

Investigation of a Hybrid Production System for Mass-Customization Apparel Manufacturing

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ABSTRACT

Competitive and Quick responsive behavior with high product mix and low volume of Global apparel market and increasing production cost compel Mass Production apparel manufacturer shifted to Mass-Customization as well as to focus on cost effective production strategies. The study was focused on the apparel production systems of apparel manufacturers to investigate the regular progressive bundling system (PBS) and a hybrid production system. In the proposed system bundling system was integrated with modular production system (MPS) and named as bundle modular production system (BMPS). A suitable package based on MTM was employed to standardize an existing production line in order to explore the existing and proposed system in the context of time study, work study, layout and costing. The study showed favorable results for the proposed system in case of above mentioned issues. The study revealed that the hybrid system required 12% less capital investment or line installation cost than traditional PBS. Moreover, Space, Labor, Utility and Depreciation cost per product also lower than PBS for a casual woven shirt. Practice of this system will reduce the production cost and lead time and hence will enable the companies to cope up with the volatile market behavior with a reduced production cost.

Keywords: PBS, MPS, BMPS, Apparel production, time study, work study, costing

Introduction

The low cost of labor in developing countries opens a way to grow up their economies through labor-intensive product exports. So these exporting of labor-intensive goods such as textiles and clothing has been a great initiation for industrialization and export-led economic growth (Jayawickrama & Thangavelu, 2011). Textiles and clothing

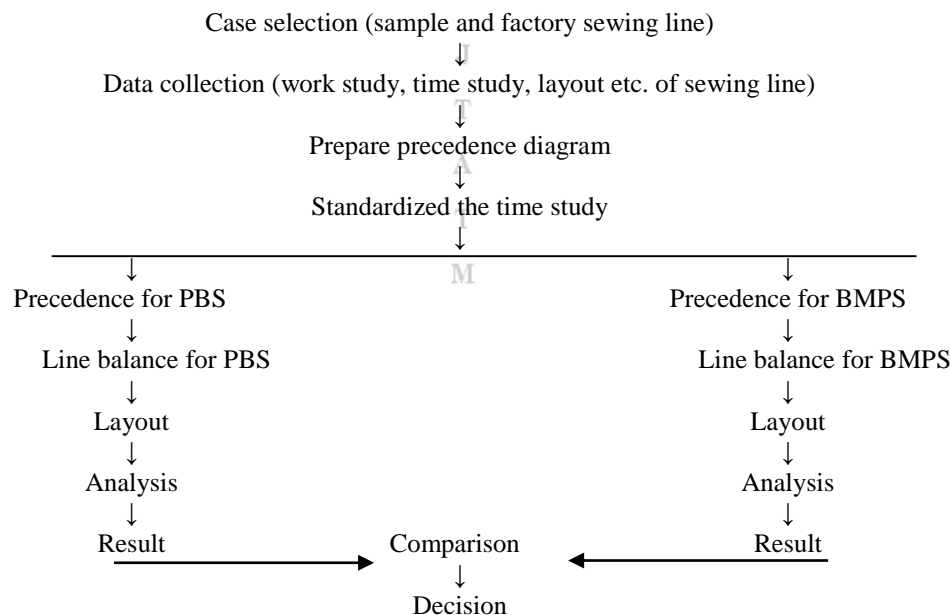
industries are divided into two: textiles and ready-made garment industry. Traditionally these industries are divided into production of fibers, fabrics and finished clothing. The natural fiber production is the territory of agricultural economies while the production of synthetic fiber requires the ability to innovate or adopt new technologies. Fabric production is a highly automated capital-intensive activity and susceptible to

technological advances. The clothing industry is basically labor intensive and requires specialization for competitiveness in the global market (Jayawickrama & Thangavelu, 2011). The clothing product lines are divided into classic style and fashion forward according to the degree of style changes (Kincade & Kanakadurga, 2013).

According to definition, the activities of an apparel manufacturer are collecting the design and materials (i.e. fabrics, accessories etc.) then doing the subsequent process of apparel production such as fabric inspection, spreading, cutting, sewing, pressing, finishing, garments inspection, packaging etc. and delivery to retailers or buyers (Glock & Kunz, 1995). Among these activities sewing is the dominant one as well as labor intensive (Tyler, 2009). Though there are

many better production systems than progressive bundling for sewing floor, it was used all over the world for several decades and still today. Among the different garments production system PBS, MPS and UPS fascinate both the researchers and practitioners. But unit production system (UPS) (Jayawickrama & Thangavelu, 2011) also called mechanical system, requires a huge capital investment for installation of overhead material conveyor unit. The main advantages of UPS are automatic material movement from one operator's station to the next station and can be installed for both PBS and MPS. Nowadays some factories are trying to implement Modular Production System for their factory as it is said that the factory will be more benefited than progressive Bundling System of production.

