Journal of Optimization in Industrial Engineering
Vol. 16 , Issue 1., Winter & Spring 2023, 9 - 17
DOI:10.22094/JOIE.2022.1904036.1763

Research Article

Productivity Improvement Through Customized Lean and Six Sigma for Garment Manufacturing Industries

Teshome Bekele Dagne *

College of Engineering and Technology, Wolkite University, Wolkite, Ethiopia.

Received 10 July 2020; Revised 27 December 2022; Accepted 28 December 2022

Abstract

Today's highly flexible and dynamic customer demand for the best quality of products with lower selling price and short delivery time makes garment manufacturing industries globally stiff to survive and to compete in the world market. Lean concentrates on the elimination of production wastes to create a production system highly adaptive to meet market demand. Six sigma, on the other hand, is a continuous improvement plan that is intended to reduce variability. However, the scale of implementation of lean and six sigma in developed and developing countries varies based on the technologies' own manufacturing. In this paper, a customized lean and six sigma is implemented through DMAIC (Define, Measure, Analyze, Improve, and Control)-based methodology for the emerging garment industry in Ethiopia. In addition, the efficiency of the customized lean and six sigma in reducing the quality problem and enhancing the productivity is proven through a real case study. The customized lean and six sigma helps the case company to lower the lead time by 36.05%, increased the sigma level by 21.03%, and increase labor productivity by 25.54%.

Keywords: Customized; DMAIC; Lean; Six sigma; Productivity improvement

Nomenclature

CT	Cycle time
VSM	Value stream mapping
VA	Value-added activities
NVA	Non-value added
PBS	Progressive Bundle System
DPMO	Defects-per-million-opportunities
DMAIC	Define-measure-analyze-improve-control
WIP	Work in process inventories
SIPOC	Supplier-Input-Process-Output-Customer
Pkt pre	Pocket preparation
Pkt att	Pocket attaching
A. welt att	Auto welt attach
Welt top st	Welt top stitch
St Ph serging	Seat patch serging stitch
Side Sm.	Side seam top stitch
Knee ph.	Knee patch
Back r.	Back rise over lock
Back pkt. Ol	Back pocket over lock

1. Introduction

The labor-intensive nature of the garment industry makes developing countries put their economic foundation in the garment and textile. Ethiopia as a growing country has put garment and textile as a pillar-manufacturing sector in its growth and transformation plan. Ethiopia has been targeted export revenue of textile and garment worth of USD 500 million, but this remains a simple ambition that the actual exports were USD 99 million, the reason behind this is because the productivity, quality, and price affordability of the garment product could not be computing over the world global market (Demissie and et al., 2015).

In developing countries, the garment industries manufacturing cost of the product and the productivity of the industries are far from the international benchmark of the garment sector. This is due to the manufacturing process is full of messy and the entire product flow is not visualized. The occurrence of a quality problem at the early stage is not easily traced and incurs a cost of late detected quality problems. In addition, the production system is a progressive bundle system (PBS), which makes difficult to mapping the flow of product in the production process. These core problems in the emerging garment industries make it globally stiff to compete in the world market. Therefore to solve stated above problem, the garment sector needs to reform their manufacturing procedure and need to follow the state of the art manufacturing system like lean manufacturing systems to address their manufacturing wastes and six sigma to improve product quality in order to fully utilize their resources.

The novelty and originality of the present study are: (1) a customized lean and six sigma is proposed for the Ethiopian garment manufacturing industry. (2) The customized lean and six sigma implemented using

Corresponding author Email address: teshome.dagne3@gmail.com

DMAIC problem-solving method in the Ethiopian garment manufacturing industry. (3) The efficiency of the customized lean and six sigma in reducing the quality problem and enhancing the productivity is proven through a real case study.

The remainder of this paper is organized as follows: Section 2 introduces a related literature review. Section 3 reports the case study and DMAIC methodology implementation steps. Section 4 presents the conclusion and future research direction.

2. Literature Review

The clothing industry is labor-intensive and has a relatively low requirement for fixed capital as a result entry into the clothing industry is relatively easy (Abdulmalek & Rajgopal, 2007) Among the textile and garment sector, the garment industry is the most labor and material intensive. The cost of production of the garment sector is more dependent on its labor and material consumption. The productivity and success of the garment factory mainly depend on the human factor. An improvement on the human factor in the garment operation process using the lean tool will have a considerable result in the overall performance of the garment (Chadalavada & et al.2015).

