

Technology and Education Inputs for Productivity Enhancement in Garment Manufacturing in the Developing World

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Abstract

Efficient production management in the garment manufacturing industry is estimated by using work measurement techniques. These techniques are based on standard processing timings. Several studies have been undertaken using the time study technique to enhance productivity of the garment production lines in an apparel manufacturing factory. Efficiency is translated into the time spent on carrying out a particular function, this time consumption is dependent upon the worker's level of fatigue and quality of output. The entire onus of responsibility of the worker's output becomes anchored on his or her ability to carry out repetitive actions over long durations of time.

Objectives:

This paper examines the work of various scholars as well as scrutinizes the performance of certain repetitive actions in the garment manufacturing process in apparel industries employing large numbers of workers. The objective is to project a rationale for the development of work aids to significantly enhance productivity.

Methods:

A secondary data review is being conducted to find out the work of other researchers in the field of garment manufacturing. The author has developed his own contribution in the form of work aid interventions to help in the process. A Review of literature on the subject was attempted to obtain the required information and insights on the subject.

Finding

There is a widely felt need for the creation of active work aids in the garment manufacturing industry to promote the worker efficiency as also the overall productivity of the industry.

Scope

The research based study has large and far-reaching scope for the garment manufacturing industry. All manufacturing units are constantly on the lookout for promoting efficiency and productivity. They are willing to appreciate all forms of interventions to improve time management and enhanced output of products. The findings of this review paper have broad based applicability for the garment manufacturing industry not only in India but also in most of the developing world.

Key Word: Productivity, manufacturing, efficiency, work timings, time study, work measurement, standard processing and secondary data review.

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Introduction

The garment manufacturing sector plays a significant role in the economic development process of most countries but is most important in countries of the developing world. The garment sector has contributed significantly to the process of industrialization since the 18th century. The entire success of the garment manufacturing sector is dependent on the productivity or overall output of the sector. Thus, productivity is of crucial essence when considering the viability and economic success of any garment manufacturing unit in particular or the entire garment manufacturing sector in itself. Vital lessons have been learnt with regard to work aids for making the output more productivity efficient in the past half a century. The correlation between productivity and a number of factors that influence it must to be analysed repeatedly to guarantee optimum outputs.

Productivity is a function of the effectiveness of the organizational effort to produce goods and render the required services over a period of time. There are several different approaches to ensure productivity improvement which have been examined by various researchers. According to Chowdury and Rahman (2010) some of the greatest problems faced by the operations department can result from high levels of personnel turnover dissatisfaction, absenteeism and boredom on the assembly line. Rahman (2010) worked on providing flexibility in the assembly system which could be redesigned with certain possible alternatives. Bhagirath (2015) focused on the assessment of manpower efficiency to ascertain whether increase in the number of workers resulted in

higher productivity, higher worker efficiency rate and overall performance of the unit. Several previous studies have focused on the human factors responsible for improving productivity. Researchers tended to break down the human factors while attempting and attempted to rearrange the processes and balancing the assembly line simultaneously.

This paper examines the avenues leading to higher productivity among garment manufacturing clusters. An analysis was conducted to understand the existing conditions like:

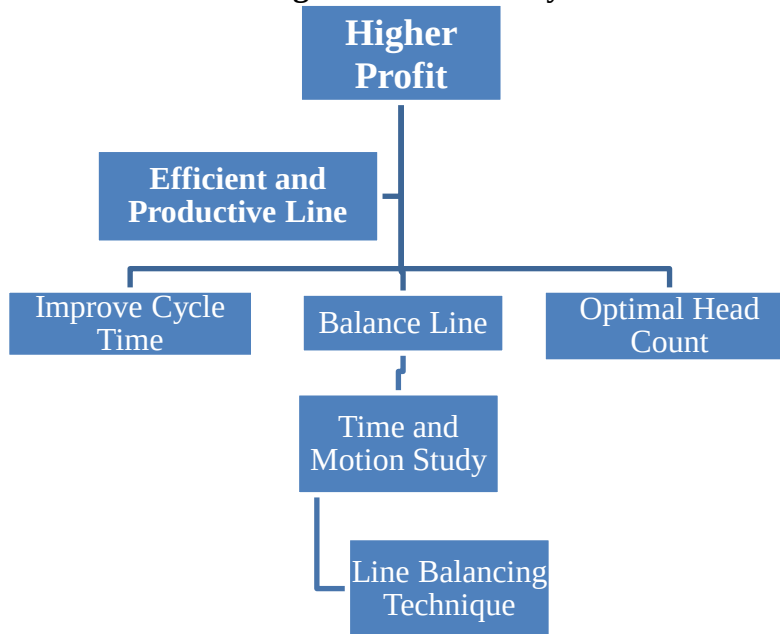
- (i) The human factors
- (ii) Process stages
- (iii) Nature of the work
- (iv) Patterns and design of the process
- (v) Product demand.

There were various other factors of human interface that were manifested through the workers and the units' management. These factors were studied with special attention to the extensive application of time and motion study and line balancing techniques to assess the assembly line.

Productivity Enhancement Through Line Balancing

The methods involved were the collection of literature and its detailed analysis on the establishment of a more efficient productive line. Figure- 1 shows the contributions of improving the cycle time, balancing the work assembly line and allocating work to influence optimal function and to increase profitability of the company.

Figure1. Profitability Determinates



Source: Productivity Improvement in a Sewing Line through Line Balancing in a Garment Manufacturing Company in the Philippines (2018).

