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Lean Production Principle for Improving Productivity: Empirical Case Study in Garment Industry in Ethiopia

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Abstract

Lean production has been industrialized in manufacturing industry in the Global North on account of delivering quality products. The industry in the Global South on the other hand is facing problems that could easily be minimized using the production principle. This paper is organized to adapt lean production for improving productivity of garment industry in Ethiopia. The target is to alleviate variety between company's productivity and customer demand. Shop floor visit, questionnaire survey, and focus group discussion-based data mining approaches have been used for this purpose. The qualitative part was used to map out baseline data of existing manufacturing process whereas the quantitative part was aimed to construct empirical findings obtained from qualitative organization. Aggregate results accordingly show that there are substantial lean wastes such as longer lead time, high WIP inventory, longer routes, and unutilized resources. It has been meanwhile renown that if appropriate lean production tools have framed and implemented, the impact of these wastes could meaningfully be minimized and a smooth process flow can be ensured. For instance, a lead time for a single round neck t-shirt in the case study has shown an improvement of 18.3% and a 3.9% improvement of resource utilization.

Keywords: Lead time;Lean production; Takt time; Workload balancing; Kanban sizing; Garment industry.

1. Introduction

Textile and garment sector has come a long time since the days when it started undertaking in developed countries. Through time, it has shifted to Asian countries on account of relatively low labor cost and abundant raw materials. Asian and other developing countries have consequently started to be destination of the sector. As part of this, Ethiopia has established modern textile factory in 1939 under the name of Dire Dawa Textile Mills[1].This is because Ethiopia is endowed with favorable geographical and weather conditions to grow and produce cotton. Ethiopian government is meanwhile providing export incentives and it is creating opportunities of international trading environment.

On the other hand, with evolutionary and fast-growing need for fashion clothing, researchers and manufacturers have been inventing different frameworks to create astonishing array of styles. Considerable efforts have been also undertaking to develop tools and techniques to harmonize and implement these frameworks. Lean production is one of the frameworks that has been used to minimize lean wastes and to fully utilize activities that add value from customers' perspective [2, 3].

In contrast to its benefits found in the Global North, its astonishing. The industry is facing with problems that could easily be minimized after implementing lean production. In line with this, garment industry in Ethiopia is suffering many lean wastes such as longer lead time, high work-in-process (WIP) inventory, longer routes, and unutilized resources[4, 5, 6]. This paper is, therefore, organized to confer importance of lean production for improving productivity and for exploring its implement-ability in the case of garment industry in Ethiopia.

2. Contextual survey

After world war-II, Japanese manufacturers started to face with vast shortage of materials and human resource which resulted in the birth of lean production business model. Then after, increased market volatility, global competitiveness, and sales crisis together forced manufacturers to commit to journey of world-class manufacturing performance through adapting lean systems[7].

Lean is elimination of waste (Toyota Production Systems), a philosophy that means (produce what is needed when it is needed), and a methodology of (determination of value-added activities in a process)[8]. Lean production is, therefore, a Japanese production philosophy focusing on reducing lean wastes and on maximizing activities that add value from customers' perspective [3, 9, 10].

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Practical experiences have proven that the philosophy is being on implementation in manufacturing industry in the Global North and it is reducing the impact of lean wastes on their process. Meanwhile, it is currently coexisting with the recently emerged manufacturing platform called industry 4.0 [11, 12]. On the other hand, different researchers and manufacturers have been framing lean manufacturing. Without being exhaustive, [11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25]could be cited and the prevailing results show it is meaningfully on adoption in the real industrial globe.

In [11],it is clearly presented that lean production concerns with strict integration of human in manufacturing for avoiding lean wastes.[18] have also applied and validated lean tools as ways of improving manufacturing systems in garment industry. [23] have meanwhile examined an empirical relationship between the principle and performances of different production plants in automotive industry. From these theoretical and empirical studies, it can be drawn that though its impact varies from country to country and from sector to sector, applicability of lean production has been forcefully considered as a route to high-productivity.

2.1. Lean production in developing countries

Garment firms in Bangladesh [26], apparel industry in Sri Lanka [27], manufacturing industry in Malaysia [28], garment industry in India [29], and sugar industries in Kenya [30]are amongst companies in developing countries who have validated the importance of lean production. All authors who investigated the significance have confirmed that lean production is imperative for productivity improvement in any business sector. Familiar to its adoption in developing countries, studies in the case of manufacturing in Ethiopia have showed that the philosophy has comparative advantage mostly in metal and textile factories. The works of [2, 4, 31, 32] are some applicability findings in this context.