Study Framework



Literature Review

Apparel production system (APS) is an integration of materials handling, production processes, personnel and equipment that directs work flow and generates finished products (Hanthiringe & Liyanage, 2008), (Vijayalakshmi, 2009). There are different types of APS but literature shows a confusing scenario about the

terminology for different APS. Selection of APS depends on the manufacturer's ability on the capital investment, product type, personnel and equipment.

Progressive bundle system is a system traditionally employed in apparel production where the task of assembling the garment is broken down into small operations, and bundles of work are

progressed down the production line through each operation in sequence until the assembly process is complete (<http://www.textilesintelligence.com/glo/index.cfm>). The AAMA Technical Advisory committee (1993) reported that 80 percent of the apparel manufacturers used this system of garments production. In this System, one operator will perform a single operation on all the pieces within the bundle before it is transferred to the next operator who will perform the next operation on all the pieces within the bundle (Babu, 2012). PBS is also referred as Progressive bundle synchro straight line system and batch system. In the apparel industry, cells for manufacturing and assembly are called modules (Black & Schroer, 1993). The classic definition of Modular Production System is offered by the Apparel research Committee of the American Apparel Manufacturers Associations in September of 1989 was: “A contained manageable work unit of 5 to 17 people performing a measurable task. The operators are interchangeable among tasks within the group to the extent practical. The team members must have complementary skills who are committed to common purpose, set of performance goals, and approach for which they hold themselves mutually accountable.” Modular Manufacturing System is also called Cellular Manufacturing Units, Compact Work Teams, Flexible Work Groups, Toyota Sewing System (Glock & Kunz, 1995) and Kanban manufacturing system (A. Kumar, 2004). In modular production system, the sewing room would have a number of sections, each containing versatile operators capable of performing all the operations required for a specific component.

Both systems provide some qualitative and quantitative advantages. But the key benefit of modular systems over PBS is their impact on throughput times for garments (Cole, 1992), (Hill, 1992). In case of qualitative benefits such as specialized and all levels (unskilled, skilled, and semi-skilled) of labor are involved in PBS whereas MPS requires trained labors to carry out several operations (Babu, 2012). Again for

flexibility, product mix and quick responses, PBS faces difficulties in line balancing but MPS faces less as it balance the cells/modules and then whole system/ Line (Colovic, 2011). But the manufacturing flexibility can be achieved by the right facility layout (Bai & Zhang, 2011). MPS improves quality due to team work and job sharing whereas teamwork and job sharing is very seldom in PBS. But practically poor quality due to lot mix-up, shade variation, size variation, etc. is very few in PBS than MPS depending on skill levels of workers.

Many researchers try to analyze the advantages of the modular production system by simulation such as WITNESS simulation model (Wang, Schroer, & Ziemke, 1991), ProModel Simulation model (Kalaoğlu & Saricam, 2007). The WITNESS simulation model showed 100% operator utilization and very few WIP but it did not consider the machine idle time and operators' movement within and between modules. There was also no actions taken for different types of machines. To increase the production the whole system should be multiplied. The ProModel simulation model also had the similar assumptions and output like WITNESS. The ProModel simulation model was employed to analyze the productivity, Labor efficiency, Machine usage ratio, Throughput time and WIP for the rabbit chase, Linked cell method and Shared cells method. But in all three cases the productivity depends on capacity of decouplers. A similar simulation model showed that multifunctional and walking workers can manage great variations in processing times among the sewing stations in modular system (Black & Schroer, 1993). Another simulation based research on three different sizes of batches (50, 25 and 1 units between operations) for In-line production and batch of a unit for Modular manufacturing system for T-shirt was revealed that production per week, productivity of the manpower, time of loads and average inventory in the system were extemporizing in case of Modular manufacturing system (Castro, Castro, Mirón, & Martínez, 2004). The paper also

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showed that in the modular manufacturing system the space necessity decreased 41.73% with the advantages of job sharing. But this simulation also did not consider different types of machine for different stitch types/classes formation.