This study has used the descriptive method of investigation. Secondary data review has been supplemented with actual hands-on-work observations pertaining to the operations within the assembly line of a garment manufacturing unit. The human face of the line includes various personnel of the lower and middle level management like the Supervisors, Production Engineers, Managers and Line Leaders.

Furthermore, the following tools were used as instrumental to the study:

- i) The Fishbone diagram was resorted to for analyzing the root causes of problems and relationships that contribute to functioning of the assembly line;
- ii) The Pareto Diagram was instrumental in graphically understanding how problems occurred in each of the processes. They were ranked to determine the factors contributing maximum to the assembly line mechanisms.
- iii) The Time and Motion study method was used to estimate the existing operation cycle time and analyze the deficiencies as well as setting and alternative standard time for the line.

- iv) The Work Sampling Method has been used to determine the amount of work, delay accruing besides other relevant work observation at random time.

Defining Productivity

Attempts have been made to encapsulate productivity in a number of definitions. It has been recognized to be a direct relation between efforts put in and the output. The output is in the form of products and services. Some of the underlying notions on productivity have been encapsulated as:

- (i) Productivity can be seen as the major determinant enabling manufacturing organizations to compete in the global market.
- (ii) Among the important factors increasing the competitive capacity of companies is the utilization of their production effectively.
- (iii) In most garment manufacturing units the sewing section is the heart of the production department. Most of the manpower operates on the basis of production capacity. Thus, the human face of the unit contributes maximum to the productivity.

- (iv) Most studies' findings have been applied to substantially increase the productivity of the sewing department.
- (v) The factors affecting the productivity of any production unit are many and varied. Productivity can be increased by several methods such as modernization, automation and technological improvements but this involves substantial capital investment.
- (vi) Productivity can be understood to be the optimum utilization of existing resources.

The objective of improving the productivity is served through systematic analysis of the available processes, work methods, operations and resources.

The British Standards Institution (BSI) defines the technique of work study as:

“A management service based on those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts, and which lead to the systematic investigation of all the resources and factors which affect the efficiency and economy of the situations being reviewed in order to effect improvement”.

Thus, work study has been recognized as a common technique for evaluating and improving productivity in operations. It is a combination of the method study and work measurement approached. While method study deals with the methods of doing work, work measurement tends to deal with the estimated time for doing work. Most managements concentrate on the volume of products rather than paying attention to how these products are produced. The focus of most units is on the profits rather than on the process and its loopholes that impact directly upon the production. Method study examines the details of the activities being performed by the manpower so that they can be viewed and unwanted aspects of the work process that adversely impact upon the productivity are eliminated.

Significant aspects of productivity are dependent upon:

- i) Conducive Work Space for sustained

- effort
- ii) Distances regularly walked and time taken by manpower
- iii) Inventory equipped to consistently feed work processes
- iv) Ergonomically designed work station
- v) Work aids for improving efficiency of manpower
- vi) Minimizing wastages and improving assembly line efficiency at all points
- vii) Obtaining maximum output in minimal time, inventory, space, labour
- viii) Equitable and smooth Funds flow

Review of Work by Various Scholars on Productivity Enhancement

Japanese industries had initiated the concept of 'Lean Manufacturing' to improve productivity. Several scholars have studied the impact of lean manufacturing and the ways to improve productivity. Some of them are: Landsberghis et al (1999), Saurin and Fabricio (2009), etc. Landsberghis et al. (1999) had analysed the impact of lean production as also total quality management on the worker's health. The study revealed that lean production implementation had resulted in intensified work pace and demand.

Several studies showed that workers operating sewing machines had reported experiencing discomfort even pain in the left shoulder, the neck, the back and the lower extremities (e.g. Vihma et al., 1982; Wick and Drury, 1986; Blader et al., 1991). These complaints were further aggravated by a seated working posture. An elevated left upper arm posture, a forward inclined posture of the head and trunk and non optimum ankle and knee angles were also causative of severe discomfort over prolonged periods. Vihma et.al, (1982) felt the sewing machine operator's work to be more static. Wright, (2001) stipulated that well-designed, convenient sewing areas, whether large or small, saved time and energy. This led Theresa Chan, L.K., (2002) to develop a work seat with ergonomic design for sewing operators. It became important for most organizations to study the behavior of employees and ensure that their jobs are relevant to the organization goals. (Campbell, McCloy, Oppler and Sager, 1993) Work place design, motivation and job

satisfaction, are significant factors influencing performance.

