Challenges and Potential Impact of Applying Lean Manufacturing Techniques to Textile Knitting Industry: A Case Study of a Knitting Factory in Sri Lanka

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Abstract

Application of lean manufacturing in mass production, especially in apparel industry, has become a popular practice in meeting the objectives of waste minimization and productivity improvement these days. But when it comes to batch production, for example textile knitting which is an upstream process of the supply chain, application of lean techniques is a challenge. This study investigates challenges of application of lean techniques to a textile knitting factory in Sri Lanka. . The purpose of the study was to investigate the challenges in improving the productivity through lean techniques in a less labour intensive batch production environment. The objectives of the study were to quantify the impact of lean practices and to identify the key challenges specific to the knitting industry. The case study based research approach was followed thought the project which is similar to that used by Kasul and Motwani's study. Interviews, observations and archival sources were the sources from which data was collected. The results were calculated of main product categories based on the volume and price. For example it was found that the process Value added (VA) to Non-value added (NVA) ratio for JCOL 56(the main product) is 4.64% and with the suggested improvements for waste minimization it was found the ration could be improved to 9.37%. Therefore improving the process would bring in a lot of financial & non-financial gain as well as the lead time reduction which is a key factor in reducing the operational costs.

Keywords:

lean manufacturing, productivity, textile knitting

1. Introduction

"Lean manufacturing is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, value is defined as any action or process that a customer would be

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willing to pay for" Michel Gouse [1] describes. Basically, lean is focusing on giving higher value with less work. Lean manufacturing is a process management philosophy derived mostly from the Toyota Production System (TPS) Toyota Motor Corporation [2], identified as 'Lean' only in the 1990s Womack & Jones [3]. It is well known for its focus on reduction of the original Toyota seven wastes to improve overall customer value, but there are different arguments on how this can be best achieved. The steady growth of Toyota, from a small company to the world's largest automobile manufacturer, is simply because of this high focus.

The main objective of this study was to increase the current output level of the company. This was followed by a set of secondary level goals which include reducing the cost of operation, optimization of labour allocation, creation of improved production planning & scheduling system, improvements of WIP between production processes and improvements to the factory layout with less or no capital investments.

With the optimized working conditions of the workers and changes made in the working environment will eventually result in the workers' well-being and their job satisfaction which in turn will lead to a significant increase in the factory's overall productivity and its output to a significant level in the future as well.

1.1 Background of the Company

The company [4] started with an initial investment of US$ 4 million and a production capacity of 7,000 Kg per week; they commenced operations in 1992 with an employee base of a mere 40. Today, it has grown into a large organization of a total investment of US$ 200 million and the production capacity up to 250,000 Kg per week with an employee base of 675. The annual turnover today is in excess of US$ 58 million, proving it to be an organization with a potential for growing by leaps and bounds which encouraged us to select this organization for our project [5][6].

Their products include an interesting range of Cottons, Polyesters, Spandex, Lycra, Rayons, Wool, Viscose, Modal, and a multitude of such blends. They also produce single Jersey, Interlock, Fleece, Polar Fleece, Rib, Pique, Structures, Pointelle and Marl fabrics and also a comprehensive Flat Knit section which produces bands & collars, and can accommodate Jacquard and Tipping.

Knitted fabrics are divided in to two basic types: weft knitted & warp knitted, weft knitted fabric will divide as single jerseys (which are plain knit & purl) & double jersey (which are rib and interlock), warp knitted fabrics will divide as tricot & Rachel [8].

2. Methodology

The methodology used for presenting the case study is explored in this section. First the research method is explained, followed by a brief description about the lean concepts used.

2.1 Research Method

The case study based research approach was followed thought the project which is similar to that used by Kasul and Motwani's [13] study. Interviews, observations and archival sources were the sources from which data was collected. Interviews were conducted with the operational staff, unit managers and quality managers. In person interviews were conducted with those who were most familiar with the manufacturing process. The other sources of data were unstructured interviews from other management and non-management personnel during the period of this study.

2.2 Summary of Key Lean Concepts

The main concept of lean manufacturing is enriched with many sub philosophies. Here we have summarized those sub philosophies in the context of selected case company.