Beside the simulation a number of surveys by researchers from practitioners show the benefits of MPS over PBS. According to interviews, surveys and theory the detail discussions on benefits of PBS and MPS and over each other was shown for America (Ichniowski, 2000). Such extensive survey shows that modular system perform better than PBS for fashion forward production where high degree of style change, high frequency of style change and low volume of production in the context of quick responsiveness to retailers (Dunlop & Weil, 1996), (Kincade & Kanakadurga, 2013). Another research based on interviews with managers and surveys of worker attitudes and perceptions shows that team production system performs better than the traditional bundle system on quality, costs, and responsiveness to retailers as well as in reducing work-in-process inventory, throughput time and improving the production process (Berg, Appelbaum, Bailey, & Kalleberg, 1996).

A survey and simulation research work shows that for a limited volume order Mass-Customization (MC) is important and Kanban production system shows better performance than PBS in both Mass-Customization and Mass Production (MP) (A. Kumar, 2004).

Literatures on the implementation of MPS or Cellular systems also demonstrate that MPS is better than PBS. In a T-shirt based Garment industry, Lean based cellular layout has reduced the WIP nearly 70% to 80% and lead time from 2 days to 20 minutes from the PBS Layout (B. S. Kumar & Sampath, 2012). Analysis on WIP for 42 different garment manufacturing lines shows

SMV analysis

this is a common problem across the industry and implementation of sub-cell concept or the work groups like as modules on 20 lines revealed an improvement of 56% for WIP reduction (Ratnayake, Lanarolle, Perera, & Marsh, 2009).

Methodology

Production of same garments in both PBS and MPS with same workers and in same time is practically unmanageable. But Methods-Time-Measurement (MTM) and similar packages (like PMTS, GSD etc.) create a credible way to convert the data from each other. Hence a woven shirt sewing line motions were standardized for each work station with a suitable MTM package and stitching time were standardized by a formula for each operation. The formula was $\text{Stitching time} = \text{SPI} \times \text{Seam Length (in inch)}/\text{machine RPM}$. As a result all standardized sewing line data were found as free from stations' ergonomics, workers' performance variations and even from learning curve issue. According to precedence of tasks and target output per day (1000pcs/day) balanced production line and lay-out were prepared for both PBS and BMPS. The materials input and movements in each section of MPS were managed with bundle system like PBS. Then these standardized and balanced lines were analyzed to compare each other. In both cases the resources (e.g. machine, worker type and bundle size) were kept same for the same operation to avoid system variations.

Analysis and Results

Time study analysis

Under time study analysis SMV, Idle time and Production rate for individual work station and balanced lines were analyzed for both systems.

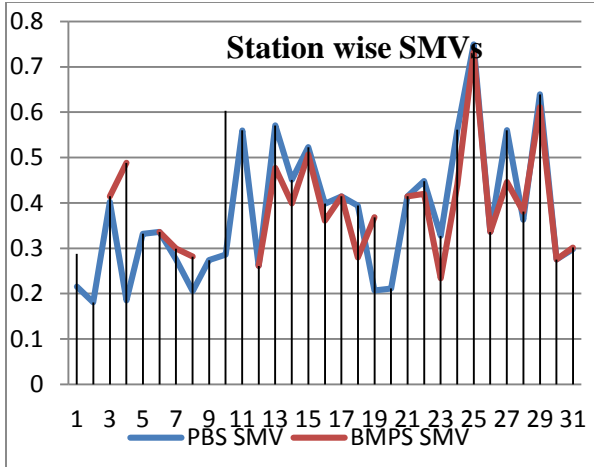


Figure 1. Work station SMVs

Figure 1 shows that task wise SMVs for PBS create continuous line where as in BMPS the SMVs create broken line because of combined tasks and sectional tasks in BMPS. For PBS the highest SMV is 0.75 and the lowest is 0.18. Similarly, for BMPS the highest SMV is 0.73 and the lowest value is