Lean manufacturing can be defined as "A systematic approach to identify and eliminate waste through continuous improvement by flowing the product at the demand of the customer"(Deodhar & et al. 2014). Lean manufacturing helps to identify productive and non-productive activities. Productive activities focus on any activity that the customer will pay for value-adding to the product. Non-productive activities describe the customer does not consider as adding value to his product (i.e., waiting time, defective works and reworks, inspection time, wrong motion, improper transportation). Lean manufacturing improves productivity, save manufacturing cost and increase market competency (Singh & et al. 2018) (Asif & et al. 2019)

Six sigma is used to solve the problem of the high rejection of yarn cones in a garment company. It was found that variation in yarn length; yarn count, empty yarn container weight, and yarn moisture content were the root causes for this rejection (Drew & et al. 2016). Six sigma as a strategy for improvement and problem-solving methodology that can eliminate the root cause of effects (Demeter & Matyusz ,2011). (Kumar et al. 2008) highlighted the potential of DMAIC six sigma in realizing the cost savings and improving quality by using the case study of a leading manufacturer of tools. The study examined one of the chronic quality issues on the shop floor by utilizing Six Sigma tools. The study showed that the DMAIC Six Sigma process is an effective and novel approach for the machining and fabrication industries to improve the quality of their processes and products and ensuring profitability by driving down manufacturing costs (Kumar & et al. 2008). Six sigma was described as business improvement approach that finds and eliminate defects or causes of mistake in processes (Muthukumaran & et al., 2013). Tushar et al.,(2008) adopted the DMIAC methodology in manufacturing companies to identify, quantify and eliminate sources of waste in an operational process, up to optimization usage of the available resources, improve the sustainable performance of the production line improvement with well-executed control plans in future (Fursule & et al., 2012).

The concept of merging lean and six sigma can be traced back to 1997 when BAE Systems tried to combine lean manufacturing principles with six sigma. The company named their program lean sigma strategy to protect the market share in the aerospace industry (Gupta & Bharti, 2013). They mixed, the Kaizen team with Black Belts planning at reducing variation within their processes. As a result, BAE systems achieved substantial improvements in productivity, lead time, savings, and reliability. In 1999 an effort to combine Lean manufacturing and six sigma was carried out by Maytag Corporation. The corporation re-engineered one of its production lines making use of the core concepts of lean manufacturing and six sigma by this approach the corporation reduced down manufacturing costs and achieved savings in million dollars (Bheda, 2004). Though six sigma is adept at identifying and eliminating defects, it does not address how to optimize the system by improving process flow. Lean methodologies, on the other hand, lack the statistical analysis required to achieve a truly "lean" system. By combining the lean and six sigma methodologies, aims to achieve total customer satisfaction and improved operational effectiveness and efficiency by removing waste and non-value added activities, decreasing defects, decreasing cycle time, and increasing first-pass yields. (Kumar & Abuthakeer, 2012) However, a separately implementation of lean and six sigma methodologies often fail to lead to results that achieve the dramatic improvements that organizations desire. As a result, the integration of lean and six sigma is important for productivity improvement and to sustain the continuous improvement in manufacturing system (Byrne & et al., 2021) (Mulugeta, 2021)

&Table 1 summarizes the issues addressed by lean manufacturing and six sigma.

The Ethiopian government defined the textile and garment sector as a top priority sector in its industrial development package. The government planned to achieve $1 billion from the exports of textile and apparel products from 2010-11 to 2014-15. However, the performance of the Ethiopian textile and apparel exports during the first three years period was only $305 million, which is only 48% of the target(Demissie and et al., 2015).. This shows that the country did not succeed in making use of this valuable opportunity because it is unable to compete in the global market mainly due to the productivity and quality of garment products.

DMAIC method (i.e., Define, Measure, Analyze, Improve, and Control) used as a tool to improve the output parameters like product quality, lead time, labor productivity, and manufacturing cost with the consideration of input parameters like defects, non-value-added and value-added activity within the process (Rose, & et al. 2020) (Jamadar & and et al. 2019). Table 1. Summarized issues addressed using lean manufacturing and six sigma.

Table 1
Summarized issues addressed using lean manufacturing and six sigma

Issues addressed	Lean manufacturing	Six sigma	Source
A customer focused value stream	√	x	(Wilson, 2010)
Create a visual workplace	√	x	(kumar & et al. 2012)&(Arnheiter & Maleyeff 2005)
Attacks work-in-process inventory	√	x	(George Michael, 2005)
Good house keeping	√	x	(Khanna, 2015)
Reducing variation and achieve uniform process outputs	x	√	(Barac, 2010)
Focuses on statistical tools	x	√	(Nash & et al. 2006)
Employs a structured, rigorous and problem solving methodology	x	√	(Nourbakhsh & et al., 2013)
Attacks waste due to waiting, over processing, motion, over production, etc.	√	x	(Byrne and et al., 2021) &(Peash & Hayen (2012)

Note: (√: yes, x: no)

3. Case Study

Nowadays, medium-scale garment industries' inauguration in Ethiopia becomes higher and higher. NovaStar garment is one of the emerging garment industrial plants with high export products in Ethiopia. Their main products are baseball pants in various order sizes and potential customers are the USA and Europe. However, those medium-scale garment industries have limited potential and are unable to meet today's highly flexible customer demand for best product quality and short delivery time, make emerging garment manufacturing industries globally stiff to survive and to compete in the world market. Especially, the production line hardly faces challenges from a quality problem and meeting target production plan due to high defect level and unnecessary movement of the work pieces in their production line. Therefore, in this paper customized lean manufacturing and six sigma is implemented in the baseball pant production line of the NovaStar garment to reduce the quality problem and enhance productivity. The customized lean manufacturing is used to eliminate unnecessary movement of work pieces (transportation waste) within each workstation cell while the six sigma helps to detect and reduce the rate of occurrence of defect level at the source.

