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ISSN: (Print) (Online) Journal homepage: <https://journals.bdu.edu.et/index.php/ejta>

To cite this article: Chipambwa Walter, Chisosa Fadzai. D (2025) PRODUCTIVITY IMPROVEMENT THROUGH TIME STUDY IN A GARMENT FACTORY, Ethiopian Journal of Textile and Apparel, 43 -53,

DOI: <https://journals.bdu.edu.et/index.php/ejta>

# Productivity improvement through time study in a garment factory

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ABSTRACT

This study focuses on time study as a tool for improving productivity in the apparel industry. A qualitative case study research was carried out for a garment unit producing graduation gowns, using an observation guide and recording each process in five cycles to come up with an average time for each operation. Five cycles were observed to ensure statistical stability and minimize variability in task times. In the study, it was highlighted that using different employee ratings resulted in different Standard Minute Value (SMV) for the construction of a single graduation gown. Employees need to be trained so that they perform their tasks as fast as they can so that the overall time taken to finish one product is also reduced. Though allowances in time per task should be allocated, they should be as minimal as possible for all the tasks in the production line. By optimizing SMV through employee training and process standardization, garment manufacturing factories can reduce production costs by 15%, enhancing their competitiveness in price-sensitive markets. The overall key highlight is that the cost price of one single gown is determined by the standard minute value thus having control over it also means being more competitive on the market.

**KEYWORDS:***​*time study, productivity, apparel production, efficiency, manufacturing

**INTRODUCTION**

The global pressure on the apparel manufacturing sector forces companies to continuously improve their production systems so that they reduce operational costs while assuring that they maintain the quality of the products they supply to the market (Kamal & Yesmin, 2022; Nattrass & Seekings, 2018; Subhashini & Varghese, 2021). Failure to do so compromises their chances of survival in the market as they face global competition. The garment industry is labour-intensive thus there is a need to look at ways of reducing cost production and at the same time maintaining the quality the customers expect (Ocampo et al., 2020). One way of reacting to these global pressures is by applying various lean tools to the production system (Flores et al., 2021). Strategies employed by organizations to gain a competitive edge are crucial for the success of their operations (Khan et al., 2021). In the clothing manufacturing industry, different strategies can be applied to improve productivity and these include process optimization, technology adoption, workforce engagement, sustainable practices, quality management, and strategic management (Alzoubi et al., 2022; Ewnetu & Gzate, 2023; Islam & Adnan, 2016; Subhashini & Varghese, 2021). These methods depend on choice, trustworthiness, cost-effectiveness, and the ability of the personnel to execute them. Alzoubi et al. (2022) and Park-Poaps et al. (2021) report that the garment industries in developing countries benefit from lower labour costs; thus, they should put more effort into sourcing raw materials cheaply and try to reduce operating costs so that they can supply products competitively on the global market. Many African nations are ranked under developing economies, despite having abundant human and material resources. Almost all apparel industries try to improve their production capacities and the quality of their products to sustain themselves in the viciously competitive market. Chisosa and Chipambwa, (2018) indicate that clothing manufacturing entities have to implement innovative management systems such as time study in their production processes to meet deadlines, reduce lead times, and optimize material use, with the ultimate goal of being competitive in the market or remain viable. According to Mulugeta (2021), lean tools can be used to improve productivity in garment manufacturing as these have the ultimate goal of improving the efficiency of the entire production system. Improving the efficiency of the production line, results in reduced total cost of production and overheads as more products are produced using the same resources. Historically the apparel manufacturing industry has been labour-intensive and slow in adopting technological developments (Fromhold-Eisebith et al., 2021; Parschau & Hauge, 2020). Technological developments such as Computer-Aided Design (CAD), 3D virtual sampling, automation, sustainable practices, and data-driven strategies, have made the industry achieve higher productivity levels at less cost (Donmezer et al., 2023; Murugesan et al., 2024). As these technologies and innovations evolve, they promise to improve the apparel manufacturing sector, balancing profitability with planetary responsibility. To enhance the efficiency of a garment-making line, the target is to reduce or improve the total time taken to construct one piece of garment from the start to the end, in line with the production system employed (Bongomin et al., 2020; Nchalala et al., 2023). While lean tools like 5S and Kaizen are widely adopted, time study remains underutilized in developing economies for addressing labor-intensive bottlenecks.

