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LEAN MANUFACTURING TOOLS & TECHNIQUES FOR THE PRODUCTIVITY IMPROVEMENT IN ASSEMBLY LINES OPERATIONS OF INDUSTRIES

Zohaib Iftikhar[*1], Ramesh Kumar[*2], Karim Bux[*3], Abdul Haseeb[*4], Muhammad Ali Khan[*5], Arshia Naz[*6], Hassam[*7], Abdul Salam Soomro[*8]

[*1,2,3,4]UG Student, Industrial Engineering & Management, Mehran UET, Sindh, Pakistan.

[*5]Assistant Professor, Industrial Engineering & Management, Mehran UET, Sindh, Pakistan.

[*6,7]Yunus Textile Mills (YTM) Limited, Karachi, Sindh, Pakistan.

[*8]Professor & Chairman, Industrial Engineering & Management, Mehran UET, Sindh, Pakistan.

ABSTRACT

The businesses are now keener for the efficient & effective utilization of key resources i.e. (man, machines, material, money and time) to maintain good health of their businesses. Organizations are continuously searching for ways of productivity improvement and besides other tools, researchers also support lean manufacturing (LM) tools for it. The assembly lines exist in various industries and there is a need to highlight the potential of LM tools for their productivity improvement. A narrative literature review was conducted to put the detailed and broader picture of the major LM tools for the productivity improvement in assembly lines. The six (6) industries were selected for this purpose and the applications of LM tools in productivity improvement of their assembly lines are discussed.The evidence was collected and literature review was organized, analysed & discussed. It is concluded that many industries are aware of LM tools and have initiated their implementation in assembly lines. We have identified 29 major LM tools from review. In future, other lean tools can be discussed for the same six(6) industries and/or for others in order to put a clearer and broader picture. More research papers can be considered in order to draw better and effective conclusions.

Keywords: Lean Manufacturing; Line Balancing; Productivity Improvement; Assembly Line; Lean Tools.

I. INTRODUCTION

Production strategy needs to be improved in every industry because of fierce competition these days [2]. Over the previous one and a half-century, garment structures have been innovated from manual fitting to their mechanized assembling and robotized sometimes for batch production [3]. Assembly line is defiend as a set of workstations where several tasks are performed to produce a product [5].The Assembly line balancing (ALB) technique is among the methods of operations management for the simplification of problems related to workload and improving line efficiency [3]. Assembly lines are indicated to the specific flow-based production system, the last phase of manufacturing processes is represented by them [6]. Set of workstations are assigned tasks by ALB problem under particular constraints i.e. constraints of cycle time and precedence [6], [7]. Minimization of assembly-line production costs is pursued by optimization processes [7]. ALB and sequencing are among the hardest challenges as having been discussed in the literature [8]. Several workstations are set in order in assembly lines that ordered processes can be performed. This is the big challenge to make the arrangement or order for performing the tasks [10]. The goal of line balancing is to minimize the number of workstations and maximize production efficiency [9].

The industrial engineering approach approach is easier to improve productivity rather than investing a huge capital on buying machinery [11].Tasks of unequal time on the various stations lead to work in process waiting time which is the reason for incurring an extra cost. Working time measurement is higly needed by the companies, particularly small and medium enterprises [12].This is the reason, it has been the consideration of shop floor managers to assign the tasks of equal cycle time to the various workstations for balancing the line [13]. Each workstation is assigned a specific task and each workpiece passes the workstation successfully so that the completion of the whole product can be made possible within cycle time. The system of the assembly line was designed to make use of the expertise of every individual on the line to increase efficiency and decrease cycle time [14]. However, line balancing is a topic older than a century but still, it is of researchers' interest because it is directly associated with production efficiency. The improvement and search for a more efficient assembly line balancing approach are required to improve and sustain the efficiency of the line [15].

II. LITERATURE REVIEW

Literature review has been carried out on the major lean manufacturing tools for the productivity improvement in assembly lines of six (6) selected manufacturing industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry. The literature review is produced under multiple headings and organized, analysed & discussed in detail.

Assembly Line Balancing

The basic aim of assembly line balancing is either to reduce cycle time or to minimize the number of installed workstations [10]. Germanes et al (2017) defined line balancing as "when every one is working together in a balanced fashion" [16]. by There are various types of assembly lines i.e. straight-shaped assembly line (StAL), parallel workstation assembly line (PWAL), U-shaped assembly line (U-Line), two-sided assembly line (2SAL), parallel assembly line (PAL), multi-manned assembly line (MAL), and hybrid assembly line (HL) as represented in figure 1.