However, pertinent experiences in the garment industry are not viable as the applicability experiences noticed in Asian countries. The industry lacks understanding of lean production concepts due to rareness of applied researches. This in turn validates unlesshigh-level involvement of researchscholarsand manufacturershaveapprehended, the required change may not easily be perceived. As part of reverting such drawbacks, we are here to showscholarly initiative to further presentits applicabilityfor solving industrial problems in garment industry in Ethiopia.

3. Methodology

3.1. Research design

Theoretical generalization and empirical analysis had been used to achieve the purpose. Google Scholar, Science Direct, Scopus Index, Research Gate were among the databases used to extract mostly scientific publications and scholarly discussions. Qualitative and quantitative data mining approaches on the other hand were used to map out baseline data of existing process.

3.2. Data collection

Three garment factories in Ethiopia had been assessed and one of them was selected as a longitudinal case study. However, for privacy purpose, its appellation will not be presented and consequently, it is designated as case-X. Both secondary and primary data were used such as the secondary data that have been collected based on data composed by other sources, such as review of literatures, turning manuals, and historical documents. The primary data in turn were collected based on shop floor visit, questionnaire survey, and based on focus group discussion(s).

The shop floor visit was the best way to map out existing production process. Lead time, products produced, and bottleneck resources were recorded by directly observing all jobs of selected production line. Meanwhile, work sampling was used to present reliable picture of the entire process. For this purpose, one production line (designated as production line-3) was chosen from the total sewing lines of case-X. During this survey, a process flow chart was used to map out sequence of activities and a checklist to record elapsed time of each activity. Likewise, actual time of operations of each activity was measured using stopwatch and the minimum number of observations for ±5% accuracy and 95% confidence level was calculated with model presented in equation (1) [33].

$$\square = \left[\frac{40\sqrt{\eta\Sigma(f x^{2})-[\Sigma(fx)]^{2}}}{\Sigma(fx)}\right]^{2} \qquad (1)$$

Explanation of notations in the equation have been presented in the index part of section 4 and based on equation (1), number of reading cycles taken for each job was 14 times.

The questionnaire survey in turn was used to investigate parameters that affect productivity. It was obtained from 100% of operators of a single production line(which counts 28 respondents) and 15% of supervisors, and other workers of cutting and finishing sections of the whole production plant (that counts 17 respondents). The focus group discussion besides was aimed to support the shop floor visit when something is not clearly observed. It was made through piloting a meeting with top management members.

3.3. Data analysis

The intensively collected data have come into in-depth analysis using different statistical tools. The aim was to articulate three decision variables namely manufacturing lead time, resource utilization, and TiP ratio. These variables have selected because the case study owns modern sewing machineries from Juki but skirmishes to deliver products on time. Time and resource management are not at their optimal level relative to production plant’s missions to deliver right products with right quality and at a reasonable cost.

4. Results: alongitudinal case study

For convenient purpose, the following indexes, decision variables, and parameters have beenusedthroughout thestudy.

Indexes			
I	Operation index	f	Frequency of observation
T	Time for operation i	x	Value of observations
N	Number of events	K_n	# of Kanban cards
η	Initial observations	N_n	# of accepted products
∞	Number of observations	G_n	# of products produced
Notations			
O	Processing operation	□	Inspection
⇒	Moving operation	⊃	Waiting
∇	Storage	⊄	Combined operations
Decision variables			
MLT	Manufacturing lead time		
U	Resource utilization		
TIP	TiP ratio		
Parameters			
Q	Pieces going through sequence of n operations		
P_i	Processing time of i^{th} operation; computed from $P_o * n_m$		
P_o	Operation time of a product		
n_m	Operations a product moved to complete its route		
I_i	Inspection time of i^{th} operation		
M_i	Moving time of i^{th} operation		
W_i	Waiting time ofi^{th} operation		
A_t	Net available working time		
C_d	Customer demand per time period		

4.1. Description of case study

Case-X is located in northern Ethiopia, Tigray. It is furnished with state-of-the-art production technologies. It is designed to deliver customer-oriented products to Global North countries such as USA and Europe. Based on make-to-order production, the factory has been producing millions of products through its advanced technological capacity mainly single and double needle sewing machineries from Juki. For this purpose, on average, it has 16 sewing lines, and during the study time, 10 of them were producing one order type for KK customer from Germany. Seven of the 10 sewing lines were assigned to produce white colored round neck t-shirt product family with total order quantity of 327,360 pieces. All the 327,360 pieces shall be delivered to its customers within six months.

On the other hand, while case-X was producing the round neck t-shirt product family, the case factory and Juki have set ordinary PDF allowance that count 23%. 9% for Personal (P) and Fatigue (F), and 14% for unavoidable Delay (D). This is because, during prolonged work period of production, there are ordinary events that make operators not to perform constantly [33].Studies such as [33] have clearly defined rationale for setting such PDF allowances within an industrial environment. During a work, there are interruptions related to production process, such as the rest to overcome operators' fatigue, receiving instruction from supervisors, and machine breakdown. Personal needs, lunch breaks, telephone communication, etc. are on the other hand interruptions that are not related to work but personal interests. Hence, manufacturers have to pre-define allowances related with these interruptions in order to set deliverable production order sheet.