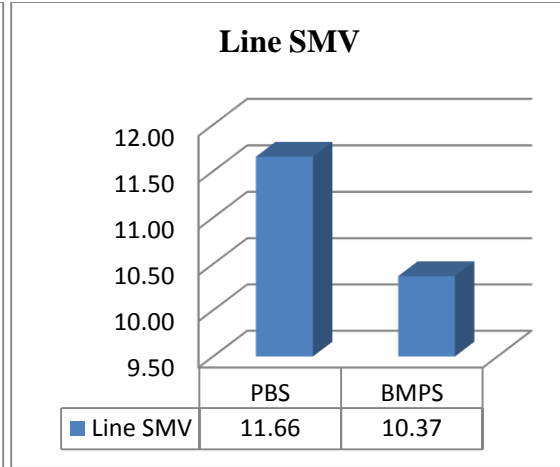


Figure 2. Total SMV

0.23. The highest SMV of BMPS is lower and the lowest SMV is higher than respective cases of PBS, which proves a scenario of better line balance. Similarly in figure-2 it is shown that total SMV of PBS is higher than BMPS.

Production/hr. analysis (before line balancing)

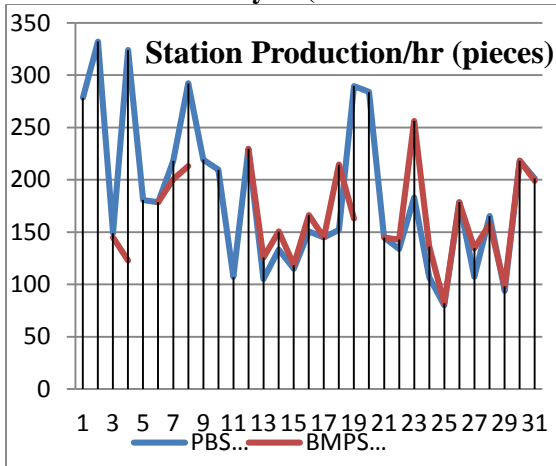


Figure 3. Work stations production/hour

Figure 3 shows that task wise production/hr. in pieces for PBS create continuous line where as a broken line BMPS; similar for SMVs of station wise for the same background. For PBS the highest production/hr. for individual work station were 332 pieces and the lowest 80 pieces. The deviations of production/hr. for individual work station were 75.90 %.

Idle time analysis (before line balancing)

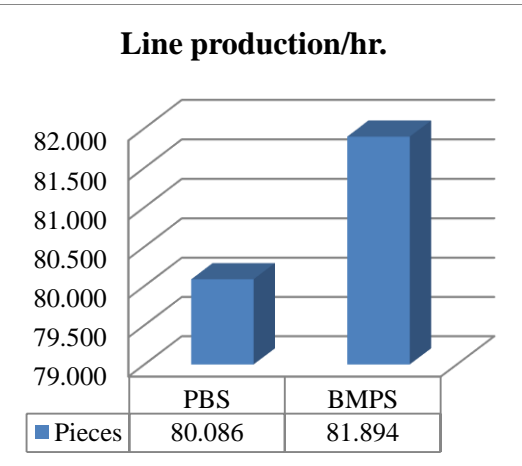


Figure 4. Line production/hour

Similarly, for BMPS the highest and lowest individual work station production/hr. were 256 and 81 pieces respectively with a deviation of 68.36%. This is also a phenomenon of better balanced line in BMPS. Similarly in Figure 4 it is shown that line production rate of BMPS is higher than PBS.

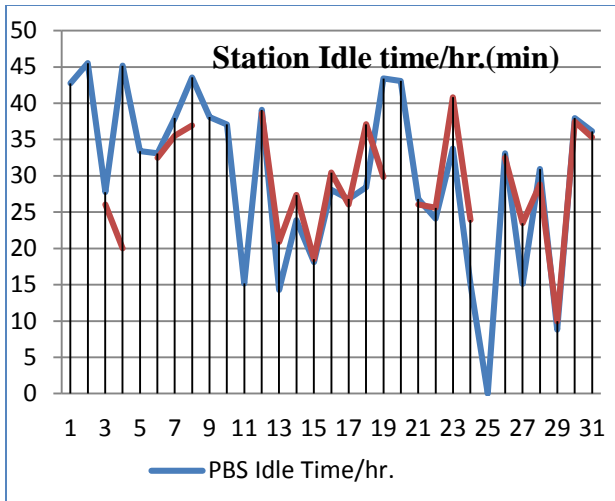


Figure 5. Work stations idle time/hour

Figure 5 shows Station wise idle times of both PBS and BMPS which is similar type line graphs for Figures 1 and 3 also for the same background. Considering individual station the maximum idle time was 45.53 & 40.83 minutes per hour for PBS & BMPS respectively. But in both cases the lowest idle time was 0 minute. This is a scenario for lack of work load balancing in both cases. Similarly in figure-6 it is shown that line idle time of PBS is higher than BPMS.