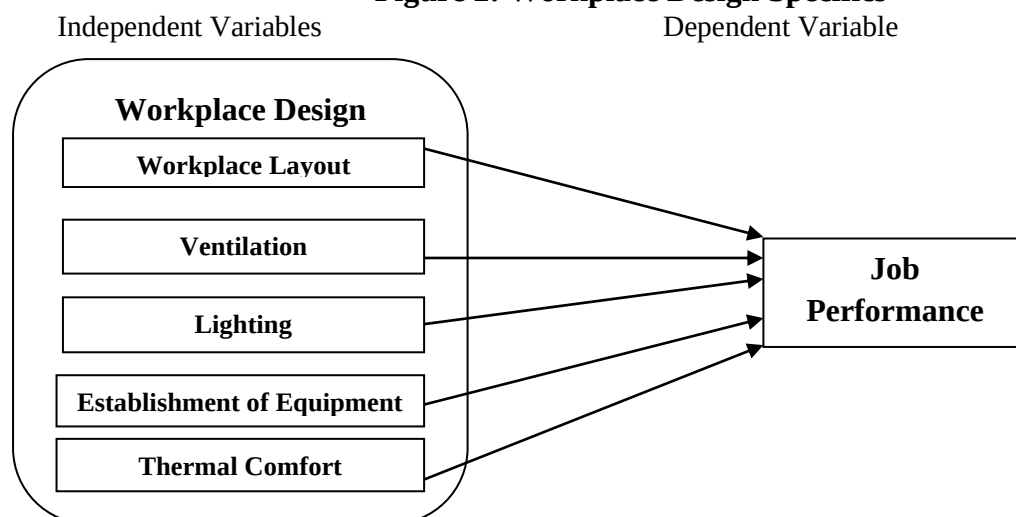
Research in this field has indicated that a strong relationship exists between the indoor environment as well as the performance of the workers. Clements-Croome (2000) suggested that productivity was improved by almost 10 % when the environmental conditions at work place are improved. Some of the research studies showed that improvements in the physical environment resulted in enhanced performance according to scholars like Sundstrom, Town, Rice, Osborn and Brill, (1994); Fisk and Rosenfeld, (1997) and Heerwagen, (2000), Leaman and Bordass, (2001), Veitch and Newsham, (1998) and Wyon, (2004). The work place layout in combination with the employing of efficient management processes was considered crucial to improving organizational performance (Uzee, 1999; Leaman and Bordass, 1993). Carmen (2013) explained that work place design considerations tended to include thermal comfort as well. It included the right combination of temperature, airflow and humidity making for a healthy work environment. The environmental quality also included a well-designed lighting system, that was ensured by providing windows and incandescent lighting for day and night activities. The amount, brightness and color of the light, its glare, variations in light levels and its use are all significant factors (R S Means, 2002). Leaman and Bordass (2000) felt that air conditioned buildings negatively effected the perceived productivity as compared to the naturally ventilated buildings.

Robertson and Huang (2006) investigated the effect of workplace design and the initiation of training interventions. They studied the relationship between workplace design and work performance measures. Their study highlighted the significant impact of environmental satisfaction and workstation layout with performance collaboration and effectiveness. Haldiya, Sachdev and Mathur (2005) were concerned that the health problems and subsequent protection measures, formed a huge gap that was observed between the knowledge and usage of protective gear. This was tied in with job performance of the human resource.

Motowidlo (2003) defines job performance as a function of employee behavior resulting in enhanced outcomes. Muchinsky (2003) explained job performance as a combination of employee behaviors making job performance a vital determinant for organizational success. According to Blumberg and Pringle (1982) there are three factors which affect job performance:

- i) Ability variables or the skill sets necessary for a job
- ii) Motivation variables or the impetus to perform a job
- iii) Opportunity variables or the combination of task manifestation variables.

According to the American Society of Interior Designers (ASID, 1999) who carried out an independent study it was revealed that the physical workplace design is one of the top three factors which affect performance and contribute to job satisfaction. This has been shown in Figure 2:

Figure 2: Workplace Design Specifics

Source: Workplace Design and Job Performance: A Study of Operational Level Employees in the Apparel Industry of Sri Lanka (2016)

Increased production volume is a direct function of assembly line efficiency and indicates the significance of the method study approach. Advantages of the method study approach are visible in the following:

- i) Same production volume achieved with less machines and workers
- ii) Performance of same operations in shorter time with lesser effort.
- iii) Labor and energy costs reduced
- iv) Decrease in product cost
- v) Overall Growth in Productivity
- vi) Greater assembly line efficiency

Thus, research has conclusively shown that workplace design affects job performance significantly. These research findings are evidence that good workplace layout, ventilation, lighting, establishment of efficient equipment and thermal comfort, all lead to significantly increasing operational level efficiency of the workers. There is a direct and strong relationship between workplace design and job performance and consequently productivity.

Productivity Enhancement in Assembly Line Balancing

Assembly line balancing entails the partitioning of tasks into subsets. These subsets are representatives of a work station load. Each work station load in turn refers to the storage, transportation and feeding policies of all sections of the assembly line. The contention of

this paper is that productivity enhancement can be ensured totally through assembly line balancing.

Battini et al. (2009) developed the methodological framework for designing and management of the feeding system for the assembly line. The various steps of pallet-to-station, trolley-to-station and kit-to-assembly line policies are interlinked to the production times and subsequently costs. The Caputo et al. (2015) model proposed the setting up of the right mix of feeding policies to minimize total cost and upgrade the magnitude of productivity.

Sternatz (2015) examined the joint assembly line balancing and parts feeding problems, especially when the operator needs more time to pick up a part supplied homogeneously. The Assembly Line Balancing and Parts Feeding Problem (IALBFP) model provides guidelines for the implementation of the integrated planning approach.

Line balancing has been cognizant of the bottlenecks where excess time, new manpower and capacity of each worker contribute towards the productivity and efficiency of the entire unit.

As all human factor processes cannot be worked on an 'Ideal situation' for long durations of time because there are a number of lacunae and pitfalls that can invariably slow down or even

stop the process it is essential to give them due recognition. A proper allowance is added on in accordance with the working conditions. The following types of allowances are considered to ensure optimum productivity:

- i) Machine allowances: That considered hassles, halts and breakages.
- ii) Relaxation allowance: Time given to man and machine to prevent damage.
- iii) Interference allowance: Takes care of any stoppages due to power outages, change in design or process as well as delay by operators.
- iv) Process allowance: This takes care of any flaws in the process or any changes which have to be done even after the process has been initiated.
- v) Special allowance: This allows for any changes that may be featured in after the process has already been started.

Production wastes result in making the manufacturing processes inefficient and directly hamper the productivity. Method study is among the most effective ways to highlight and consequently eliminate various activities that are unnecessary or non value adding.