4.1. DMAIC problem-solving implementation phases

Figure 1 depicts the procedure of implementation of DMAIC problem-solving methodology phases. The DMAIC implementation phases follows: Define (D), Measure (M), Analyze (A), Improve (I), and control (C) successive steps originated from six sigma concepts.

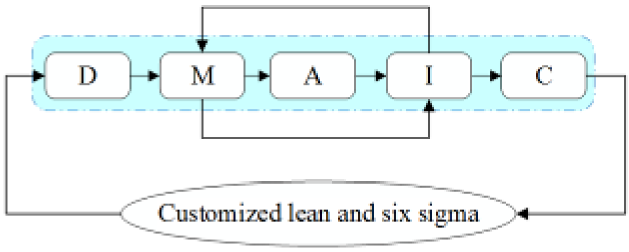


Fig. 1. Schematic diagram of DMAIC problem-solving implementation flow chart

4.1.1. Define Phase

In this phase, the goals were defined to improve the current progressive bundle production system product flow in the production line. The most critical goals were acquired using the voice of customer method (i.e., supplier-input-process-output-customer (SIPOC)) as shown in Figure 2. These goals would be helpful for the betterment of the company to easily visualize and mapping of the product flow process from end to end. In addition, the goals also help to the early direct cause of defects and bring down the defect level in order to improve the quality of the product for a given production line.

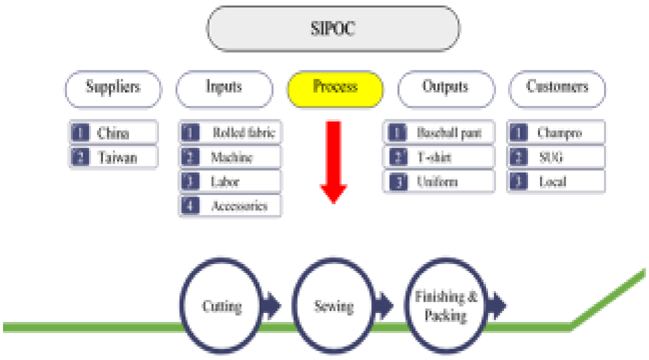


Fig. 2. Supplier-Input-Process-Output-Customer

The lion's share of causes of wastes in the stitching and finishing production line of the case company is shown in Figure 3.

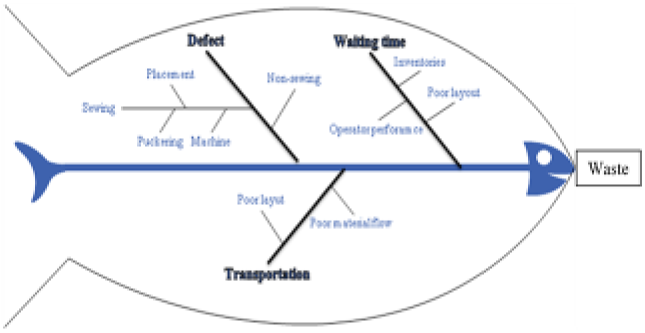


Fig. 3. Major causes of waste

4.1.2. Measure Phase

In this phase, the baseball pant product flow is measured using value stream mapping (VSM) in order to identify value-added activities (VA) and non-value added (NVA) in stitching production lines and material transportation in the finishing section as shown in Figure 4.

4.1.3. Measure Phase

In this phase, the major causes of waste are analyzed in the baseball pant production line. Figure 5 depicts the existing layout Progressive Bundle System (PBS) versus the new lean layout. In the existing PBS layout, there are more movement of helpers, poor machine layout results in unnecessary handling work pieces, and operator stitching direction makes a face-to-back system which creates unnecessary 180^0 degree movements either to give or take a work pieces and less ergonomic. In stitching production lines the existing PBS is face-to-back system creates a reparative back-and-forth movement of worker body's movement to pick and handle the work pieces. In addition, in PBS layout has high work in process inventories (WIP) results in poor detection of the quality problem at the sources and high displacement of work pieces between workstations. Whereas the new customized lean layout enables a face-to-face system to share common work pieces table for WIP movement and resolve the main drawbacks of the existing PBS layout. In addition, the new implemented lean layout solves the prior worker's pain that comes from un-ergonomic posture bodies movements.