2.2.1 Just-in-Time (JIT) Production

A system of production that makes and delivers just what is needed, just when it is needed, and just in the amount needed. At the current state mapping process we had observed the work-in-progress levels between every two processes. And some of those WIP get damage due to dirt, humidity and temperature of the store [9] [12].

2.2.2 Continuous Flow

This refers to producing and moving one item at a time or a small and consistent batch of items through a series of processing steps as continuously as possible, with each step making just what is requested by the next step. It is also called one-piece flow, single-piece flow, and makes one, move one. At the preliminary study we have understood that the company has a very slow moving process due to the nature of the industry. But they also have 4.17% rework level which is well above the normal loss related to the industry. The total number of rework calculated for the 6 months case study period was 215,167 kg [9] [12].

2.2.3 Cycle Time

This is the time required to complete one cycle of an operation in a given work stationor a separately identified process. This time includes operating time plus the time required to prepare, load, and unload. The appropriate calculation of cycle time may depend upon context. For example, if a dying process completes a batch of 500 kg every twenty minutes, the cycle time for the batch is twenty minutes. However, the cycle time for an individual part is varying with its weight. If we assume that an individual part has average weight of 20 kg, then the cycle time will be one minute [9] [12].

2.2.4 Production Lead Time

This is also known as 'Throughput Time' or 'Total Product Cycle Time'. The time required for a product to move all the way through a process from start to finish is the production lead time. At the plant level this is often termed door-to-door time. The concept can also be applied to the time required for a design to progress from start to finish in product development or for a product to proceed from raw materials all the way to the customer. As the company had WIP between almost all their processes the production lead time was relatively high. This also influenced by the higher amounts of rework levels for specific products. Some of those products cannot get right at first time due to the lack of necessary machine capabilities. The company had to operate with aged machines as they operates in a highly capital intensive industry. So one of the main paths to stay profitable is to reduce defect rate, rework levels and deliver goods on time. On time delivery is crucial in this industry as all of their customers operate in labour intensive production environments, so failure to deliver on time end up with high amounts of financial penalties [9] [12].

2.2.5 Waste Elimination

One of the key steps in Lean and TPS is the identification of steps which add value and which do not. Waste elimination is classifying all the process activities into these two categories. It is then possible to start actions for improving the value adding activities and eliminating the non-value adding ones. Some of these definitions are seems like 'idealist' but this tough definition is important to the effectiveness of this key step. Once value-adding work has been separated from waste then waste can be subdivided into 'needs to be done but non-value adding' waste and pure waste. The clear identification of 'non-value adding work' is critical to identifying the assumptions and beliefs behind the current work process and to challenging the reason or reasons behind those activities [9] [12].

The following ‘seven wastes’ identify resources which are commonly wasted. They were identified by Toyota's Chief Engineer, Taiichi Ohno as part of the Toyota Production System. Overproduction, Unnecessary transportation, Inventory, Motion, Defects, Over-processing and Waiting are identified as the seven wastes. The main method of identification of above wastes is value stream mapping. Reducing or eliminating the current state waste, we plot the future state map [10] [11].

3. Results and Discussion

The company manufactures products with around 1,500 variations. Therefore we had to select the most important products with larger impact through a Pareto analysis (Refer to Table 1). Here we used both length and weight as both these parameters are essential at the quality control stage. And all the calculations are done for a standard 300kg batch, without reworks.

Table 1: Main products according to the Pareto analysis.

	Product	**Family**	**% Vol (m)**	**% Vol (kg)**
01	JCOL56	Lycra	11.63%	9.71%
02	ICO220	Hands	9.80%	12.45%
03	IPE012	Polyester	9.09%	6.72%
04	PJCOL56	Lycra	5.84%	4.87%
05	JCO131	Jersey	5.33%	5.85%
06	SDPE050	Polyester	4.36%	3.31%
07	JCOS85	Lycra	3.34%	3.41%
08	JCO054	Jersey	3.01%	2.75%
09	PJCO240	Jersey	2.90%	2.72%
10	JCOS129	Lycra	2.86%	2.92%
11	JPC011	Polyester	2.73%	2.37%
12	BICO174	Interlock	2.70%	3.23%
13	FCOS57	Lycra	2.45%	3.57%
14	ICO048	Interlock	2.33%	2.41%
15	JCO240	Jersey	2.12%	1.98%
16	JCOS41	Lycra	1.97%	2.25%
17	PICO174	Interlock	1.64%	1.92%
18	JCOS44	Lycra	1.64%	1.67%
19	BJCO054	Jersey	1.60%	1.47%
20	JCO010	Jersey	1.56%	1.09%
21	JCO056	Jersey	1.50%	1.37%
22	JCO231	Jersey	1.42%	1.30%
23	IPE037	Polyester	1.31%	1.05%
Total % Volume			83.13%	80.39%