4.2. Results of shop floor visit

As outlined in Table 1, process flow chart has been used to represent the shop floor visit of production line-3. Each product of round neck t-shirt needs25 jobs/tasks including associated lean wastes illustrated in eighth column of the table. From the 25 jobs, three activities can be drawn. Value adding activities (normally the processing operation), necessarily non-value adding activities (moving, inspecting, and storage operations), and non-value adding activities (waiting). Their relative percentage could also be presented, such as the percentage of value adding number of activities the customer is willing to pay counts 31.67%, percentage of necessarily non-value adding number of activities counts 30%, percentage of non-value adding activities counts 21.67%, and the remaining 16.66% designates combined activities. This 'combined activities' designates two or more activities successively performed by one operator. Operator #3 in job #3, for example first attaches a shoulder and then automatically push the attached shoulder to next job to indicate a single operator performs two consecutive activities.

As mentioned earlier, manufacturing lead time (MLT) [14], resource utilization (U)[34], and TiP ratio have been used to articulate the shop floor visit. The MLT, which is a time period between receiving of order and shipment of completed products, is computed from equation (2).

$$MLT = \sum_{i=1}^{n} Q(P_i + I_i) + M_i + W_i \quad (2)$$

The result for the 25 jobs is subsequently offered in Figure 1to show the processing, inspection, moving, and waiting times of each job in Table 1.

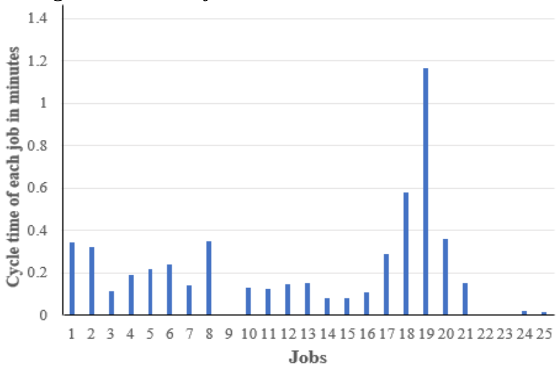


Figure 1. Cycle time of each job (source: survey data)

Based on equation (3), cumulative time of each operation for Q = 1 and for population size$n$ = 25 is presented. Accordingly, total processing operation time counts 3.016 minutes, inspection time 0.306 minutes, moving time 1.024 minutes, and total waiting time counts 0.971 minutes. The total MLT to produce one round neck t-shirt is, therefore, 5.32 minutes or 319.2 seconds. 56.69% of this time is spent on value adding activities and 43.31% on the remaining activities.

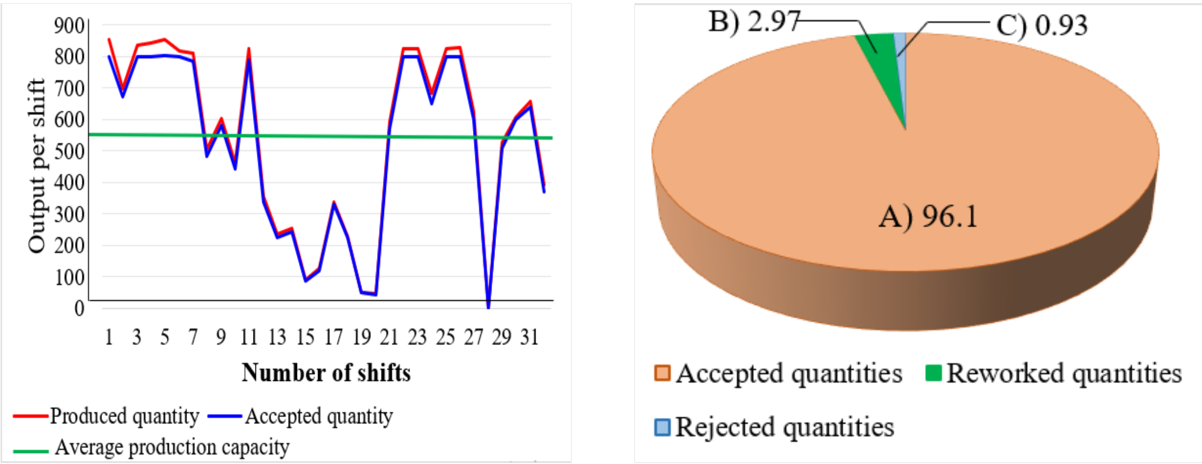
The second variable used to articulate the shop floor visit is resource utilization (U) calculated using equation (3). It refers to all available resources to produce right quantity at exactly right time.

$$U = \frac{N_n}{G_n} \quad (3)$$

The study has consequently articulated total number of accepted products relative to total number of products produced in 32 consecutive working shifts. These shifts are randomly sampled from a total of 130 net available working shifts in six months (seeFigure 2). It was accordingly recognized that there is inconsistent production output within the 32 shifts.