Various studies (Hanan & Seedahmed, 2018; Howlader et al., 2015; Jadhav et al., 2017) have been done in other garment manufacturing setups seeking to improve efficiency through the use of the time study technique. According to Paneru (2011), time study is a work measurement technique used by apparel engineers to determine the rate at which a specific operation is performed. The purpose of carrying out time study analysis in apparel setups allows us to determine the actual time taken by a qualified worker to perform a specified task under certain conditions and at a defined rate of working. Thus, the company can calculate the number of units that can be produced timeously, for example hourly, daily, or weekly. In their study on a shirt production facility, Jadhav et al. (2017) state that time study for garment operation is one of the best tools to improve efficiency and also emphasize that the order sheets of the various products on the production line are crucial as they ensure timely dispatch of the finished goods to the customer.

In a manufacturing setup, operational efficiency is one of the important indicators that can reveal how effectively the resources are being used. Production resources like raw materials, manpower, machines, energy, and other supplies have a relationship that needs to be audited so that by varying the quantities and qualities of these inputs, an optimum input combination can be established.

Time study is a work measurement technique in which we analyze data recorded during the set conditions to establish the definite time necessary for an operator to carry out an operation at a definite rate (Rajiwate et al., 2020). Ewnetu and Gzate, (2023) state that productivity improvement is vital as it reduces production lead time and manufacturing cost. Productivity improvement is also essential, as it reduces the waiting time, and bottlenecks and increases the production line efficiency, thus making the organization more competitive as it can produce more products quickly. Productivity is derived from a method study, whereas improvements are gauged by time studying. Time study and line balancing are effective techniques to influence the time for a specific operation, which in turn improves productivity (Rajiwate et al., 2020). Standard time can be obtained using a variety of ways such as time study, basic standard data system, pre-determined time, motion time systems (PTMS or PTS), work sampling and structured estimating, and standard minute value (Drew et al., 2016). To establish the standard times an operation takes various methods can be used and these include the use of stopwatch time study, the use of historical times of executing a procedure, the use of pre-determined data, and work sampling (Stevenson, 2020). Bongomin et al. (2020) state that time study is the most applicable tool for line balancing problems commonly found in sewing lines. Even though automatic sewing machines are now gaining popularity in the garment-making industry these still require an operator and there are a lot of other manual operations done in the production lines. In this study, we chose time study due to its adaptability and achievement stories associated with apparel production. Chisosa and Chipambwa (2018) reveal that apparel industries have to carry out an analysis of their operations to see where the overall costs incurred in the production line can be improved. Several methodologies have been tried and tested in improving manufacturing processes which include work-study, kanban system, and Toyota production system (TPS). Time study has also been found to be a useful solution to manufacturing challenges as evidenced in the success stories of apparel manufacturing industries in Bangladesh, India, and China (Ramdass & Pretorius, 2011). According to Kulkarni et al. (2014), work-study can be split into two major areas namely method study (motion study) and time study (work measurement). Generally, work-study seeks to achieve a certain format of how different yet related activities can be carried out such that there is effective use of resources as it sets the expected standards of performance and the expected quality to be achieved for all the processes within a manufacturing entity. The study was done at a business unit run by a university that manufactures various apparel products for the institution and the community. This unit also serves as a typical apparel industry model for the students to learn the different activities from a simple piece of fabric to the final full garment. The unit boasts of industrial machines that are used in the manufacture of various products like graduation gowns, work wear, and corporate wear for the institution's employees.