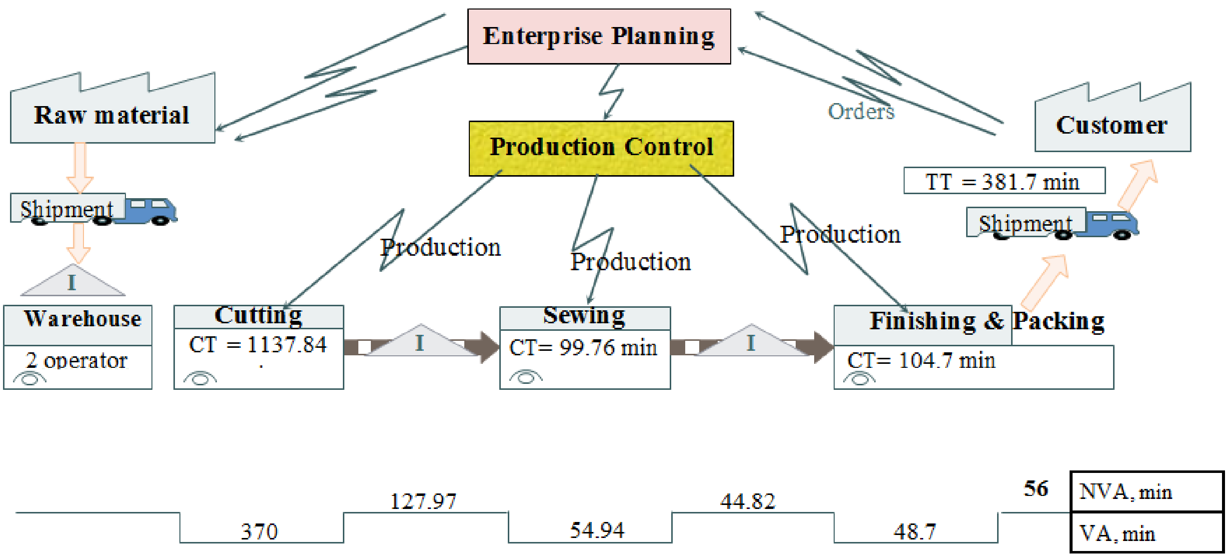


Fig. 4. VSM for baseball pant production

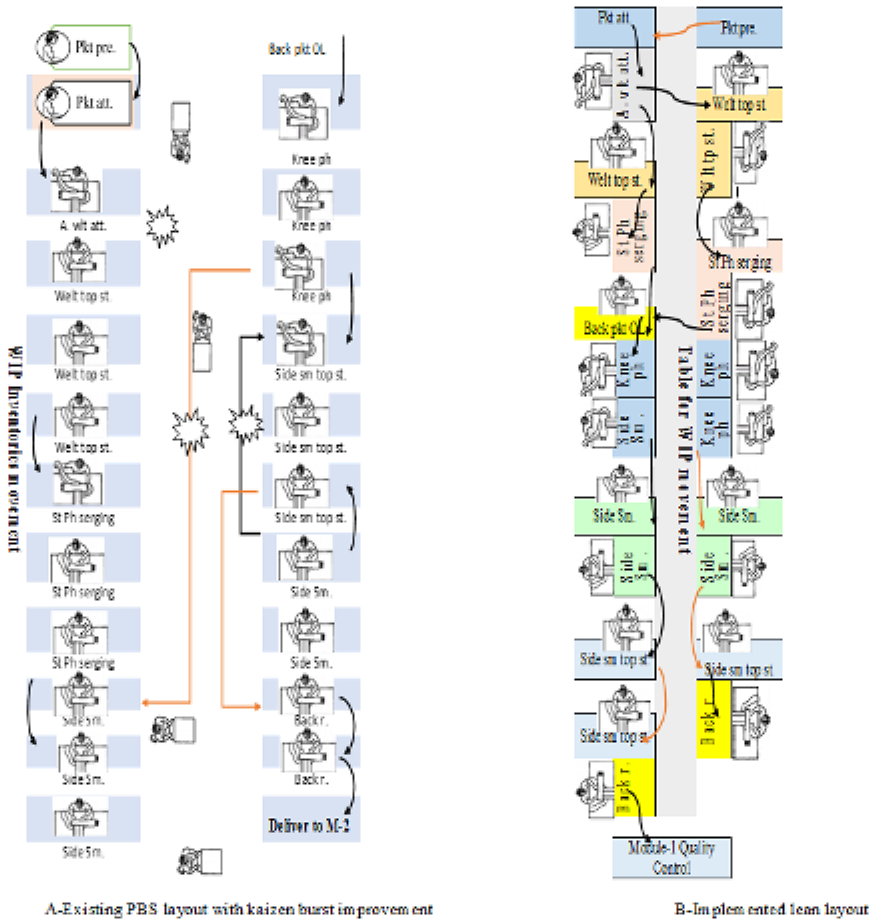


Fig. 5. Work pieces movement between existing and implemented layout in stitching production line

Figure 6 displays the overall comparison of stitching production lines in pre-and post-implementation of the customized lean layout. The lean layout out helps to reduce the prior wastes related to waiting time, non-value-added activities and work pieces material movement in each workstation.

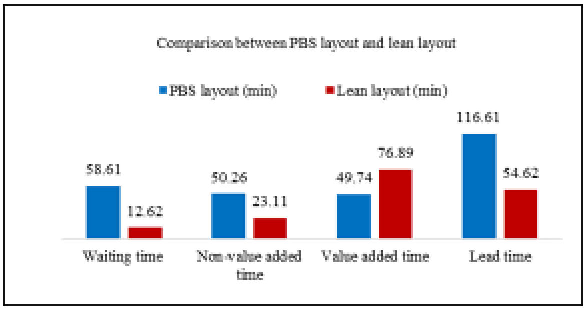


Fig. 6. Comparison between PBS and lean layout in stitching operation

The overall achievement comparison in WIP material movement and helper transportation in pocket preparation and side seam stitching section in stitching production line before and after implementation of lean layout is shown in Figure 7. The lean layout helps to remove the previous unnecessary work pieces material movement through sharing WIP moving table and eliminate helper transportation.