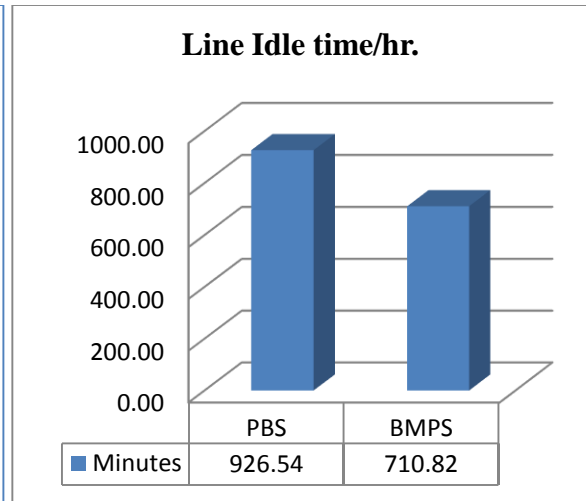


Figure 6. Line idle time /hour

Time study summary after line balancing

To maintain the delivery schedule of the order the target production/day was set for 1000 pieces and actual production of the factory were 1024 pieces. Hence in this study, the target was considered 1000 pieces per day to balance the line for both systems. After balancing lines, the data shows 1025 and 1008 pieces production/day at 80% efficiency for PBS and BMPS respectively.

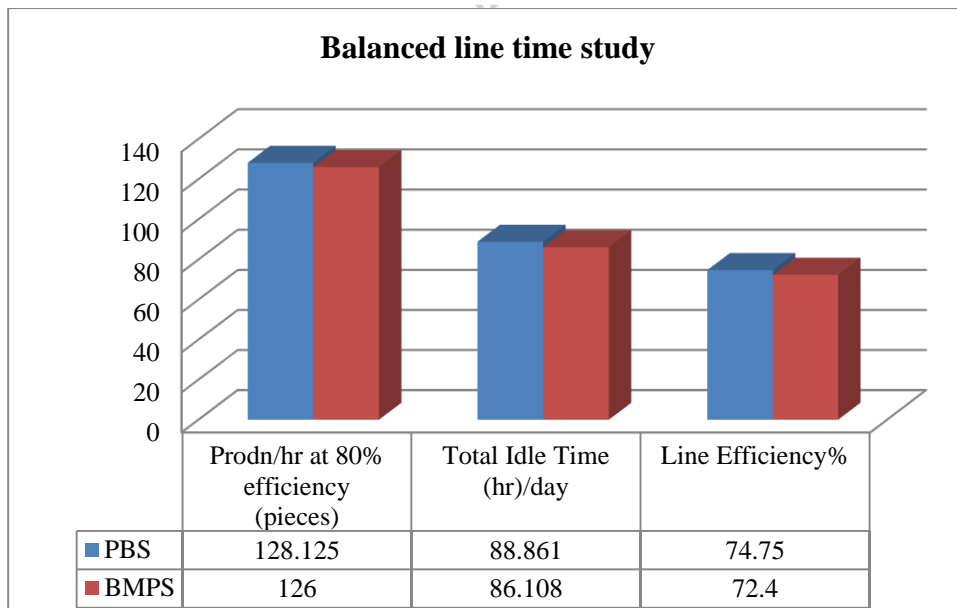


Figure 6. Time study summary after line balancing

The figure-6 shows that output rate at 80% efficiency of PBS is higher than BMPS with higher idle time and line efficiency %.

Work Study Analysis

This was done on balanced lines for both systems' basic resources i.e. 3Ms (men, machines and materials). For a sewing line operators and helpers both represent as men or labor. For both systems one machine was assigned to an individual operator. WIP or materials input was in bundle form and the number of pieces in a bundle was 35.