**Statement of problem**

The apparel-making industry faces several challenges worldwide and they are usually synonymous, these include low productivity levels, labour turnover, lead time, reworks, product returns, bottlenecks, line balancing, and line flexibility. All these problems impact negatively on the companies’ image and efforts should be made to improve these parameters as they affect the overall production efficiency. The graduation gown production line faces problems that have resulted in late order fulfillment frequently and also operational bottlenecks. The graduation gown production line faces chronic delays due to unbalanced workflows and inconsistent operator efficiency, resulting in an approximate 20% deficit or delay in order fulfillment timelines. The objective of this study was to improve the efficiency of the graduation gown production line through a time study technique. Through time study the study sought to establish the bottlenecks and also the time cycles for various operations undertaken to produce a single graduation gown with a motive of improving the line and balancing the machine setup. The study also seeks to address and contribute to the literature on how time studies can improve the productivity of garment or apparel industries in developing economies through the use of SMV, line balancing, and quality issues.

**Literature review**

Heizer et al. (2017) define time study as the systematic practice of directly observing and measuring human labour with a timing device to determine how long it takes a competent worker to complete a task at a specific level of performance. On the other hand, Yemane et al. (2017) define time study as work measurement, which is similar to Heizer et al. (2017) definition as it deals with techniques designed to establish the time for a qualified worker, to carry out a specified job at a definite level of performance. Originally proposed by Frederick Winslow Taylor (1881), the classical stopwatch is still the best method for determining operational times for tasks under time study. The pioneering advocates of industrial management and engineering recognized the importance of using analytical techniques to calculate the actual cost of manufacturing operations and setting the operation times thus enabling more precise decisions to be made in production. Time study is commonly attributed to Taylor (1856-1915) as evidenced by his earlier works and it is from his works that Bedaux (1884-1944) refined Taylor’s work resulting in the modern work measurement technique system. In coming up with a standard time, Taylor multiplied the sum of the average element times by a factor which allows for rest and other necessary delays. If used correctly time study can provide the necessary foundation for lean principles to be adopted in the organization (Klein et al., 2022). Other lean tools like takt-time, heijunka, poka-yoke, 5S, just-in time and kaizen can also be used to improve the productivity of garment manufacturing set up and this can be a springboard for growth of the company (Flores et al., 2021; Khatun, 2014; Kulkarni et al., 2014; Paneru. N, 2011; Subhashini & Varghese, 2021).

There are seven types of waste found in the garment production set up and these are overproduction, waiting time, transportation, non-value-adding processing, holding excess inventory, motion, and defects. Gay, (2025) opines that there is another eighth type of waste in garments namely, underutilized people within the production lines. The eighth waste can only be improved if the optimal input of all the employees can be attained. But this can always be a challenge as workers perform differently thus an average but acceptable process time should be established for various tasks a garment has to go through. Such developments are made possible through time and motion study and work study so that work can be measured and achievable targets can be set.

Motion study works as an alternative to time study. For the apparel manufacturing industries to survive in the competitive business environment products must be manufactured in the least possible time with the fewest possible inputs but at the same time not compromising the quality of the output (Chisosa & Chipambwa, 2018). In today's competitive business environment, clothing manufacturers must use task simplification, job design, and value analysis to increase productivity, lower costs, and deliver high-quality items. Within the garment industry time variation is a must, since the garments are made by different machine operators. For this reason, Khatun, (2014) emphasizes the need to set a standard target for different products, thereby making time study a mandatory process for improving efficiency in garment production. Yemane et al. (2017) indicate that time study helps in the efficiency of doing things right without wasting resources. They go on to state that time study can be divided into three categories and these are manual time, mental time, and machining time. Since garments are created by different machine operators and have varied processes, time variation is needed in the apparel business. Time study should then be used to evaluate the number of processes required to produce each garment. Manufacturing the appropriate number and quality of items within the allotted time and budget is crucial to production management. During the design stage of a product, the cost of the product is set and the standard time taken for production is also set (Ewnetu & Gzate, 2023). Alzoubi et al. (2022) state that by analyzing the process and the standard operating times one can then determine the standard cost of the particular product thus allowing analysis of variance between the actual and standard cost. While Paneru (2011) advocates for time study adaptability, Nabi et al. (2015) caution that rating factors introduce subjectivity. This tension highlights the need for hybrid approaches to balance standardization and workforce variability. Recent work by Ahamed et al. (2024) and Mondal and Jana, (2024) integrates machine learning with time study to automate SMV calculations, reducing human bias in rating factors.