Table 1. Process flow chart of activities of production line-3 (source: survey data)

Job#	Activities						Description
	O	⇒	∇	□	⊃	⊄	
1		√					Move cut quantities to line feeder
2					√		Feeding waits until first sewing operation starts
3						√	Shoulder attach and push to next job
4						√	Shoulder top stitch and move to next job
5	√						Neck rib tack and push to next job
6						√	Neck rib attach by same machines and operator hold them to know her/his target
7					√		Next job becomes idle until predecessor job releases processed products
8	√						Sleeve attach by same machines and push to next job
9					√		Excess products between two successive jobs due to low efficiency of next operator
10						√	Sleeve top stitch and move to next work station
11	√						Piping attach and push to next work station
12						√	Back piping top stitch and push to next work station
13						√	Front piping top stitch and push to next work station
14						√	Bringing quantitatively checked labels from satellite store
15					√		Semi processed products waiting for labels
16						√	Label attach and push to next job
17						√	Side seam by same machines and move to next job
18	√						Trade and fabric trimming
19	√						Bottom and sleeve hemming by same machines
20					√		WIP products wait until offline quality checker pulls them
21				√			Offline quality checking
22			√				Rejected products temporarily placed under conveying tables
23		√					Defective products move back for rework
24					√		Accepted products wait for ironing
25		√					Pushing checked products to iron machine for ironing



(a) Recorded production output per shift

(b) Percentage of resources utilized vs. defective products

Figure 2. Existing production capacity (source: survey data)

For example, as shown in Figure 2(a),production output recorded in shift-1 is 850 pieces and in shift-28 is zero at same working environment and with similar resource availability. This does not mean production line was closed. Production line was opened and all resources were ready for work. However, production stopped for the whole shift due to overshadowing of raw materials. The figure additionally depicts, on average, total number of products produced during the 32 consecutive shifts are 539 pieces per shift with a standard deviation of 281.51 to indicate there is 52.2% lower dispersion degree of population data. Similarly, average number of accepted products become 518 pieces with standard deviation of 270.38 and dispersion level same as before, Part (A) ofFigure 2(b). Equation (3)hence gives, on average, resources have utilized 96.1% (518/539).Parts (B) and (C) ofFigure 2(b)likewise witness the deviation of unutilized resource with percentage of reworked quantities and rejected quantities as 2.97%and 0.93%respectively. This illustrates that there exists production deviation within the existing manufacturing systems.

TIP ratio, computed using equation (4), is the third variable used to articulate the impact of WIP inventory on the production systems.

$$\frac{MLT}{P_i} \tag{4}$$

It measures time a product spends in production relative to actual processing time. According to equation (4) and cycle times in Figure 1,TIP ratio is found to be 1.76:1 (obtained by dividing 5.32 minutes in 3.016 minutes).This value indicates total time a product spent in production system is 1.76 larger than the processing time.

Triangulating the MLT, U, and the TiP ratio summarizes the shop floor visit analysis. At the time of production uncertainty, it is apparent to affect one variable over the other variables. If, for example, case-X were able to use its resources (man, material, and energy) efficiently, the MLT (normally the waiting time) would be able to have reduced value to indicate a product spent in a production is at a lower deviation with scheduled plan. This implies, waiting time will still go through the production if practitioners do not control their resource utilization. Any effort for efficiency would not alone help to improve productivity if resource utilization is not importantly controlled.

4.3. Results of questionnaire survey

This survey, summarized in Figure 3, was aimed to investigate level of WIP inventory, operator's contribution to production efficiency, industrial working environment, and production improving tools and techniques used.

Figure 3(a)and Figure 3(b) accordingly shows53% of respondents believe it is highly important to reduce WIP inventory and 65% of respondents said 'operator's contribution has high impact for improving productivity' respectively. On the other hand, as shown in Figure 3(c), around 31% of respondents have low satisfaction level with existing working environment and 31% have moderately satisfied. In line to this, production plant was using its own tools and techniques to standardize its working environment and to increase productivity. Consequently, 44% of respondents said 'over time' is thebest tool used to achieve productivity and 19% said 'developing good working plan', Figure 3(d). These results, therefore, verify productivity variables are not at their optimal level.

4.4. Results of focus group discussion

This survey confirms that there is variation between scheduled production order sheet and products delivery rate to customer(s). Respondents said the root causes for such variation are backflow of semi-processed products, unorganized storage of frequently used accessories, scraps, seek leave, annual leave, and absenteeism. Though some of these root causes are ordinary, most of them are not acceptable in the currently dynamic market.