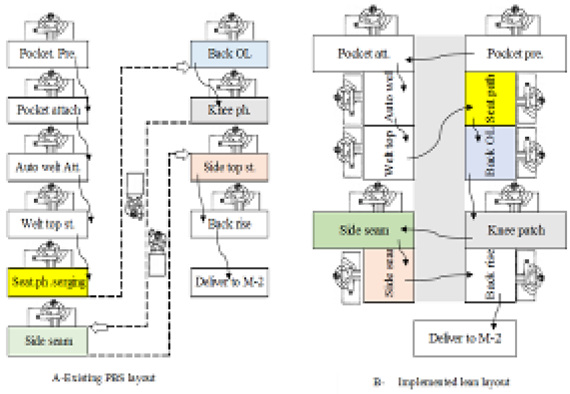


Fig. 7. WIP and helper movement in pre-and post-improvement for side seam stitching operation

Figure 8 illustrates the relationship between transportation waste in distance and time before and after customized lean implementation for the side seam stitching section. The work piece's flow displacement in the existing PBS layout was 4 meters. After customized lean layout implementation the previous works pieces flow displacement becomes 1.25 meters. In addition, the lean layout helps to reduce the non-productive worker movement drastically. Thus, because of implemented lean layout, the non-productive transport time was reduced by 21.77% as compared to the previous PBS layout.

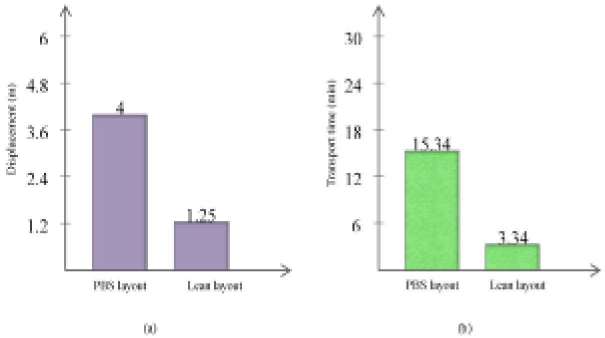
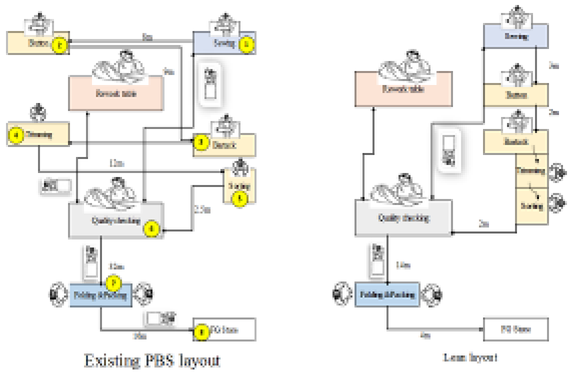


Fig. 8. Transportation waste in side seam stitching operation (a) distance (b) time

The overall achievement comparison in WIP material movement and helper transportation in finishing production line before and after implementation of lean layout is shown in Figure 9. The lean layout helps to remove the prior high transportation waste in WIP material displacement and helper movement.



(Note: Bartack refers to stitching for reinforcing areas of a garment)

Fig. 9. WIP and helper movement in PBS and lean layout in finishing section

Figure 10 depicts that the material transportation waste reduction after lean implementation in the finishing production line. The material transportation in the existing PBS layout was 87.5 meters and after implemented the lean layout was 25 meters, which means the non-productive worker movement has been decreased drastically as shifting from the existing PBS layout to the lean layout. In addition, the graph indicates that because of the changed layout, the non-productive transport wastes reduced by 71.43 % as compared to the prior PBS layout.

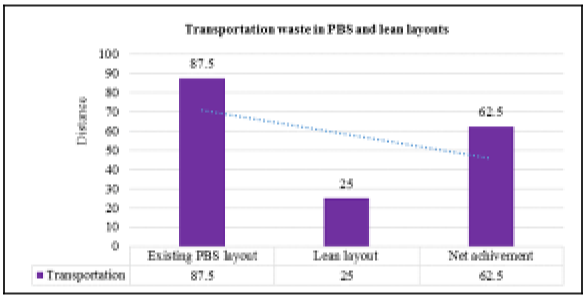


Fig. 10. Transportation waste in finishing production line

The occurrence of defect rates in the production line is ranked and traced as their root causes using a cause and effect diagram. Figure 11 displays the major causes of the observed defect in stitching and finishing production is identified and prioritized through a Pareto chart.