**Methodology**

A qualitative case study was conducted on a graduation gown production line to evaluate time study’s efficacy in apparel manufacturing companies in developing economies. Five cycles were observed per task, aligning with Howlader et al. (2015) recommendation for stabilizing cycle time averages. Operators were selected to reflect the factory’s skill diversity (1–5 years of experience), and a 15% allowance was applied for fatigue and machine setup, consistent with industry standards (Jadhav et al., 2017). To mitigate the Hawthorne effect, observers discreetly recorded times during routine production. The study was a case study of a single line producing graduation gowns with an overall objective of improving the line's efficiency. Systematic observations were carried out to establish the activities taken to construct a single graduation gown in the natural setting allowing the workers to go on with their tasks without hindrance. A time study was done using following the stages as listed,

1. Analysis of work- ​*complete job and its operations are split up into various elements which* *are finalised after conducting a motion study*
2. Standardization of methods- ​*all the constituents of the job such as materials, equipment,* *tools, working conditions, and methods are standardized*
3. Making time study- ​*The study is done on a printed time study record sheet*

In carrying out time study the formulas were,



*Standard time* = *Average time* × *Rating factor* + *Other allowances*

Standard time is the time which is taken by a worker to do a specific task or job. Standard times also include other allowances that might be involved in doing the job or task such as setting of job, repairing tools, checking of job, and fatigue.

The rating factor is the average time a worker takes to do an operation expressed as a percentage of the efficiency of an experienced operator. In other words, it simply compares the operator to his or her fellow average workers. Normal performance targets must be such that they give a standard output that is within the range capacity of the majority of workers in the production line. It would be wrong to set high standards only achievable by the best worker as estimates based on them would never be fulfilled.

*The performance rating can be assumed to be 100% for all employees and that gives us an SMV1.*

*The way employees perform is different and their efficiency in relation to other employees at different stations will give us SMV2 thus the rating factor for each employee becomes different.*

Rehman et al., (2019), recommend the use of resources such as printed time study record sheets and also, the use of a stopwatch to observe and measure time to do a single operation cycle in seconds. When the use of stopwatch time study was ushered by Taylor, it faced a lot of criticisms one of them being the Hawthorne effect but it eventually gained more acceptance and is now being used as the technique for work measurement (Kwasnitschka et al., 2024). The Hawthorne effect is when subjects change their behaviour as they become conscious of being watched or studied (McCambridge et al., 2014). This implies that a worker might change the speed of executing a task in the line as they become aware that they are being watched. This can lead to wrong standard operating times being set and as such one should time the operation in such a way that they reduce the Hawthorne effect. Paneru, (2011) states that the experience of the person carrying out the time study is a key variable as it can affect the whole production system, which is one of the major problems that affect the apparel industries.