JCOL56 was running in 77.74% efficiency, but with the recommendations the new process is expected to run in 83.17% efficiency. That is a 5.43% overall productivity improvement. This can be improved further more if the current building plan inside the factory premises is modified. The company may opt to implement the recommendations with no or little capital investment first being in line with the corporate objective.

3.1 Waste type 1: Unnecessary Transportation of Goods

The company carries out their operations in three main buildings which are physically separated. So with the process each and every product which is included in the Pareto analysis has to flow through these buildings. This has become a huge waste that act as a catalyst for other wastes such as waiting (Refer to Table 2).

Table 2: Reduction in Transportation distance between departments

Department / Location		**Transportation**			**Percentage Reduction**
From	**To**	**Present**	**Future**	**Saving**	
RMS	Knitting	380 m	140 m	240 m	63.16%
Knitting	Preparation	170 m	130 m	40 m	23.53%
Preparation	Dye House	280 m	180 m	100 m	35.71%
Preparation	Finishing	280 m	170 m	110 m	39.29%
Finishing	Dye house	30 m	30 m	Nil	0%
Finishing	Printing	215 m	115 m	100 m	46.51%
Finishing	FGWH	280 m	280 m	Nil	0%
Total		1635m	1045m	590m	36.09%

With respect to the current system and layout the process is engaged with 57.51% more transportation in total, than the proposed layout even though some constraints were kept untouched during the development.

Even though the main calculations were carried out considering JCOL56 standard size 32 roll batches, the feasibility of the layout was checked by applying different product in to it. This was essential as almost all the products have different material flows through the system. So the following data shows the main products according to the product groups/ families (See table 3). During this study a maximum value and a minimum value were considered as the material distance depends on the position of the machines use inside the finishing department.

Table 3: Transportation variations inside the finishing department

Product	**Present (m)**		**Proposed (m)**		**Saving**	
	Max	**Min**	**Max**	**Min**	**Avg.**	**%**
JCOL56	590	510	430	360	155m	28.18
ICO220	410	330	380	310	25 m	6.76
IPE012	410	330	380	310	25 m	6.76
PJCOL56	620	540	530	460	85 m	14.66
PJCO240	440	360	410	340	85 m	21.25
BICO174	410	330	380	310	25 m	6.76

3.2 Waste type 2: Overproduction

In the case study scenario an overproduction was clearly identified and quantified in the knitting department. The department produces at their operating capacity irrespective of the delivery date to the customer and they sometimes create an unnecessary pull at the beginning of the process due the massive capacity they are operating with.

Table 4: Types & total capacity available at the knitting department

Type	Qty	Machine Capacity (month)	Operating Capacity (month)	Operating Capacity (%)
Fleecy	16	60,000 kg	20,000 kg	33.33
Interlock	47	210,000 kg	110,000 kg	52.38
Jersey	62	350,000 kg	260,000 kg	74.29
Rib	51	220,000 kg	80,000 kg	36.36
Terry Jersey	50	280,000 kg	180,000 kg	64.29
Flat Knits	34	N/A	N/A	N/A
Total	260	1,120,000 kg	650,000 kg	58.04

But they have to produce in advance in order to facilitate higher customer demand for specific products in certain months which has identified according to the six months sales forecast.

For example if many of their customers place orders for Fleecy to deliver after six months, knitting department cannot face that demand with the available capacity. In that case they have no options other than developing an inventory in between the knitting department and the preparation department. However the time in the store as an inventory can be reduced because at the moment they keep a stock of 35 inventory days in average.