To sum-up, though the production plant is equipped with state-of-the-art machineries and engaged in producing export standard products, there are lean wastes that could easily be minimized using different production principles. Cognizant to this, special effort to adapt emerging technologies with capacity to reduce the snags must come into action. Within this framework, lean production principle has been proposed and implemented here in our case.

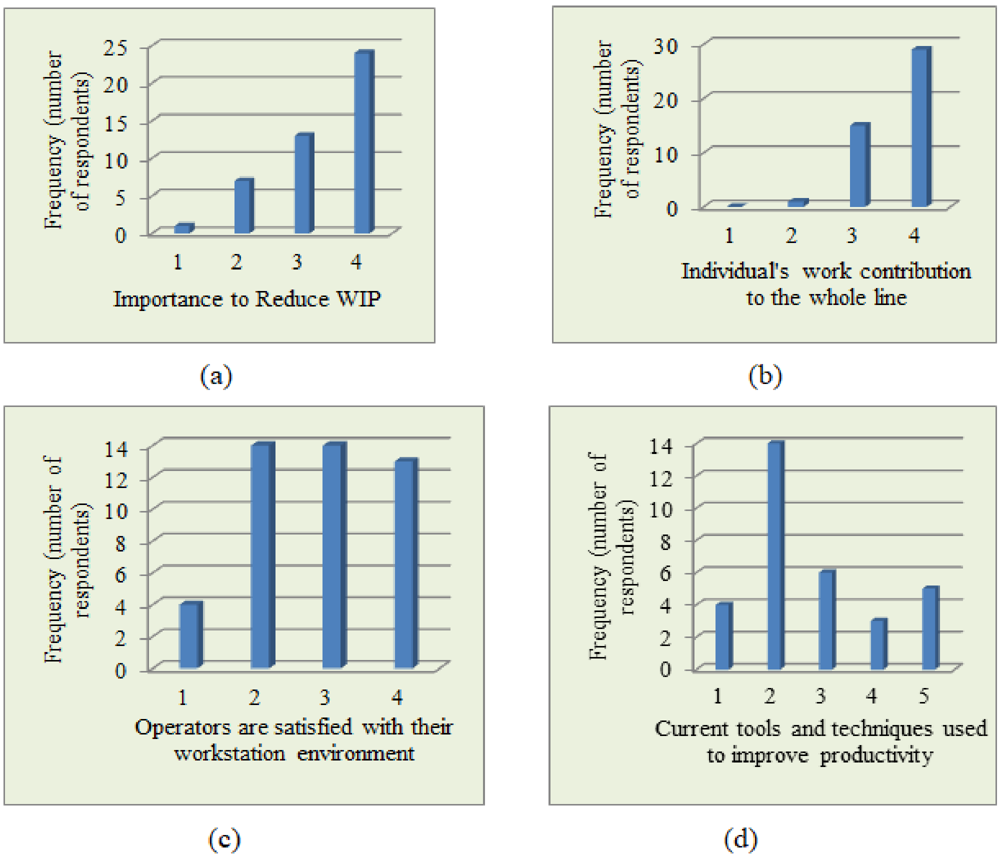


Figure 3. Parameters that affect productivity (source: survey data)

5. Framing and implementing lean production

5.1. Adapting lean production framework

[10]has presented five lean manufacturing elements to improve productivity such that a hard-fact manufacturing flow is among them. The author in turn presented more than eight lean tools(Figure 4(a)) to assess products and their associated manufacturing process. However, only takt time, workload balancing, and kanban sizing have been selected to reduce impact of the lean wastes in our case;Figure 4(b).

5.1.1. Takt time calculation

Measuring the implementation progress of lean production is one of the important steps to apply other lean tools and techniques. That is why calculating takt time (TT) took the first effort in lean production. It tunes rate of work output to rate of customer demand in production setting[35]. It reflects leveling customer demand with aim to produce a pace not much higher than or lower than takt time. Manufacturers must always strive to adjust the MLT to follow takt. One should never measure takt time with stop watch rather he/she must calculate using equation(5).It is expressed as 'seconds per piece', to indicate customers are buying a product once every second[25].

$$TT = \frac{A_t}{C_d} \tag{5}$$

5.1.2. Workload balancing

Once takt has decided, it is now a matter of comparing several activities of manufacturing process with the calculated takt. The goal is to design a balanced work cell. Machine time, man time, and setup time together need to be examined relative to takt time. This implies manufacturing complexity has to be levelled throughout workstations using complexity monitoring heuristic called workload balancing [36].It is used to show how actual work elements of complex process fit into a decided takt time.