**Results and discussion**

Table 1: Time study sheet

|  |
| --- |
| **TIME STUDY SHEET** |
| SHEET #: TS001 |  | MACHINE: SNLS  |
| OPERATION: GRADUATION GOWN  | STYLE INFO: UNDERGRAD GG |
| FABRIC: BLACK MANDY | ATTACHMENT/GUIDE: N/A |
|  | Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 | Stage 6 | Stage 7 | Stage 8 | Stage 9 |
| Operation  | pleating | elasticizing back | ironing pleats | yoke preparation | elasticizing sleeves | top stitching | joining yoke and gown | sleeves insertion | hemming |
| time 1/sec | 123 | 81 | 106 | 63 | 72 | 62 | 147 | 151 | 140 |
| time 2/sec | 122 | 80 | 97 | 69 | 66 | 58 | 122 | 162 | 138 |
| time 3/sec | 123 | 79 | 104 | 61 | 62 | 69 | 143 | 150 | 134 |
| time 4/sec | 121 | 94 | 99 | 64 | 66 | 67 | 150 | 163 | 134 |
| time 5/sec | 138 | 83 | 110 | 66 | 64 | 64 | 160 | 160 | 127 |
| Total time/secs | 627 | 417 | 516 | 323 | 336 | 320 | 722 | 786 | 641 |
| No. of cycles  | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Ave time/secs  | 125.4 | 83.4 | 103.2 | 64.6 | 67.2 | 64 | 144.4 | 157.2 | 128.2 |
| Allowance | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% | 15% |
| Rating1  | 95% | 90% | 85% | 90% | 90% | 80% | 85% | 95% | 85% |
| Rating 2 | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| SMV1  | 136.9 | 86.3 | 100.9 | 66.9 | 69.6 | 58.9 | 141.2 | 171.8 | 125.3 |
| SMV2  | 144.2 | 95.9 | 118.5 | 74.3 | 77.3 | 73.6 | 166.1 | 180.8 | 147.4 |
| Standard time  | (Total SMV1+ Total SMV2)/2(957.8+ 1078.1)/2 = **1017.95** **secs** |
| Standard time (mins) | **16.97****Minutes** |



 Fig 1 Time study bar chart

The four processes of pleating, hemming, sleeve insertion, and joining the yoke take the most time as shown in Figure 1. The employees assigned to these tasks should therefore be well-experienced and should be highly skilled so that they execute the task quickly. The effect of the differences in ability to execute a task is shown by the two ratings used in the study. The rating factor used to calculate the SMV is affected when the efficiency of the employee is poor and this can lead to incorrect SMV for the product. Usually most scholars (Jadhav et al., 2017; Nabi et al., 2015; Rajiwate et al., 2020; Rehman et al., 2019) prefer assuming a rating of 100% for employees thus giving the standard time in which a full product should be produced. If the rating is calculated for the specific employee doing the task is less than 100% which is the ideal scenario the overall SMV of the product is lower. In this study, two values of SMV were averaged to use the ideal rating and the actual rating so that a more realistic SMV could be established.

The two values of SMV were averaged to come up with a mean value that takes into consideration the 100% rating and the varying rating factors on employees at different stages of construction of the graduation gown. The 100% rating factor could not be taken as the ultimate since employees differ in their level of efficiency. As shown in figure 1 the SMV using the ideal rating of 100% results in a higher SMV of the product. When the employees are less efficient it appears as if the product will take less time since an unknown factor comes into play. The reduced total time taken to finish one graduation gown becomes lower and can be a misrepresentation as the employees might fail to surpass such a target set for them. Unlike Jadhav et al. (2017) findings in shirt production, sleeve insertion in the case of graduation gown required 157.2 seconds (vs. 120 seconds), suggesting garment complexity affects SMV scalability.

Therefore, to come up with a more realistic position the employees need to put effort such that they excel in their duties. In line, monitoring has to be increased to reduce time losses as employees pick up more jobs at their workstations. We recommend implementing an overhead supply system to minimize workstation disruptions. Therefore, the line can produce 26 graduation gowns per day with the current number of nine employees. A normal working day shift is 8 hours and this translates to 435 minutes excluding teabreak and lunch time. Conventional time study relies heavily on mechanical devices and the use of human judgment to establish the rating factor. In the process of coming up with a rating factor, the issue of subjectivity becomes an important parameter as it can affect the SMV of the product. In this study, the two SMVs used reveal how the rating factor can affect the SMV. On the other hand, assuming that all employees can work at the same rate is rather not practical in a real industrial setup as humans differ in, the way they execute their duties. The only way to improve the accuracy of standard time in the conventional time study is to improve the rating ability. Performance rating is necessary in direct time study because all workers perform work at a different pace or performance rating as defined by the organization's definition of 100% standard performance. However, there is a variation of inconsistency in the performance ratings but the variation is measured by a standard deviation of +/-2 commonly agreed by the engineers accounting for observer's errors. Normally, time study engineers re-examine the level of accuracy, and consistency of their studies in individual plants, practice, times do combined time studying in industrial groups, and hold seminars in their industrial constituencies. In this study, the effect of the two values of the SMV for the graduation gowns produced showed how these change the capacity of the production line given two scenarios of the rating factor. The SMV for the graduation gown shows the total time taken to produce one product by considering the individual timeframes taken by each task from start to end. If the SMV becomes too high it also implies the cost price of such a garment becomes higher as fewer products are made with the same production setup. Also filtering back of reworks affects the capacity of the production to produce more products thus the do it right the first time should be encouraged within the line so that reworks are avoided.