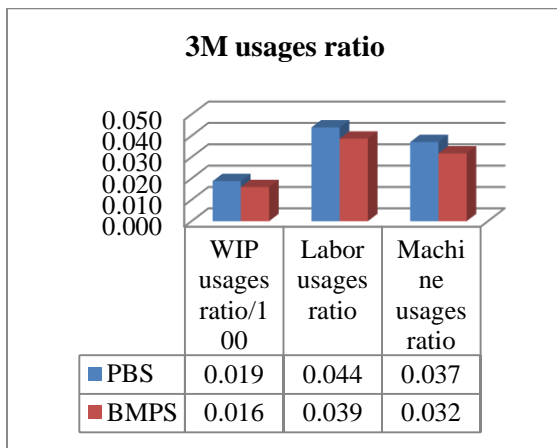


Figure 7. 3M usages ratio for PBS and BMPS

The Figure 7 shows the resources usages ratio for both systems. Labor, Machine and WIP usages ratio are higher in PBS than BMPS as number of work stations, operators and bundles were more in PBS which were required to achieve the production target.

Layout analysis

Materials movement and space required are the main concentrations to layout analysis. Again these two issues are directly related to the shape of layout i.e. straight, U-shape or combine shape. In this study both issues were covered considering the station size with the following assumptions and equations-

Avg. operator's station length, $L = 45$ inch
 Avg. operator's station width, $W = 40$ inch
 Avg. helper's station length, $l = L$ inch

Avg. helper's station width, $w = 30$ inch
 Station to station distance, $L_s = 0$
 No. of operator's station = N_o
 No. of helper's station = N_h
 No. of bundles = N_b ,
 and all bundles move from the starting of the line.

Therefore, the Total Space = $\{N_o (L \times W) + N_h (l \times w)\}$ sq. inch and the Total Materials Movement = No. of Bundle x Total Length of the Line = $N_b \times (N_o \times W + N_h \times w)$ inch
 For PBS, Total Space = $38 \times (45 \times 40) + 7 \times (45 \times 30) = 77850$ sq. inch,
 Materials movement = $55 \times (38 \times 40 + 7 \times 30) = 95150$ inch.
 For BMPS, Total Space = $32 \times (45 \times 40) + 7 \times (45 \times 30) = 67050$ sq. inch,
 Materials movement = $46 \times (32 \times 40 + 7 \times 30) = 68540$ inch.

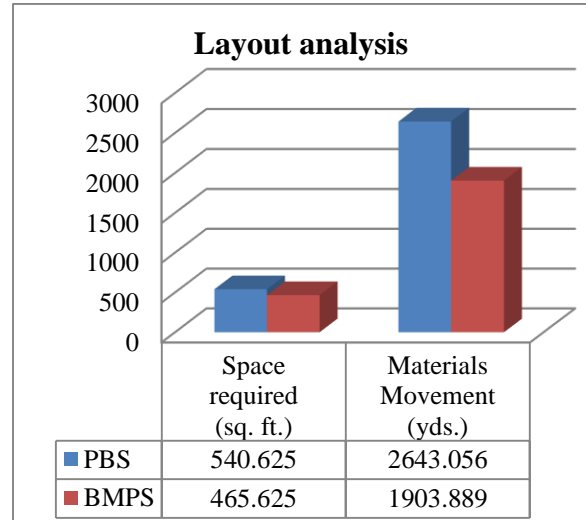


Figure 8. Layout analysis for PBS & BMPS

Space uses and materials movements are important issues for any system. Here figure-8 shows that PBS need more space and material movements also higher than BMPS.

Cost Analysis

Capital investment, Space, Labor, Utility and Depreciation cost were analyzed to compare the costing of these two systems in this study. Material cost and managerial cost were not analyzed for the study because these two categories of cost remain same for both systems.

The capital investment or line installation cost was calculated by considering the machines required for both systems. Table-1, 2, 3, 4 & 5 and Figures 9 and 10 show the

capital investment or line installation cost and other above mentioned cost for PBS and BMPS.

Table 1. Capital investment or line installation cost

M/c type	No. of m/c (PBS)	No. of m/c (BMPS)	Rate (USD)*	Total cost (PBS)	Total cost (BMPS)
S/N Lock Stitch M/c	34	28	615.00	20910.00	17220.00
Feed of the Arm M/c	2	2	930.00	1860.00	1860.00
Button Attaching M/c	1	1	3300.00	3300.00	3300.00
Button Holing M/c	1	1	3600.00	3600.00	3600.00

* Machine rate vary model to model & Brand to Brand.

Table 2. Space cost

System	Space Required (sq.ft.)	Space cost /month (USD)	Space cost/product (USD)
PBS	540.625	702.813	0.0033
BMPS	465.625	605.313	0.0029

Let, rent of space 1.3 USD/sqft/month. 26 working day/month and 8working hrs./day.