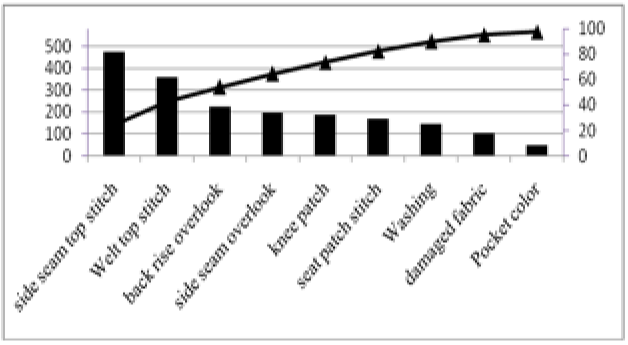


Fig. 11. Pareto analysis for types of defects

The major defects identified from the Pareto chart analysis are further considered for analysis and the most occurring defect are summarized in Table 2.

Table 2

Major defects identified from the Pareto chart

S.no	Defect Types
1	Side seam top stitch
2	Welt top stitch
3	Back rise overlook

Through brainstorming with shop quality supervisors, all potential causes for the major defects are identified. The root causes are given in the cause and effect diagram. The cause and effect diagram illustrates how defects are identified, measurement, and corrective action taken for side seam top stitch is illustrated in Figure 12 and Table 3 respectively. The same procedure and corrective action were taken for others defects.

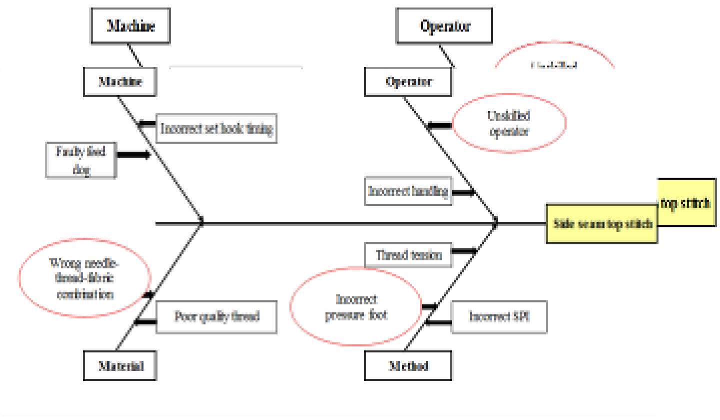


Fig. 12. Cause and effect diagram for side seam top stitch operation

Table 3
Correction measurement for side seam top stitch operation

Cause	Solution
Operator	Provide adequate training to the operators to boost their skill
Wrong needle-thread-fabric combination	A correct combination of needle-thread-fabric
Incorrect pressure foot	Tension, SPI, and pressure foot should not be fiddled with much

After identifying and prioritizing the major causes of defects, operators are trained in all aspects of their job and after the remedial actions are taken; the products are checked for defects. The number of defects before and after implemented correction solution is shown in Figure 13.

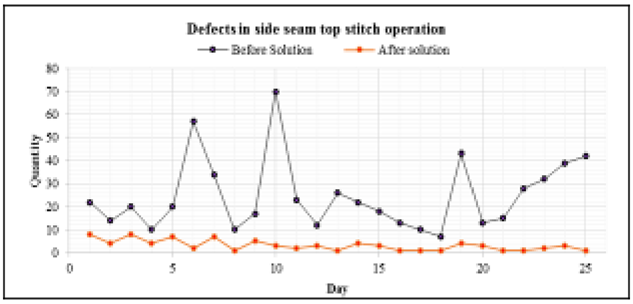


Fig. 13. Defect level before and after corrective actions for side seam top stitch operation

4.1.4.. Improve phases

In this phase, the overall improvement achieved due to the implementation of the customized lean and six sigma in the case company in terms of quality improvement, cycle time and labor productivity are described in detailed.

I. Sigma level improvement

Table 4 summarizes the total number of defects collected data before and after taking the remedial correction measurement considering the root causes of defects at stitching and finishing production line.
Figure 14 depicts the sigma level improvement in terms of defects-per-million-opportunities (DPMO). The average sigma level before improvement was 2.71 and after taking the necessary corrective action, the improvement becomes 3.28. This shows that the total defective percentage has been decreased drastically. Therefore, this helps NovaStar garment industries to maximize the percentage yield from 89.8% to 97% and increase the process quality level by 21.03%.

Table 4
Number of defects

Metrics	Before improvement	After improvement
Total checked	19130	19130
No. Defectives	1951	435
% Defectives	10.20	2.27
DPO	0.101986	0.022739
DPMO	101986.4	22739.15

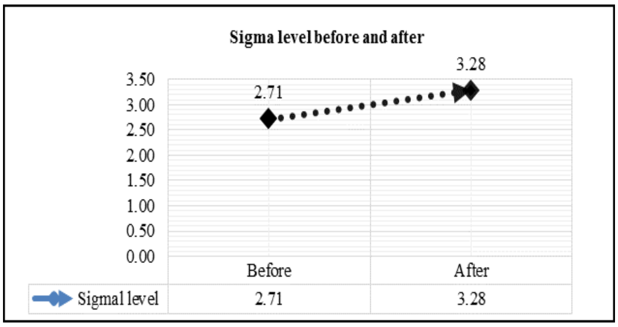


Fig. 14. Comparison of sigma level improvement

II. Cycle Time

The total cycle time (CT) comparison between the existing PBS layouts with the lean layout is illustrated in Table 5. The PBS layout has a higher cycle time for a given task as compared to the new lean layout for the same tasks in stitching and finishing the production line. The new lean layout enables to improve the cycle time by 29.12% in the stitching production line and 63.72% in the finishing production line. The prior total cycle time in PBS layout has been improved by 30.83% per baseball pant production after customized lean layout implementation.