Because there are a lot of different operations that are done manually in the garment-making industry, the sewing operations have to go under close supervision so that tasks are executed using minimal time and at the same time maintaining high-quality standards. Improving the line productivity in garment manufacturing significantly affects the overall efficiency in an organization and allows the company to charge competitive prices for their products.

**Conclusion**

Time study is important for the garment industry as it unravels the key bottleneck process in the line so that the supervisors or managers can specifically target these for improvement. The more experienced workers ought to be given those tasks that are referred to as key along the line so that the line is balanced. It should also be highlighted that multi-skilling of employees is also necessary so that in case another employee from the line falls sick they can easily rotate duties along the line in order of their efficiencies. For a manufacturing unit to come up with a true SMV the work-study office should establish the times allowed for any allowances that might be difficult to quantify and these should be given as supporting notes in coming up with SMV for the process. This study introduces a dual-rating SMV model to reconcile idealized efficiency (100% rating) with real-world operator variability, offering a pragmatic framework for labor-intensive industries. For developing economies, SMV optimization can reduce reliance on low-wage labour by aligning productivity gains with automation investments. Quality is a continuous process and garment manufacturing entities should always try to improve their quality as this is key to their survival in the competitive market. Thus, in garment production, the managers should continuously carry out time study analysis of their operations so that they identify areas where there are opportunities to alter the time taken to produce a single product. Factory managers can use SMV benchmarking to identify skill gaps and prioritize training for bottleneck tasks such as sleeve insertion. Some of the operations might imply buying new machines with new technologies for example investing in new automated sewing machines that can improve the total time taken to do a task.

**REFERENCES**

Ahamed, Z., Asanka, D., & Rajapakse, C. (2024). Optimizing Production Efficiency in the Garment Industry: The Role of Predictive Analytics Techniques in Sri Lanka’s Textile Sector. *2024 8th SLAAI International Conference on Artificial Intelligence (SLAAI-ICAI)*, 1–6. <https://doi.org/10.1109/SLAAI-ICAI63667.2024.10844970>

Alzoubi, H. M., In’airat, M., & Ahmed, G. (2022). Investigating the impact of total quality management practices and Six Sigma processes to enhance the quality and reduce the cost of quality: the case of Dubai. International Journal of Business Excellence, 27(1), 94–109. <https://doi.org/10.1504/IJBEX.2022.123036>

Bongomin, O., Mwasiagi, J. I., Nganyi, E. O., & Nibikora, I. (2020). Improvement of garment assembly line efficiency using line balancing technique. Engineering Reports, 2(4). <https://doi.org/10.1002/eng2.12157>

Chisosa, F. D., & Chipambwa, W. (2018). An Exploration of how Workstudy can Optimise the production of Zimbabwe’s Clothing Industry. Journal of Textile and Apparel Technology and Management, 10(3), 1–11.

Donmezer, S., Demircioglu, P., Bogrekci, I., Bas, G., & Durakbasa, M. N. (2023). Revolutionizing the Garment Industry 5.0: Embracing Closed-Loop Design, E-Libraries, and Digital Twins. Sustainability, 15(22), 15839. <https://doi.org/10.3390/su152215839>

Drew, J., McCallum, B., & Roggenhofer, S. (2016). Journey to Lean: Making Operational Change Stick. Palgrave Macmillan.