Table 3. Labor cost

System	No of Operators	No of Helpers	Total labor cost/month (USD)	Total labor cost/product (USD)
PBS	38	7	2736	0.013
BMPS	32	7	2346	0.011

Let, 65 USD and 38 USD wages per month for operator and helper respectively and 26 working day/month and 8working hrs./day.

Table 4. Utility cost

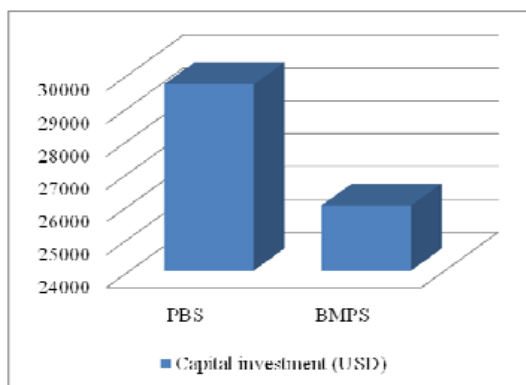
System	No. of m/cs	No. of lights	Total utility cost/hr. (USD)	Total utility cost/product (USD)
PBS	38	11	15.64	0.015
BMPS	32	9	13.16	0.013

Average power consumptions by M/c/hr.= 0.4 KW,
 Average power consumptions by Light/hr.= 0.04 KW,
 Average no. of lights per 100sq.ft. = 2 pieces
 Power rate = 0.09 USD/KW (commercial).

Table 5. Depreciation cost

System	Total m/c cost (USD)	Depreciation cost/year (USD)	Depreciation cost/product (USD)
PBS	29670	1483.500	0.006
BMPS	25980	1299.000	0.005

Let, 5% straight depreciation for 3years,
250 working days per year and 8 working hrs. per day.

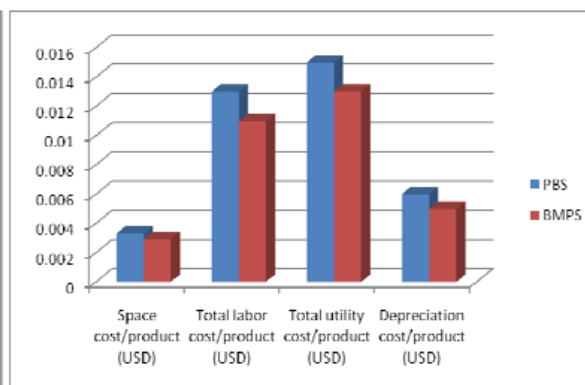


**Figure 9. Capital investment
Depreciation cost**

Figure 9 shows that Capital investment was higher for PBS than BMPS as higher number of machine assignation increase the line installation cost. On the other hand, Figure 10 shows Space, Labor, Utility and Depreciation cost per product were higher in PBS system.

Conclusions

Looking for a better production system for Mass-Customization Apparel Manufacturing this analytical study proved that Bundle Modular Production System were more advantageous than Progressive bundling system. In case of time study it was found that the SMV for BMPS 11.04% less than PBS. In terms of individual station SMV, idle time and production/hr. the standard deviations were 17%, 29% and 37% less respectively in BMPS. Again to balance the line for the target production quantity up to 14th and 8th bottlenecks were eliminated (by multiplying workstation) for PBS and BMPS respectively. So the study revealed that stations workload of BMPS was better balanced than PBS. In case of resources usages ratio it was found that the men,



**Figure 10. Space, Labor, Utility and
Depreciation cost**

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machine and WIP usages ratio for BMPS were 12.36%, 13.51% and 14.96% less than PBS. While analyzing layout for both systems, the study found required space was almost 13.87% less in BMPS which proves better space utilization of it. Materials movement was also 28% less in BMPS. The most sensitive area of the analysis was cost analysis and it was found BMPS as more cost effective than PBS. For instance capital investment or line installation was 12.44% less for BMPS than PBS. Space, Labor, Utility and Depreciation cost per product were also 12.12%, 15.38%, 13.33% and 16.67% less in BPMS respectively. As a whole this quantitative analysis shows a means to reduce lead time by increasing productivity, cost of production in the context of apparel production engineering to adopt the manufacturer for volatile and quick response market.

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