Howworkload is balanced? In order to optimize the MLT, bottleneck resources must be minimized, operations must be well assigned to machines, inter-machine movements must be minimized, workforce must be allocated efficiently, and total number of circuits made by products must be minimized [25, 37]. It has to be determined if individual work elements of an activity can be reduced, shifted, re-sequenced, combined, or eliminated.

5.1.3. Kanban sizing

After scheduling is completed, generated takt must be transferred into production using Kanban system. Kanban is a Japanese word meaning signboard to replace what has been used [38]. Kanban sizing is therefore a method of just-in-time production system that uses standard lot sizes with single card attached to product [38, 39]. It is a pull production system aimed to trace transportation information and production information to prevent overproduction.

On the other hand, its implementability has its own rules and regulations. [40] for instance mentioned six most commonly used rules in which 'no items should be transported without kanban' is one of them. Top management commitment, vendor participation, inventory management, and quality improvement are subsequently necessary to implement those rules[24].Reducing WIP inventory is the ultimate target of kanban sizing. To reduceWIP inventory, it is important to eliminate waiting time, reduce customer's pickup volume, and reduce variation in production rate.For this purpose, calculating the number of kanban cards using equation (6)[41] is necessary. The goal is not to exceed the calculated number of kanban cards.

$$K_n = \frac{\left(\frac{\text{designed production rate designed cycle time}}{\text{Net available time}}\right)}{\text{Container size}} \tag{6}$$

5.2. Implementing the adapted leanframework

Calculating takt time followed by workload balancing and kanban sizing validate the adapted lean production framework. In order to calculate the takt time, working and non-working days or hours or minutes or seconds in a given time interval must be identified, PFD allowances must be acknowledged, and number of production lines must be outlined, see Table 2. The required takt is calculated at the last row of the table. The manufacturing system needs to complete a job of one round neck t-shirt every 59.2 seconds to stay in step with customer's demand. All existing cycle time should consequently pace this time by improving and balancing all activities and resources.

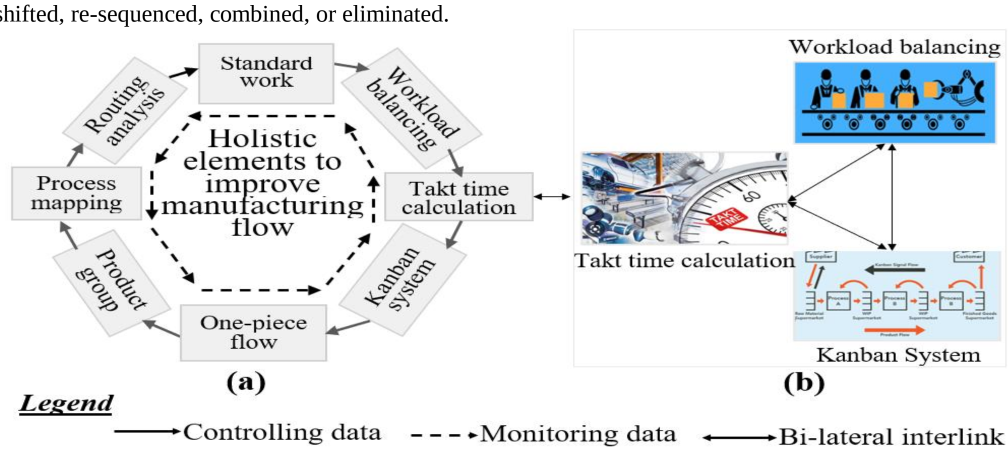


Figure 4. Adapted lean production framework. (a) Manufacturing flow elements (adapted from [10]), **(b)** Adapted lean production tools and techniques

Balancing the workload begins by comparing cycle times in Figure 1with the takt time computed in Table 2. Though it is not expected each height in Figure 1will be equal, it was good if they were similarly heighted. However, there is significant variation in each bar. The highest bar in job 18 for example indicates bottleneck resource. This implies jobs with shortest bars have high WIP inventory until jobs with highest bars complete their task. Thus, unlike job 18, cycle time of each job should be similar to each other and synchronized to takt. This synchronization has been made by redistributing jobs within the entire production time rather than considering a single job's time.

To do the synchronization, recall from Figure 1and Table 2 respectivelythat the existing production process needs an MLT of 319.2 seconds and atakt of 59.2 seconds. To make the synchronization, eliminating waiting time is minimum requirement. The waiting time of all the waiting jobs (job #2, #7, #9, #15, #20, and #24 inTable 1) counts 58.26 seconds. Hence, MLT without the waiting time gives260.77 seconds.