Table 5: Overproduction quantities in the month of March 2011

Product	Rolls	Weight (kg)	Percentage of the monthly capacity
ICO48	755	15,100	2.097%
ICO220	105	2,100	0.291%
JCOL56	110	2,200	0.305%
JCOS144	420	8400	1.166%
PJCOL56	160	3200	0.444%
SDPE050	20	400	0.055%
SDPE021	35	700	0.097%
TPE477	45	900	0.125%
TPE488	40	790	0.109%
TPE514	115	2300	0.319%
Total	1805	36,090	5.002%

3.3 Waste type 3: Inventory

At the present stage the case study company operates with inventory buildups in between all the processes. And according to the information collected during the study, the company cannot completely eliminate inventory in between processes as this is not a continuous production line. So in order to smooth the production they had to keep a batch sized inventory in between all the processes. By reducing the inventory levels the company can save huge amount of space inside their factory premises.

Table 6: Waiting time related to six major products

Product	Present (m)		Proposed (m)		Saving	
	Max	Min	Max	Min	Avg.	%
JCOL56	590	510	430	360	155m	28.18
ICO220	410	330	380	310	25 m	6.76
IPE012	410	330	380	310	25 m	6.76
PJCOL56	620	540	530	460	85 m	14.66
PJCO240	440	360	410	340	85 m	21.25
BICO174	410	330	380	310	25 m	6.76

Table 7: Storage space reduction in each department

Department	Current (m^2)	Future (m^2)	Saving (m^2)	Saving as a percentage
Knitting	150	80	70	46.67%
Preparation	2800	840	1960	70%
Dye house	300	150	150	50%
Finishing	1800	1080	720	40%
Printing	60	60	Nil	0%
Brushing	600	450	150	25%
RMS	1800	1200	600	33.33%
FGWH	1800	600	1200	66.67%
TOTAL	9270	4420	4850	52.32%

3.4 Waste type 4: Defects

This is the most visible and one of the biggest challenges at the current stage of operations in the case study knitting mill. In general this industry has a normal defect rate due to the parameters and the nature of the process. Most of the identified defects go through the rework process. Rework cost depends on the defect identification stage. This can be mainly break in to two categories with internal failure identifications to external failure identifications. If any internal failures are identified, they can either rework at their cost with the available time or discuss with the client to get an applicable scrap rate. This gets more complicated with the clients who have financial penalties attached to specific delivery dates. The below table presents only the costs related to rework quantities (without financial penalties) [7].

Table 8: Scraped quantities from MAS intimates [17] for 2011 first two quarters

Product	Quantity	Value
JCO207	20 kg	$ 145.25
JCOL56	2140 kg	$ 12965.55
JCOS144	580 kg	$ 3775.80
Total quantity	2740 kg	$ 16886.60

3.5 Waste type 5: Over-processing

As all external failures are considered in the defects section, in this section only internal failures were considered for over processed products within the period. The following table summarizes the main defects that occur in the production process (Refer to Table 9).
Table 9: Main defects identified and reworked, according to the Pareto analysis.

Defect	Rolls	Kilos	% volume
Stain	1538	30647	11.42%
Off shade	1182	23537	8.77%
Length shrinkage	1174	23376	8.71%
Low GSM	1122	21286	7.93%
Oil	842	17019	6.34%
Ash	733	15114	5.63%
Rough handle	596	11909	4.44%
Pressure mark	593	11845	4.41%
Chemical mark	533	10994	4.10%
High GSM	515	9856	3.67%
Narrow width	377	7504	2.80%
Unlevel	333	6804	2.54%
Dirty & stain	336	6546	2.44%
Pleats	268	5279	1.97%
Softener mark	241	4778	1.78%
Miggration	226	4523	1.69%
Bad selvedge	209	4150	1.55%
Total		215167	80.19%

3.6 Waste type 6: Waiting

Several waiting points were identified throughout the process during the study. Below mentioned data briefs the total time related calculations of selected six major products (See Table 10). With the solution the company can clearly eliminate the type 2 muda (Non value adding – non essential activities) from the production process. But still almost all products have approximately 10% VA time. For example JCOL 56 is still engaged with 90.27% NVA time.

Table 10: Waiting time related to six major products

Product	Current State			Future State		
	NVA (Days)	VA (Hours)	Type 1+2 Muda (Hours)	NVA (Days)	VA (Hours)	Type1 Muda (Hours)
JCOL56	30	31.91	688.09	15	31.91	328.09
ICO220	44	25.16	1030.84	15	25.16	334.84
IPE012	35	26.08	813.92	15	26.08	333.92
PJCOL56	30	35.16	684.84	15	35.16	324.84
PJCO240	40	30.75	929.25	15	30.75	329.25
BICO174	35	25.91	814.09	15	25.91	334.09

3.7 Waste type 7: Motion

As this is a more machine intensive industry savings related to motion is relatively low than a labour intensive industry. However the following motion related data were identified during the study carried out at their premises (See Table 11).