Three types of activities can be described which are:

- i) Main activities - that bear the responsibility of the entire process.
- ii) Incidental activities - that are taken on as they are by-products.
- iii) Additional activities - those that have been featured in after the process was planned and implemented.

Method study is therefore defined as a systematic recording as well as critical examination of existing and also the most utilized proposed ways of developing and applying effective methods, and reducing costs.

Thus, Method study is applied to the process for:

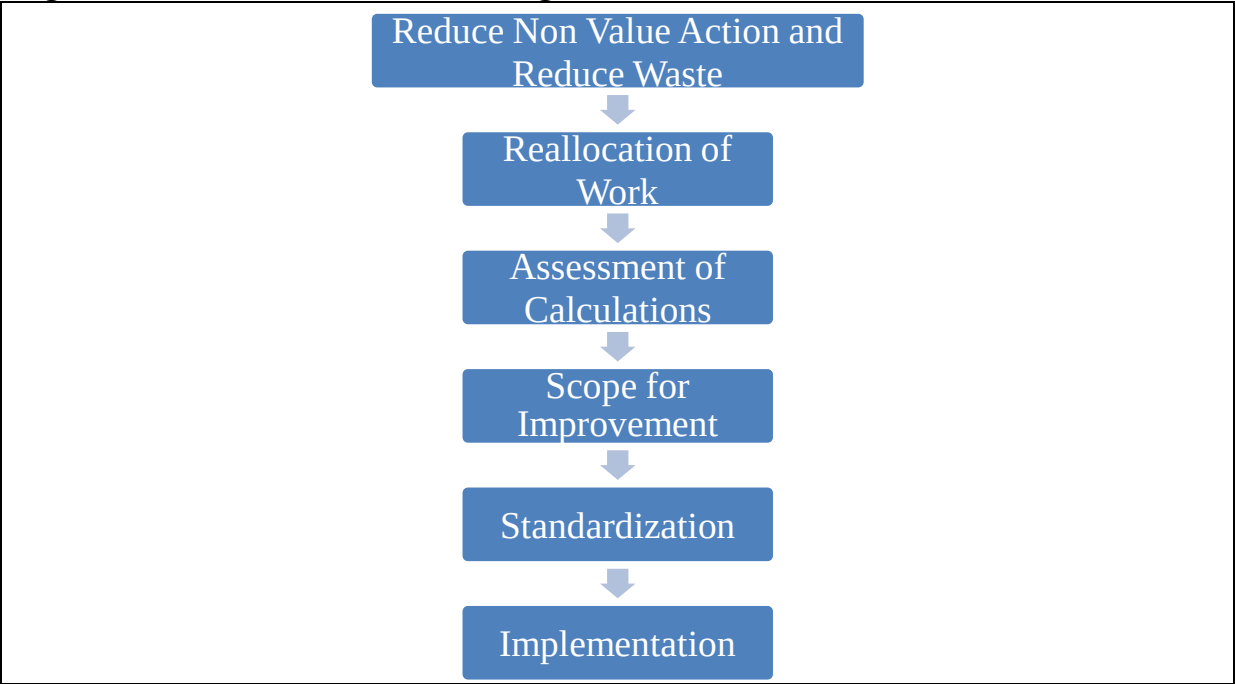
- (i) Eliminating, combine or simplify operations.
- (ii) Reduction of process or operational time
- (iii) Cutting down delays
- (iv) Increased and improved quantum of output
- (v) Improved quality of products

It can be deduced that the method study approach can be useful for:

- (i) Increasing operator performance
- (ii) Improving safety measures
- (iii) Decreasing fatigue
- (iv) Decreasing hazards
- (v) Enhancing productivity

Besides the workplace benefits to the manufacturing unit and its manpower this approach also results in bringing down the cost subsequently by providing simplicity and ease of human endeavor besides saving time and material. Assembly lines are comprised of work oriented stations where components of the products are pieced together and undergone a series of processes where they are treated in different ways. The work pieces are transferred from one station to another. Assembly line balancing is attained when the duration of time lost is reduced to the minimal.

Figure 3: Flowchart for Line Balancing



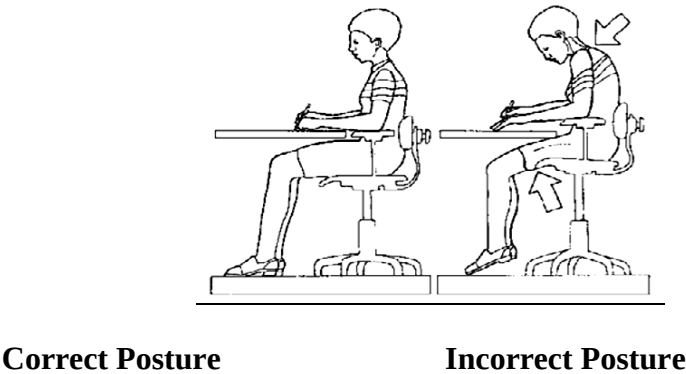
Source: Compiled by Researcher

The Significance of Work Aids

Lower back problems are on the increase in the garment manufacturing sector. This is largely because most workers sit or stand at their workstations all day. They are usually provided with seats that have no backrest. An adjustable chair is an essential input for individual workers. It can be adjusted for the height of the worktable and the repetitiveness as well as volume of the task. Such a chair should provide

full lower back support. It must allow workers to move forward and backwards easily. There should be adequate leg room under the worktable so that position of the legs can be changed easily. The feet must be placed flat on the floor. A footrest must be provided to ease muscle fatigue and eliminate pressure on the thighs and knees. Figures 4 and 5 below give a depiction of correct seating:

Figure 4: Correct Seating Posture Attained by Ergonomic Work Aid for Seating Work Position of the Garment Manufacturing Unit Worker

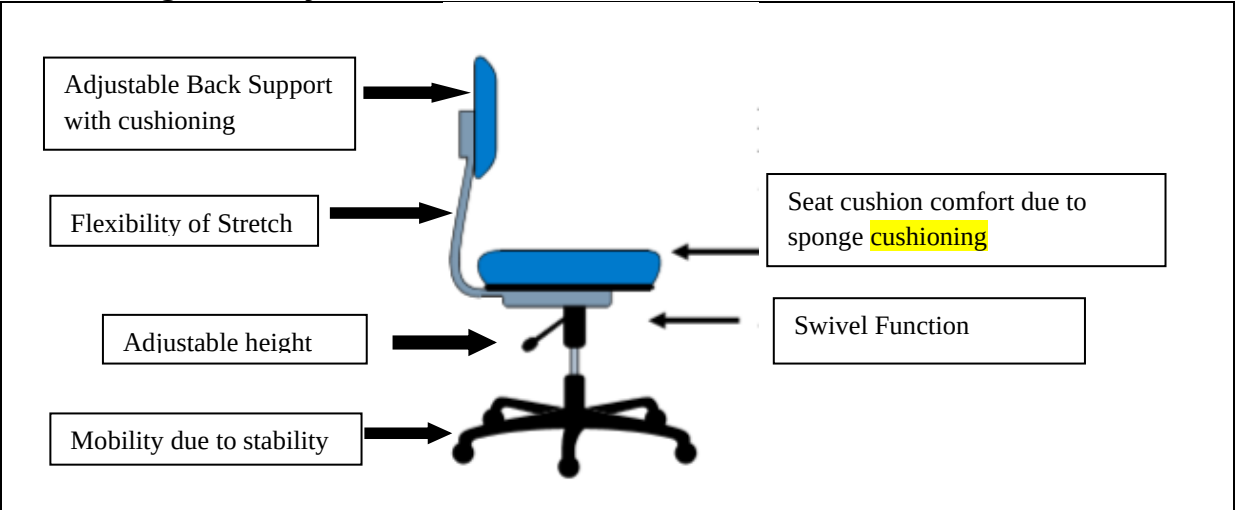


Source: Your Health and Safety at Work. Ergonomic (6/6/2012)

The height of the chair should be adjustable to ensure that the chair can be lowered, tilted

either backward or forward according to the worker’s requirement.

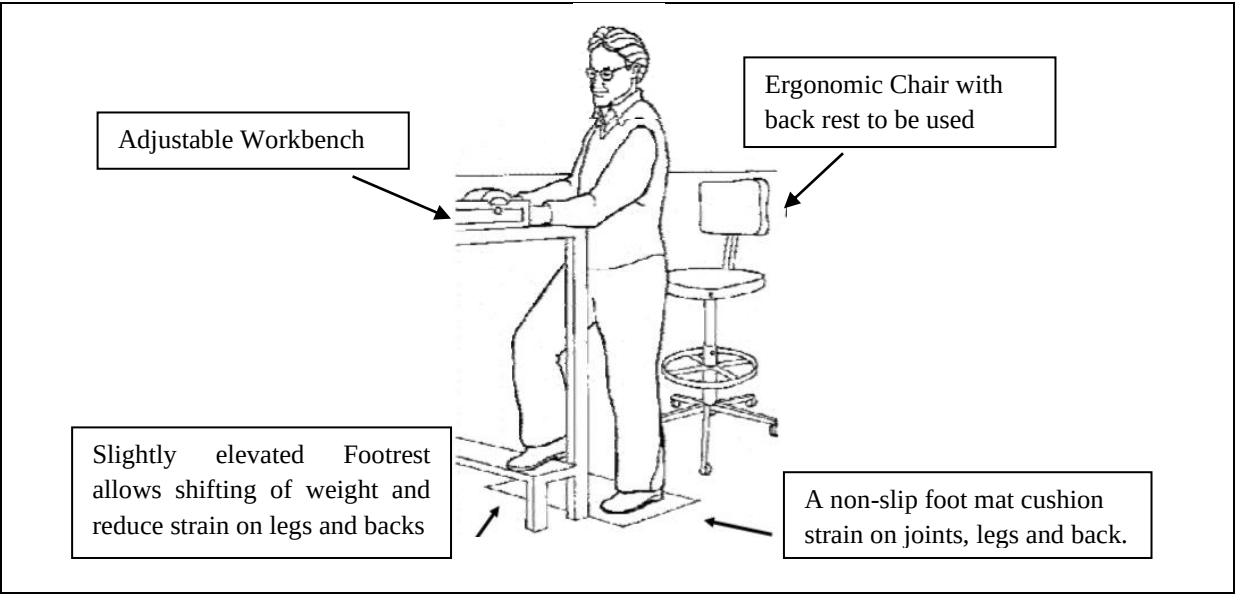
Figure 5: Adjustable Chairs with Backrest to be Provided for all Seated Workers



Source: Compiled by Researcher

In the garment manufacturing industry there are several workers who stand all day at their workstation. This standing for long periods on hard floors, often bare feet, can result in backache, sore feet and tired muscles. This is shown in Figure 5.

