</th>
<th>MPAPS or MCAPS (Outcomes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performance metrics</td>
<td></td>
</tr>
<tr>
<td>1. ???</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. xxx</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. +++</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Discussion and Conclusions

The research of MC lacks an accumulation of reliable findings in practice and quantitative simulation. The challenge for this research is how to fulfill and linkage the weakness of MC apparel industry. As the field of MC matures, the study has changed from perceptions to actions with real information and virtual data. After mapping business processes in the As-Is section to find out mass-customised problem, there are three kinds of garment industry from surveying seven Thai companies, i.e., Mass-produced products (more than 70% companies); Tailored-made products including one-piece production; and Catalogue products but it is remarkable that the catalogue of shirts has not been found. In addition, those companies do not understand how to manage customised products but do away with the IE problems such as line balancing and statistical process control. Thus, it is a good time to fill in this loophole. In the qualitative problem, all of them are essential to solve customized products using some techniques in the to-be section. For the quantitative problem, this paper proposes the directions of doing simulation modeling towards the apparel production systems but not doing in-depth experiments and not getting their results. In the following paper, the simulation environment described in the previous section will be developed using DES under ARENA software to discover the most appropriate characteristics of MPAPS and MCAPS.

6. Acknowledgement

Authors are indebted to Professor Dr. Bart MacCarthy and mass customisation research team at the University of Nottingham. We owe a gratitude to Thai textile institute and supply chain management consultants from KMUTT and Mahidol University for their supports and valuable contributions. We also thank to Dr. Thananya Wasusri, Assistant Professor Dr. Rien Boondiskulchok and Assistant Professor Dr. Manop Reodecha for their help.

7. References