The newly designed MLT, therefore yields 4.4 theoretical work stations found by dividing 260.77 seconds in 59.2 seconds. Here, the theoretical work stations should be five as there will not be decimal work station. The five theoretical work stations again result 52.15 seconds per work station for the synchronized jobs obtained by dividing 260.77 seconds in 5 work stations. This time is consequently the averagely designed cycle time for the synchronized job groups. This implies, all cycle times of all synchronized jobs in the new work stations should circulate around this time in order to stay takt. This has summarized at the third and fourth columns of Table 3where Y_2 is the balanced working cells without the waiting activities in Table 1and Y_1 the before-lean workstations.

Table 2. Computing takt time

Item description	**Time**	**Quantity**	**Clarification**
Total number of days in six months	180		KK needs to receive its products in six months
Non-working days within six months (e.g., Sunday and holidays such as Easter)	33		Production was at the first half of a year
Products last shipment time in days	17		Ethiopia to Germany
Net available working days in six months	*130*		*180 - (17+33)*
Total time available per shift in minutes	540		9 hours * 60 minutes
Lunch time per shift in minutes	60		Lunch time
PFD allowance in minutes	125		23% * 540 minutes
Net available time per shift in minutes	*355*		*540 - (125+60)*
Net available time in six months in minutes	*46,150*		*355 * 130*
Total order quantity in pieces		327,360	Round neck t-shirt
Customer demand per shift per seven production lines in pieces		2519	(327,360 * 355)/46,150
Customer demand per shift per single production line in pieces		*360*	*2519/7*
Computed takt time in seconds	**59.2**		**(355/360) * 60 seconds**

Table 3. Newly designed and balanced workload

<table>
<tr><th colspan="2">Pre-lean workload</th><th colspan="2">After-lean workload</th></tr>
<tr><th>Y_1</th><th>Time per work station (in seconds)</th><th>Time per work station (in seconds)</th><th>Y_2</th></tr>
<tr><td>1</td><td>20.46</td><td rowspan="4">51.66</td><td rowspan="4">1</td></tr>
<tr><td>3</td><td>6.78</td></tr>
<tr><td>4</td><td>11.4</td></tr>
<tr><td>5</td><td>13.02</td></tr>
<tr><td>6</td><td>14.4</td><td rowspan="4">50.63</td><td rowspan="4">2</td></tr>
<tr><td>8</td><td>20.98</td></tr>
<tr><td>10</td><td>7.92</td></tr>
<tr><td>11</td><td>7.33</td></tr>
<tr><td>12</td><td>8.70</td><td rowspan="6">52.64</td><td rowspan="6">3</td></tr>
<tr><td>13</td><td>9.24</td></tr>
<tr><td>14</td><td>4.81</td></tr>
<tr><td>16</td><td>6.54</td></tr>
<tr><td>17</td><td>17.35</td></tr>
<tr><td>18'</td><td rowspan="3">67.02</td></tr>
<tr><td>18</td><td>52.02</td><td>4</td></tr>
<tr><td>18''</td><td rowspan="4">53.82</td><td rowspan="4">5</td></tr>
<tr><td>19</td><td>34.68</td></tr>
<tr><td>21</td><td>9.12</td></tr>
<tr><td>25</td><td>1.02</td></tr>
<tr><td>Total</td><td>260.77</td><td>260.77</td><td></td></tr>
</table>

The existing 'trade and fabric trimming' job shown in column 2 of the table embraces the highest time which is 67.02 seconds. 7.82 seconds above takt time and nearly 15 seconds above the newly designed cycle time per work station.Thus, in order to stay synchronized, about 6 seconds of this task should be performed by operator in work station-3 (Y_2 inTable 3) and 9 seconds of the task by operator in work station-5to reduce a global delay. The other jobs of Y_1 simply demands grouping within the five theoretical works stations. Clearly, a balanced workload in order to stay takt.

Kanban system has finally been used to sustain the balanced workload. Kanban card framed for producing the roundneck t-shirt is shown inFigure 5.

Product Name: t/shirt	**Process**
Part number: ART-5575	
Part description: Round neck and short sleeve	
Part quantity: __	**Sewing**
Point of consumption: fabric=289 gsm, and labels=1	
Point of supply: Warehouse	

Figure 5. Kanban card

Number of kanban cards determines the manufacturing process improvement. Accordingly, equation (6) gives 14 kanban cards are required given that designed production rate is 360 pieces/shift, newly designed cycle time is 52.15 seconds, available time per shift is 355 minutes, and size of container is 4 bundles, only for the round neck t-shirt.

*How kanban card circulates?*Diagrammatic illustration of newly designed kanban circulation isshown in Figure 6such that the Arabic numbers indicate the jobs.

When customer (it could be next workstation or customer at the loading station) comes for his/her pickup, the kanban cards have been removed and placed in a temporary kanban post. From this post, the kanban cards are picked upand transported to kanban shelf at the end of a sewing line. The production workers withdraw kanban cards from the shelf in sequential order and the production process produces the product quantity listed only on the kanban cards. The operator again attaches the kanban cards to products produced and places them in a designated spot, ready for pickup.