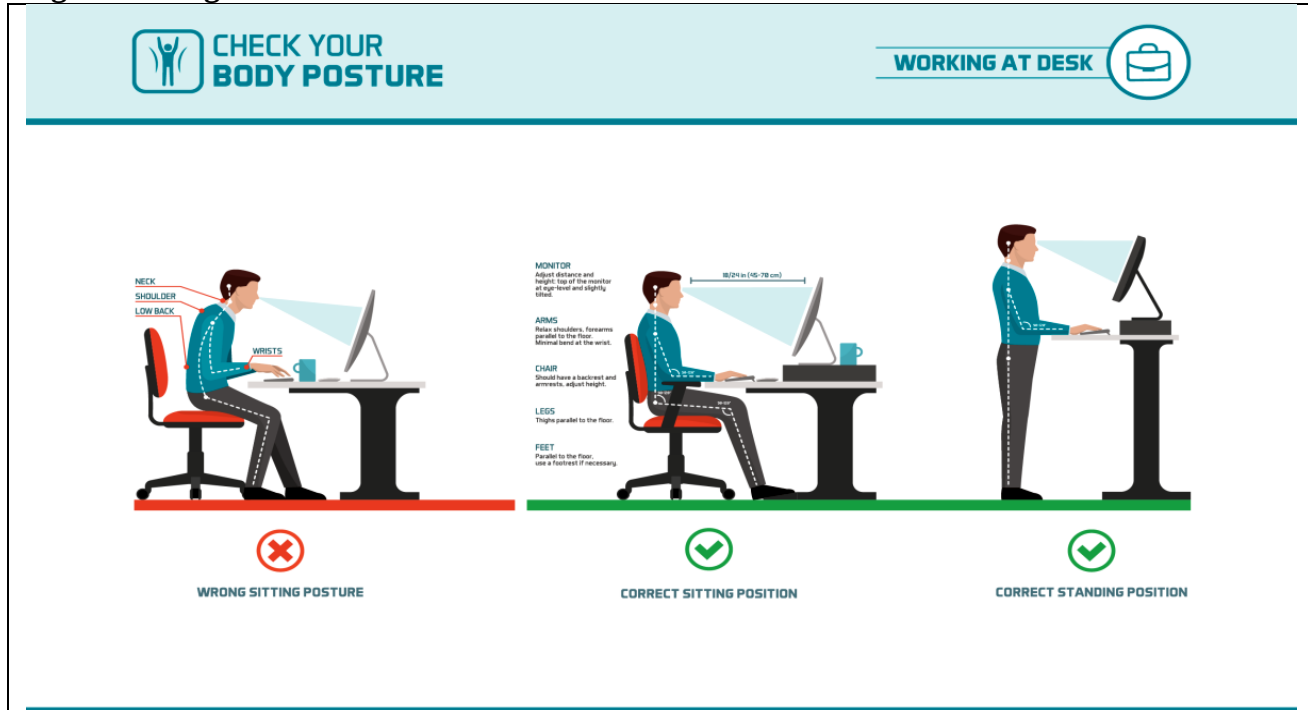
Figure 6: An Ideal Ergonomic Standing Workstation for Standing Work Position



Source: Source: Your Health and safety at Work Ergonomic (6/6/2012)

The height of the workbenches must be designed for optimum worker output. Worker needs to keep the arms low and the elbows close to the body. This can be done either by lowering or raising the seating or by making the work platform adjustable and worker friendly.

Figure 7: Height of workbenches



Source: 5 Benefits of Ergonomics in the Workplace (2017)

Productivity Enhancement with Ergonomic Workstation in Garment Manufacturing Industry

The organization of a workplace environment designed ergonomically is a major contribution towards attaining optimum productivity. Giving due credence to the anthropometric aspects, of work physiology, it is essential to know the employee's personal characteristics, hardships, time taken for the job as well as environmental conditions at the work place. This can be attained through ergonomic solutions which result in:

- (i) Reducing or eliminating static muscle work
- (ii) Decrease force application
- (iii) Choosing the correct directions for applying force
- (iv) Changing work timing
- (v) Altering Shifts
- (vi) Providing occasional breaks.

Workplaces that are arranged according to ergonomic rules make optimum use of human resources and maximum productivity is achieved. Workstations equipped with ergonomic work aids positively impact upon employee productivity and enhance profits. There

are numerous occupational hazards to the health and safety of workers in the garment manufacturing sector. These are in the form of noise, high temperatures, work fatigue, dangerous manual handling which can result in several musculoskeletal disorders due to heavy lifting and carrying of loads, poor lighting, repetitive, monotonous movements and accidents.

Conclusively, workplace design and ergonomically developed work aids can make the work process completion easier. Care should be taken to ensure a conducive work environment. This is possible only through the anthropometrically estimated and designed environmental features that are suitable for the veracity of human resource working in the industrial unit.

(Permission obtained for work; Requisite patent permission of work and interventions are pending. The permission were not required at this stage as experimentation was being carried out for doctoral research by the correspondence author.)

The main goal of ergonomics is, therefore, to increase productivity and efficiency by increasing human work output.

Conclusions

Based on the findings of the study an improper line layout inappropriate for cut goods storage, sewing machines and pressing machines due to improper process flow, longer process time in pairing and aligning of cut goods had all contributed to the many bottlenecks.

Productivity can be taken to be a ratio of output to input during the production process of goods and services. Productivity gets lowered by decreased amounts of labor, capital, energy or materials. Productivity is increased through workstation efficiency and balancing of all activities to obtain an efficient work load distribution equation. Better productivity results from the worker exerting minimum effort at the workstation and ensuring better balancing within the work environment.

The apparel industry is a buyer-driven industry. The customer is king in the apparel production industry making for stiff and intensified global competition. The concepts outlined in this study are significant factors for improving the productivity and efficiency of the garment manufacturing industry. It is through the application of industrial engineering methods like work study, line plan, capacity study, method engineering and other operational management systems that the garment manufacturing industry can progress towards the timely delivery of goods. It must be understood that high profits can be generated only through developing a well managed, efficient, working environment which the worker recognizes as an ergonomic happy work place.