Table 11: Process related motion calculation with departmental breakdowns

Department	Current	Future	Saving	Saving as a percentage
RMS	60 m	55 m	5 m	8.33%
Knitting	10 m	5 m	5 m	50%
Dye House	105 m	105 m	Nil	0%
Printing	30 m	30 m	Nil	0%
Finishing	141 m	98 m	43 m	30.5%
FGWH	15 m	15 m	Nil	0%
Other	7 m	5 m	2 m	28.57%
Total	368	313	55	14.95%

3.8 Value Adding & Non Value Adding Time

At the current state mapping stage, their value adding time to non-value adding time ratio was calculated as 2.39% (Refer to Table 12). With the improved work-in-progress levels the ratio was calculated as 6.99%. This was mainly possible by reducing non value adding time before preparation and dying processes. So the total average time consumption was 21600 minutes in the future state which is originally 63180 minutes in the current state. With this result ICO 220 has recorded a 65.81% door-to-door time reduction.

Table 12: Average value adding time and non-value adding time for ICO 220.

Process/Department	Time before the process	Time for the process
1. Knitting	24 Days	510 Minutes
2. Preparation	18 Days	65 Minutes
3. Dye House	4 Hours	490 Minutes
4. Hydro Machine	6 Hours	90 Minutes
5. Splitting Machine	4 Hours	105 Minutes
6. Stenter Machine	2 Hours	95 Minutes
7. Compactor	3 Hours	80 Minutes
8. Inspection	2 Hours	75 Minutes
9. FGWH	24 Hours	Nil
Total Time	63180 Minutes	1510 Minutes

4 Conclusion

With the present financial crisis, the company has to find cost reduction options which will enable the company to increase their profit margin without increasing the selling cost of the products.

It was found that the process Value added (VA) to Non value added (NVA) ratio for JCOL 56 at the current state is 4.64% and with the results obtained throughout the case study the developed future state has an improved ratio of 9.73%. So at the moment JCOL 56 production process has only 90.27% non-value adding activities which were originally 95.36%. Therefore improving this process would bring in a lot of financial gain as well as the lead time reduction. Also the company can consume lots of non-financial gains such as employee satisfaction and customer enlightenment. This can be improved further if the current building plan inside the factory premises is modified according to the proposed layouts. The saving can be further improved by reinvesting the initial annual savings on building the correct infrastructure to further improve the efficiency [16].

And the company should have to identify the lean fundamentals from the top to bottom in the hierarchy in order to gain successful long term results through the proposed philosophy. This will also include customer focus, continuous improvements in the value streams, Pull through the system, maintain flow, respect people and strive for perfection. So the most underline principle is that anyone can use lean tools but the most difficult part is to sustain that philosophy in the volatile operational level.

It is important remembering the implementation of lean as a manufacturing discipline and that is only the start of a long journey, which for a company can be very profitable. Some changes will take a longer time to give its output. When lean is implemented and used properly it can become an effective tool to drive the company towards continuous improvement. Once integrated into the organizational culture of the company, it becomes the standard for daily operations. Decisions will make in according to optimize all activity and keep waste to a minimum. Companies that do this better than the competitors become more profitable regardless of outside economic conditions [15].

According to change of the attitudes and the mindset of the current work force, the company has to heavily invest on employee training sessions which ensure the sustainability of the proposed lean manufacturing methods. Sustainability of the system would definitely be a complex and a difficult task as this is directly related to the behavior patterns, thinking levels and habits of the workers who worked there for a considerable period of time. The programs should overcome the natural resistance to change of the people [14].

Application of lean manufacturing to knitting industry is challenging when compared with industries like garment industry due to the lengthier cycle times associated in the production and the scale of the product(s) being handled. Future researchers are encouraged to focus on developing a software based solution in dynamically handling the variety of the product categories being handled as the complexity of various combinations of resources involved with huge variety of products makes it further challenging in order to continuously reap the benefits of lean.

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