Ewnetu, M., & Gzate, Y. (2023). Assembly operation productivity improvement for garment production industry through the integration of lean and work-study, a case study on Bahir Dar textile share company in garment, Bahir Dar, Ethiopia. Heliyon, 9(7), e17917. <https://doi.org/10.1016/j.heliyon.2023.e17917>

Flores, H. S., Paucar, L. F., Castro, P., Marcelo, E., & Alvarez, J. C. (2021). Increased Efficiency in a Garment Sector by the Integration of Lean Manufacturing Tools. 2021 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 654–658. <https://doi.org/10.1109/IEEM50564.2021.9672821>

Fromhold-Eisebith, M., Marschall, P., Peters, R., & Thomes, P. (2021). Torn between digitized future and context dependent past – How implementing ‘Industry 4.0’ production technologies could transform the German textile industry. Technological Forecasting and Social Change, 166, 120620. <https://doi.org/10.1016/j.techfore.2021.120620>

Gay, C. (2025, May). 8 Wastes of Lean Manufacturing. Machinemetrics. <https://www.machinemetrics.com/blog/8-wastes-of-lean-manufacturing>

Hanan, S., & Seedahmed, A. I. (2018). Effective way to estimate the standard minute value (SMV) of a U3 shirt by using time study technique. International Journal of Engineering Sciences & Research Technology, 7(7), 179–184.

Heizer, J., Render, B., & Munson, C. (2017). Operations Management Sustainability and Supply Chain Management (12th ed.). Pearson Education.

Howlader, R., Islam, R., Sajib, H. T., & Prasad, R. K. (2015). Practically observation of standard Minute Value of T-shirt. International Journal of Engineering and Computer Science, 4(3), 10685–10689.

Islam, M., & Adnan, A. T. M. (2016). Improving Ready-Made Garment Productivity by Changing Worker Attitude. European Scientific Journal, ESJ, 12(4), 436. <https://doi.org/10.19044/esj.2016.v12n4p436>

Jadhav, S. S., Sharma, G. S., Daberao, A. M., & Gulhane, S. S. (2017). Improving Productivity of Garment Industry with Time Study. International Journal on Textile Engineering and Processes, 3, 1–6.

Kamal, Y., & Yesmin, S. (2022). Competitiveness of Global Apparel Industry: A Study Based on Transaction Cost Theory. Global Business Review. <https://doi.org/10.1177/09721509221124169>

Khan, A. N., Ishizaka, A., & Genovese, A. (2021). A Framework for Evaluating the Supply Chain Performance of Apparel Manufacturing Organizations. International Journal of Supply and Operations Management, 8(2), 134–164.

Khatun, M. (2014). Effect of Time and Motion Study on Productivity in Garment Sector. . International Journal of Scientific & Engineering Research, 5(5), 825–832.

Klein, L. L., Vieira, K. M., Feltrin, T. S., Pissutti, M., & Ercolani, L. D. (2022). The Influence of Lean Management Practices on Process Effectiveness: A Quantitative Study in a Public Institution. Sage Open, 12(1). <https://doi.org/10.1177/21582440221088837>

Kulkarni, P. P., Kshire, S. S., & Chandratre K, V. (2014). Productivity improvement through lean deployment & work study methods. 3(2), 429–434.

Kwasnitschka, D., Franke, H., & Netland, T. H. (2024). Effects of feedback in manufacturing: A field experiment using smartwatch technology. Journal of Operations Management, 70(6), 933–956. <https://doi.org/10.1002/joom.1305>

McCambridge, J., Witton, J., & Elbourne, D. R. (2014). Systematic review of the Hawthorne effect: New concepts are needed to study research participation effects. Journal of Clinical Epidemiology, 67(3), 267–277. <https://doi.org/10.1016/j.jclinepi.2013.08.015>