References:

1. Amaya, Floerfida L, et al. (2018). Productivity Improvement in a Sewing Line Through Line Balancing in a Garment Manufacturing Company in the Philippines. International Journal of Trends in Scientific Research and Development IJTSRD, ISSN No. 2456-6470, Volume – 2, Issue – 4.
2. Stallworth, O. E., & Kleiner, B. H. (1996). Recent Developments in Office Design. Facilities, 14(1/2), 34-42
3. M.V.S. Mendis. (2016). Workplace Design and Job Performance: A Study of Operational Level Employees in the Apparel Industry of Sri Lanka. International Journal of Scientific and Research Publica
4. Al-Anzi, N.M., (2009), Workplace environment and its impact on employee performance. MBA thesis, submitted to Open University of Malaysia
5. American Society of Interior Designers (1999) "Recruiting and retaining qualified employees by design." White paper.
6. Blumberg, M., & Pringle, C. D. (1982). The missing opportunity in organizational research: Some implications for a theory of work performance. Academy of management Review, 7(4), 560-569.
7. Brill, M. (1990). Workspace design and productivity. Journal of Healthcare Forum, 35 (5), pp. 51-3.
8. Campbell, J. P., McCloy, R. A., Oppler, S. H. and Sager, C. E. (1993) 'A theory of performance', in C. W. Schmitt and W. C. A. Borman (eds), Personnel Selection in Organizations. San Francisco: JosseyBass, pp. 35-70
9. Carmen, C. (2013). Office design enhances employee health. wellness & performance. Retrieved from a. <http://www.carmenrealestate.com/blog/bid/317204/of-fice-design-affectsemployee-performance>.
10. Dheerasinghe, R. (2003). Challenges, Prospects and Strategies for the Garment Industry in Sri Lanka. Staff studies: Central Bank of Sri Lanka, 33-72.
11. Fisk, W. J., & Rosenfeld, A. H. (1997). Estimates of improved productivity and health from better indoor environments. Indoor air, 7(3), 158-172.
12. Gensler Design + Performance Index, the U.S. Workplace Survey. (2006). www.gensler.com
13. Haidiya, K. R., Sachdev, R., Mathur, M. I. and Saiyed, H. N., (2005) Knowledge, Attitude and Practices Related to Occupational Health Problems among Salt Workers. Journal of Occupational Health.
14. Hameed, A., & Amjad, S. (2009). Impact of office design on employees productivity: a case study of banking organizations of Abbottabad, Pakistan.
15. Heerwagen, J. (2000). Green buildings, organizational success and occupant productivity. Building Research & Information, 28(5-6), 353-367.
16. Leaman, A., & Bordass, B. (1993). Building design, complexity and manageability. Facilities, 11(9), 16-27.
17. Leaman, A. and Bordass, W. (2000) "Productivity in buildings: the 'killer' variables", in Creating The Productive Workplace, D. Clements-Croome, ed., E and FN Spon, London.
18. Leaman, A., & Bordass, B. (2001). Assessing building performance in use 4: the Probe occupant surveys and their implications. Building Research & Information, 29(2), 129-143.
19. Muchinsky, P. M. (2003). Psychology applied to work (7th ed.). Belmont, CA: Thomson Wadsworth.
20. Paevere, P., & Brown, S. (2008). Indoor environment quality and occupant productivity in the CH2 building: Post-occupancy summary. March, CSIRO, Report No. USP2007/23.
21. Robertson, M. M., & Huang, Y. H. (2006). Effect of a workplace design and training intervention on individual performance, group effectiveness and collaboration: The role of environmental control. Work, 27(1), 3-12.

22. Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology, 25(1), 54-67.
23. Sundstrom, E. et al, (1994). Office noise, satisfaction, and performance. Environment and Behavior, 26(2), 195-222.
24. Daria Battini*, Martina Calzavara*, Alena Otto**, Fabio Sgarbossa* (2016). The Integrated Assembly Line Balancing and Parts Feeding Problem with Ergonomics Considerations. IFAC-PapersOnLine 49-12,191–196. Available online at www.sciencedirect.com
25. Andriolo, A., Battini, D., Persona, A., & Sgarbossa, F. (2015). A new bi-objective approach for including ergonomic principles into EOQ model. International Journal of Production Research, 1-18.
26. Battini, D., Faccio, M., Persona, A., & Sgarbossa, F. (2009). Design of the optimal feeding policy in an assembly system. International Journal of Production Economics, 121(1), 233–254.
27. Battini, D., Faccio, M., Persona, A., & Sgarbossa, F. (2011). New methodological framework to improve productivity and ergonomics in assembly system design. International Journal of Industrial Ergonomics, 41(1), 30–42.
28. Battini, D., Boysen, N., Emde, S. (2013). Just-in-Time supermarkets for part supply in the automobile industry. Journal of Management Control, 24(2), 209–217.
29. Battini, D., Gamberi, M., Persona, A., & Sgarbossa, F. (2015). Part-feeding with supermarket in assembly systems: transportation mode selection model and multiscenario analysis. Assembly Automation, 35(1), 149–159.
30. Battini, D., Delorme, X., Dolgui, A., Persona, A., & Sgarbossa, F. (2015a), Ergonomics in assembly line balancing based on energy expenditure: a multi-objective model. International Journal of Production Research, doi: 10.1080/00207543.2015.1074299.
31. Battini, D., Delorme, X., Dolgui, A., Persona, A., & Sgarbossa, F. (2015b) Assembly line balancing with ergonomics paradigms: two alternative methods.
32. Proceeding of the INCOM Conference 2015, Ottawa.
33. Bautista, J., Batalla-García, C., Alfaro Pozo, R., & Cano Pérez, A. (2013). Extended models for TSALBP with ergonomic risk constraints. IFAC Conference on Manufacturing Modeling, Management, and Control 2013: Saint Petersburg, 869–874.
34. Bautista, J., Batalla- García, C., & Alfaro-Pozo, R. (2016). Models for assembly line balancing by temporal, spatial and ergonomic risk attributes. European Journal of Operational Research, 251(3), 814–829.
35. Boysen, N, Flidner, M, & Scholl, A. (2007). A classification of assembly line balancing problems. European Journal of Operational Research, 183(2), 674–693.
36. Boysen, N., Flidner, M., & Scholl, A. (2008). Assembly line balancing: Which model to use when? International Journal of Production Economics, 111(2), 509–528.
37. Calzavara, M., Glock, C., Grosse, E., Persona, A., & Sgarbossa, F. (2015). The impact of alternative rack layouts on economic and ergonomic performance measures in order picking. 20th ISL International Symposium on Logistics, 5th-8th July, Bologna, Italy.
38. Caputo, A. C., Pelagagge, P. M., & Salini, P. (2015). A decision model for selecting parts feeding policies in assembly lines. Industrial Management & Data Systems, 115(6), 974–1003.
39. Carnahan, B. J., Norman, B. A., & Redfern, M. S. (2001). Incorporating physical demand criteria into assembly line balancing. IIE Transactions, 33(10), 875–887.
40. Colombini, D., & Occhipinti, E. (2006). Preventing upper limb work-related musculoskeletal disorders (ULWMSDs): New approaches in job (re)design and current trends in standardization. Applied Ergonomics, 37, 441–450.
41. Hanson, R., & Medbo, L. (2012). Kitting and time efficiency in manual assembly. International Journal of Production Research, 50(4), 1115–1125.
42. Kilic, H. S., & Durmusoglu, M. B. (2015). Advances in assembly line parts feeding policies: a literature review. Assembly Automation, 35(1), 57–68.
43. Limère, V. et al, (2012). Optimising part feeding in the automotive assembly industry: deciding between kitting and line stocking. International Journal of Production Research, 50(15), 4046–4060.
44. Neumann, W. P., & Medbo, L. (2010). Ergonomic and technical aspects in the redesign of material supply systems: Big boxes vs. narrow bins. International Journal of Industrial Ergonomics, 40(5), 541–548.
45. Neumann, W. P. et al, (2006). Production system design elements influencing productivity and ergonomics. International Journal of Operations & Production Management, 26, 904–923.
46. Occhipinti, E. (1998). OCRA: A concise index for the assessment of exposure to repetitive movements of the upper limbs. Ergonomics, 41(9), 1290–1311.
47. Otto, A., & Scholl, A. (2011). Incorporating ergonomic risks into assembly line balancing. European Journal of Operational Research, 212(2), 277–286.
48. Prince Munjal and Sirdeep Singh (2014). Research for Productivity control Assessment, Applied To The Comparative Analysis of Pid & Fuzzy Controllers In Process Industry. International Journal of Electrical & Electronics Engineering 24www.ijeee-apm.com/IJEEE, Vol. 1, Issue 4 (August,2014)e-ISSN: 1694-2310p-ISSN: 1694-2426 1
49. S. C. Tripathy and Tripta Thakur (2014). Further Presentation, BCC Efficiency, Scale Efficiency, Total Factor Productivity (TFP) Analysis And Malmquist Productivity Index For Efficiency Calculation. International Journal of Energy, Environment and Economics; Hauppauge Vol. 22, Iss. 5, (2014): 485-489.

50. Sternatz, J. (2015). The joint line balancing and material supply problem. International Journal of Production Economics, 159, 304-318.
51. Tan D. Vu, Trung T. Tran, Hoa T. Tran, Minh T. Nguye,(2016). Noise Cancellation Methods for Wearable Devices using Microprocessors. SSRG International Journal of Electrical and Electronics Engineering 3(10), 1-6.
52. Andreas Kunza*, Markus Zanka, Thomas Neschera, Konrad Wegener (2016). Virtual reality based time and motion study with support for real walking. 49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016) 303-308.
53. Md. Niaz Morshed & Kazi Saifujjaman Palash (2014). Assembly Line Balancing to Improve Productivity using Work Sharing Method in Apparel Industry. Global Journal of Researches in Engineering: G Industrial Engineering Volume 14 Issue 3 Version 1.0
54. Mst. Murshida Khatun (2014). Effect of time and motion study on productivity in garment sector. International Journal of Scientific & Engineering Research, Volume 5, Issue 5, 825, ISSN 2229-5518
55. B.Sudarshan and D. Nageswara Ra (2014). Productivity Improvement Through Modular Line In Garment Industries. 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014) December 12th–14th, 2014, IIT Guwahati, Assam, Indi
56. <http://www.lcmibd.com/industrialengineering.htm>
57. http://wiki.answers.com/Q/Industrial_engineering_work_study_in_garments
58. <http://www.onlineclothingstudy.com/2012/09/-how-to-calculate-efficiency-of.html>
59. http://wiki.answers.com/Q/Industrial_engineering_work_study_in_garments
60. 5 Benefits of Ergonomics in the Workplace (2017). Workplace Bulletin, Industry News, Workplace Bulletin.