Table 5
Cycle time comparison

Section	CT in PBS layout per item	CT in lean layout per item	Improvement in minutes per item	% Improvement
Stitching, min	54.94	38.94	16	29.12
Finishing, min	2.85	1.04	1.82	63.72
Total	57.79	39.98	17.82	30.83

III. Labor Productivity

The total labor productivity comparison between the existing PBS layout before improvement and the new lean layout after improvement is shown in Figure 15. From the comparison chart, for the first week, the PBS layout shows high production as compared to the lean layout due to until the workers adapted the new face-to-face layout arrangement. After the workers are familiar with the new lean layout based on face-to-face arrangement, the total production becomes higher and higher following the first weeks. The new lean layout face-to-face arrangement has more effective and better productivity increment than the previous back-to-face arrangement of PBS layout. The lean layout improves labor productivity by 17.55% as compared to the existing PBS one. In addition to this, in PBS layout there are high WIP inventories in each workstation of the production line, which is difficult to clear out in case of small and flexible customer demand.

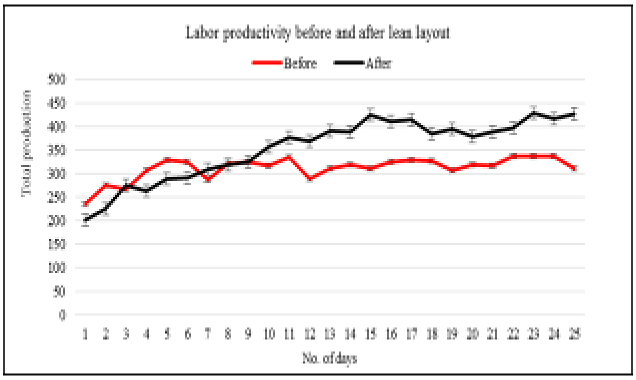


Fig. 15. Comparison of labor productivity in existing PBS and lean layout

4.1.5. Control phases

To sustain the achieved six sigma quality level, periodically workers awareness creation through training and enhancement of detecting quality problem at the source. Taking corrective action based on the identified defect is vital to sustain the gained improvement using DMAIC steps is necessary.

4. Conclusion

A customized lean and six sigma for emerging garments is introduced in the present paper to improve the quality of products and increase productivity with consideration of lean manufacturing and six sigma in the production line. Based on lean manufacturing/layout/ for product flow mapping and six sigma control scheme, smooth but efficient product quality and lead time improvement in the production line is achieved. The potential causes of wastes in the production line are studied and presented using a cause and effect diagram and prioritize through a Pareto chart in stitching and finishing the production line. Based on the implemented customized lean layout and six sigma for enhancing the competitiveness in the global market, the goal of labor productivity, improve quality, and delivery time of products is realized. Further, the efficiency of the production line after customized lean manufacturing and six sigma implementation is validated through collected data from the real case company.

The implemented customized lean layout and six sigma approach helped the case company to lower the lead time by 30.39%, increased the sigma level by 21.03%, increase labor productivity by 17.55%, and the overall improvement results in a decreased manufacturing cost by 30.83%. The result shows that a customized application of lean and six sigma are more effective and efficient in minimizing manufacturing waste in the emerging garment industries. In addition, for flexibility and fashionable products, the implemented flexible layout for the case company helps to meet the due date and easy visualization of product flow in the production line.

Several interesting extensions of this research can be conducted in the future. First, developing an integrated method to implementing customized lean and six sigma in an integrated industrial plant containing both textiles with garment section. Second, implementing a module quality-based checking for early detecting the quality problem at the source.

Acknowledgments

The authors appreciate the editor and anonymous reviewers for their valuable comments and suggestions to revise this article.

References

Abdulmalek, F. A., & Rajgopal, J. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. International Journal of production economics, 107(1), 223-236.

Abrham, S., & Geremew, S. (2018, October). Application of Lean Tools for Reduction of Manufacturing Lead Time. In International Conference on Advances of Science and Technology (pp. 1-10). Springer, Cham.

Arnheiter, E. D., & Maleyeff, J. (2005). The integration of lean management and Six Sigma. The TQM magazine.

Asif, A. A. H., Hasan, M. Z., Babur, J. U. M., Sheikh, M. M. I., Biswas, A., Uddin, M. K., & Rana, S. (2019). Lean Manufacturing for Improving Productivity at Sewing Section in Apparel Industry: An Empirical Study. International Journal of Textile Science, 8(1), 1-9.

Barac, N., Milovanovic, G., & Andjelkovic, A. (2010). Lean production and six sigma quality in lean supply chain management. Economics and Organization, 7(3), 319-334.