6. Synthesis and discussion

Lean production carrying three tools has been adapted to the context of garment industry in Ethiopia. The aim was generally to improve productivity through optimizing manufacturing lead time, resource utilization, and TIP ratio.This local validation consequently witnesses novelty of the study by illustrating its theoretical and managerial contributions and by demonstrating its sustainability implications.

6.1. Theoretical contribution

To the best knowledge of authors, important materials on lean production have reviewed to draw up the framed proposition. The review was done with postulation to establish difference and to give insight about lean production tools and techniques to manufacturers and researchers. Meanwhile, we believe the framing approach and the implementing approach we trailed differs from previous researches conducted on similar subject matter which can also be considered as novelty of this study.

6.2. Managerial contribution

The authors are certain that the adoption has brought substantial managerial contributions. Manufacturing lead time, resource utilization, and TiP ratio have shown considerable improvements after the adoption. MLTfor instance has reduced from 319.2 seconds to 260.77 seconds, 18.3% improvement. TiP ratio has meanwhile reduced from 1.76:1 to 1.44:1; an improvement of 18.18%. The 1.44:1 ratio is obtained by dividing 260.77 (the new MLT) seconds in 180.96 seconds (the sum of P_i's).If takt decided, workload balanced, and if a required material handling mechanism is provided, there is minimum chance of product rework and product rejection. Accordingly, the 3.9% unutilized resourceshave higher chance for reduction after the adoption. The following additional points are also the outcomes of the adapted framework:

- The cycle times of every job have been synchronized to takt,
- More than 90% reduction in WIP inventory has been ensured,
- The maximum time required to process the 'trade and fabric trimming'which was 67.02 seconds has reduced to 52.02 seconds. The difference between these two times gives nearly 15 seconds. This implies, as a result of using newly decided takt time and balanced workload, 15 seconds * 327,360 pieces giving 4,910,400 net working seconds or nearly 56production days can be saved.

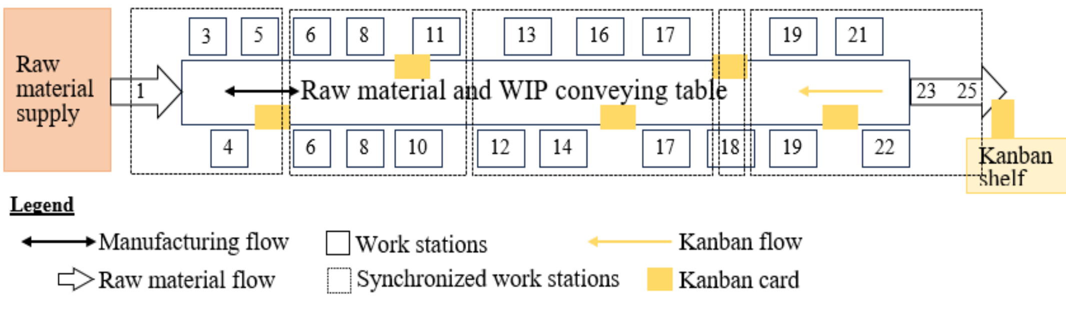


Figure 6. Newly designed kanban circulation

6.3. Sustainability implication

Sustainability role of lean manufacturing for industrial development is increasing [42, 43]. As part of this, industrial activists and other responsible bodies in the Global South (in our case the garment industry in Ethiopia) must always be geared towards sustainability assessments. The reduction in MLT and the increase in resource utilization in our case are subsequently ensuring lowered production time which in turn guarantees environmental sustainability through shortening vaporized utility operations. The study meanwhile has verified that product quality results extended life cycle of the product and hence sustainability byreducing time that products spend in production plant.

7. Conclusions

Pursuing lean production in garment industry in Ethiopia may be challenging but it is key to drastically minimize lean wastes. The aim of this study was to penetrate this challenge by analyzing existing manufacturing process of the industry. Proposition of lean production framework then followed with a target to substantially create smooth working environment and to improve productivity. The associated results obtained showed that there is high WIP inventory, long lead time, un-stabilized pace of production process to pace of customer demand, and defective products are part of the existing manufacturing process. Based on these results, takt time, workload balancing, and kanban sizing have been adapted with expectation to level production workload, achieve one-piece flow, and hence to produce right product at the right time. Manufacturing lead time, resource utilization, and TiP ratio have consequently used to empirically verify applicability of the proposition. Theoretical contribution, managerial contribution, and sustainability implication of the proposition was then discussed with a goal to validate its industrial impact.

However, the study left to continuously validate sustainability of the proposition in other garment factories. A greater applicability of this proposition is, therefore, expected to be explored considering other garment cases and other different sectors that look for same production philosophy.

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