Mondal, P., & Jana, P. (2024). Application of predetermined motion and time system in sewing automat to enhance the productivity and operator utilisation. Research Journal of Textile and Apparel, 28(4), 550–568. <https://doi.org/10.1108/RJTA-08-2022-0092>

Mulugeta, L. (2021). Productivity improvement through lean manufacturing tools in Ethiopian garment manufacturing company. Materials Today: Proceedings, 37, 1432–1436. <https://doi.org/10.1016/j.matpr.2020.06.599>

Murugesan, B., Jayanthi, K. B., & Karthikeyan, G. (2024). Integrating Digital Twins and 3D Technologies in Fashion: Advancing Sustainability and Consumer Engagement. In P. Raj, A. Rocha, P. K. Dutta, M. Fiorini, & C. Prakash (Eds.), Illustrating Digital Innovations Towards Intelligent Fashion. Information Systems Engineering and Management (Vol. 18, pp. 1–88). Springer, Cham. <https://doi.org/10.1007/978-3-031-71052-0_1>

Nabi, F., Mahmud, R., & Islam, M. M. (2015). Improving Sewing Section Efficiency through Utilization of Worker Capacity by Time Study Technique. International Journal of Textile Science, 4(1), 1–8.

Nattrass, N., & Seekings, J. (2018). Trajectories of development and the global clothing industry. Competition & Change, 22(3), 274–292. <https://doi.org/10.1177/1024529418768608>

Nchalala, A., Alexander, T., & Taifa, I. W. R. (2023). Establishing standard allowed minutes and sewing efficiency for the garment industry in Tanzania. Research Journal of Textile and Apparel, 27(2), 246–263. <https://doi.org/10.1108/RJTA-09-2021-0112>

Ocampo, J., Hernández, J., Márquez, J., & Vizán, A. (2020). The Effect of Process Improvement Practices on Manufacturing Competitiveness of Apparel Factories. Journal of Technology Management & Innovation, 15(1), 15–26. <https://doi.org/10.4067/S0718-27242020000100015>

Paneru, N. (2011). Implementation of Lean Manufacturing Tools in Garment Manufacturing Process Focusing Sewing Section of Men’s Shirt [Masters]. Oulu University of Applied Sciences.

Park-Poaps, H., Bari, M. S., & Sarker, Z. W. (2021). Bangladeshi clothing manufacturers’ technology adoption in the global free trade environment. Journal of Fashion Marketing and Management: An International Journal, 25(2), 354–370. <https://doi.org/10.1108/JFMM-06-2020-0119>

Parschau, C., & Hauge, J. (2020). Is automation stealing manufacturing jobs? Evidence from South Africa’s apparel industry. Geoforum, 115, 120–131. <https://doi.org/10.1016/j.geoforum.2020.07.002>

Rajiwate, A., Mirza, H., Kazi, S., & Momin, M. M. (2020). Productivity Improvement by Time Study and Motion Study. International Research Journal of Engineering and Technology, 7(3), 5308–5311.

Ramdass, K., & Pretorius, L. (2011). Implementation of modular manufacturing in the clothing industry in KwaZulu-Natal: A case study. South African Journal of Industrial Engineering, 22(1), 167–181.

Rehman, A. ur, Ramzan, M. B., Shafiq, M., Rasheed, A., Naeem, M. S., & Savino, M. M. (2019). Productivity Improvement Through Time Study Approach: A Case Study from an Apparel Manufacturing Industry of Pakistan. Procedia Manufacturing, 39, 1447–1454. <https://doi.org/10.1016/j.promfg.2020.01.306>

Stevenson, W. J. (2020). Operations Management (14th ed.). McGraw Hill.

Subhashini, R., & Varghese, M. (2021). Methods of Improving Productivity in Apparel Industry. International Journal of Research in Engineering, Science and Management, 4(4), 130–141.

Yemane, A., Haque, S., & Malfanti, I. S. (2017). Bottleneck Identification Using Time Study and Simulation Modeling of Apparel Industries. Proceedings of the International Conference on Industrial Engineering and Operations Management,

321-330.