Bheda, R. (2004). Improving working condition and Productivity in the Garment Industry. Contact Communications, Stitch World.

Byrne, B., McDermott, O., & Noonan, J. (2021). Applying Lean Six Sigma Methodology to a Pharmaceutical Manufacturing Facility: A Case Study. Processes, 9(3), 550.

Chadalavada, Hemadri, Samuel Raj, D, Kumar, Ashok, & Sankar, K. (2015). Production Lead Time Reduction in a Battery Manufacturing Unit using Lean

Manufacturing. Paper presented at the International Journal of Engineering Research and Technology.
Dadi, G., & Azene, D. (2017). A TQM and JIT integrated continuous improvement model for organizational success: An innovative framework. Journal of Optimization in Industrial Engineering, 10(22), 15-23.
Demeter, Krisztina, & Matyusz, Zsolt. (2011). The impact of lean practices on inventory turnover. International journal of production economics, 133(1), 154-163.
Demissie, A., Zhu, W., Kitaw, D., & Matebu, A. (2015). Quality Assessment on the Garment Enterprises in Ethiopia. In IIE Annual Conference. Proceedings (p. 743). Institute of Industrial and Systems Engineers (IISE).
Deodhar, Sunil V. Desale and Sharad V. (2014). Identification and eliminating waste in construction by using lean and six sigma principles. International Journal of Innovative Research in Science, Engineering and Technology, 03(04).
Drew, J., McCallum, B., & Roggenhofer, S. (2016). Journey to lean: making operational change stick. Springer.
Fursule, N. V., Bansod, S. V., & Fursule, S. N. (2012). Understanding the benefits and limitations of Six Sigma methodology. International journal of scientific and research publications, 2(1), 1-9.
George Michael, L. (2005). The lean six sigma pocket tool book: A quick reference guide to nearly 100 tools for improving process quality, speed, and complexity. Edición McGraw-Hill.
Gupta, N., & Bharti, P. K. (2013). Implementation of Six Sigma for minimizing the defects rate at a yarn manufacturing company. International Journal of Engineering Research and Applications, 3(2), 1000-1011.
Jamadar, V. M., Shinde, G. V., Kanase, S. S., Jadhav, G. S., & Awasare, A. D. (2019, February). Productivity Improvement in a Manufacturing Industry Using Value Stream Mapping Technique. In International Conference on Reliability, Risk Maintenance and Engineering Management (pp. 79-84). Springer, Singapore.
Khanna, R. B. (2015). Production and operations management. PHI Learning Pvt. Ltd.
Kumar Chakrabortty, R., & Kumar Paul, S. (2011). Study and implementation of lean manufacturing in a garment manufacturing company: Bangladesh perspective. Journal of Optimization in Industrial Engineering, (7), 11-22.
Kumar S. Anil and Suresh. (2008). Production and operations management. New age international Pvt. Ltd.
Kumar, B. S., & Abuthakeer, S. S. (2012). Implementation of lean tools and techniques in an automotive industry. J. Appl. Sci., 12(10), 1032-1037.
Mulugeta, L. (2021). Productivity improvement through lean manufacturing tools in Ethiopian garment manufacturing company. Materials Today: Proceedings, 37, 1432-1436.
Muthukumaran, G., Venkatachalapathy, V. S. K., & Pajaniradja, K. (2013). Impact on integration of Lean Manufacturing and Six Sigma in various applications-a review. Journal of Mechanical and Civil Engineering, 6(1), 98-101.
Nash, M., Poling, S. R., & Ward, S. (2006). Using Lean for faster Six Sigma results: A synchronized approach. CRC Press.
Nourbakhsh, K., Z. Ali, I.M. Shah and G. Sara. (2013). Investigating the influence of six sigma implementation in Khorasan steel plant in year 2011. Res. J. Appl. Sci. Eng. Technol., 06(13), 2296-2306.
Peash, M., & Hayen, A. (2012). Application of Lean Manufacturing Tools in Garments Production (Doctoral dissertation, Daffodil International University).
Rahmati, S. H. A., Kazemi, A., Saidi Mehrabad, M., & Alinezhad, A. (2013). A New Fuzzy Method for Assessing Six Sigma Measures. Journal of Optimization in Industrial Engineering, 6(13), 39-47.
Rose, A. N. M., Mohamed, N. M. Z. N., Noor, H. M., & Mohd, A. (2020, June). Improving productivity through value stream mapping (VSM): A case study at electrical & electronic company. In Journal of Physics: Conference Series (Vol. 1532, No. 1, p. 012005). IOP Publishing.
Singh, J., Singh, H., & Singh, G. (2018). Productivity improvement using lean manufacturing in manufacturing industry of Northern India: A case study. International Journal of Productivity and Performance Management.
Wilson, L. (2010). How to implement lean manufacturing (pp. 45-197). New York: McGraw-Hill.

This article can be cited: Dagne, T. B. (2023). Productivity Improvement through customized lean and Six Sigma for Garment Manufacturing Industries. *Journal of Optimization in Industrial Engineering*, *16*(1), 9-17.
doi: 10.22094/joie.2022.1904036.1763