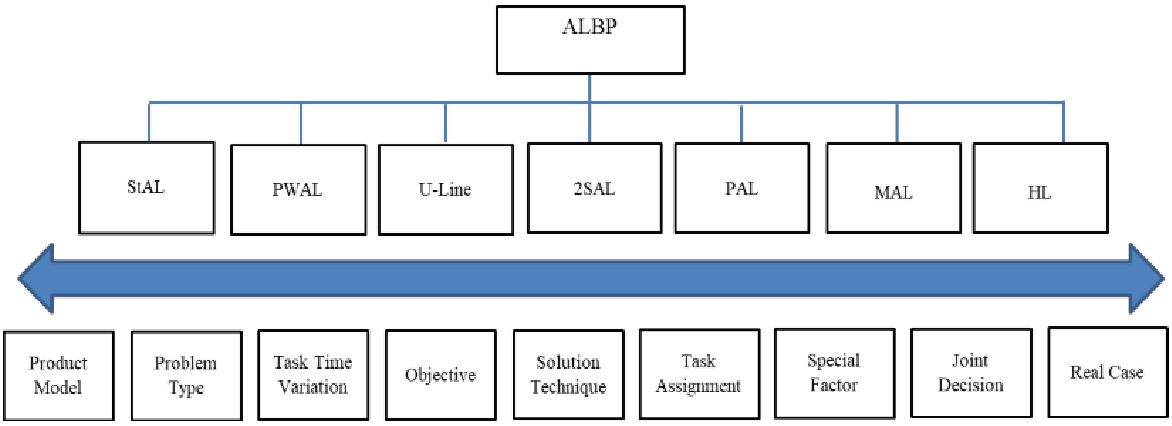

Figure 1. Classification of assembly line balancing problem (Source: [17])

Applications of Lean Tools for productivity improvement in assembly lines

Several researchers have contributed to the literature on the topic of assembly line balancing. The mathematical modeling & simulations are the proven modern optimizations tools for the productivity improvement by line balancing techniques of lean manufacturing [5] [6] [7]. There are numerous published articles about lean technique of line balancing by using time & motion study [10] [17]. Kumar et al. (2020) conducted the case study at the assembly & production line of Automobile Industry to investigate the productivity. Line balancing, time & motion study and OEE were used and existing OEE is calculated, compared with world class OEE, gap is identified and corrective measures were suggested to minimize the gap. Three OEE losses i.e. downtime, speed loss and quality loss are measured and the responsible factors behind these losses are identified [18]. Khan et al. (2020a) conducted the systematic review of lean manufacturing practices about the assembly &production lines of Automobile Industry [19]. Rajput et al. (2020) conducted the case study at the production line of Automobile Industry to investigate the productivity. The annual data is collected from Pre-treatment Electrode Deposition Line (PT-ED Line). Takt Time in one of the process of PT-ED Line of paint shop is reduced from 2.04 mins to 1.78 mins. This is done with the help of electrodes replacement and increasing of amperes of the electrodes in the Cathode Electrode Deposition (CED) process. This reduction in takt time increased the daily production of paint shop from 245 units to 280 units [20].

Kathem et al. (2021) used lean concepts and a line balancing approach to the minimization of lead time and non-value added activities and to the improvement of productivity in the footwear industry. Rockwell arena software was used in the research. Results indicated that the reduction in non-value added activities were 36%; production cycle time was reduced to 31% and productivity was increased by 43% [2]. Sahito et al. (2020) conducted the case study on the assembly line of pharmaceutical to evaluate the productivity and investigation of lean manufacturing wastes. The major causes of the identified lean wastes were identified by the detailed analyses with Ishikawa diagram. The defect waste, motion waste, waiting waste and over processing waste are identified as the most deadly wastes at the selected production line. The activities which created the wastes are identified and measured. The corrective actions are suggested for the reduction or elimination of the identified lean wastes [21]. Khan et al. (2020b) conducted the systematic review of lean manufacturing practices in Pharmaceutical Industry [22].

Haque et al. (2018) conducted research by using the ALB technique and suggested a new sewing layout; the number of required laborwas reduced from 20 to 18. Moreover, it was indicated that if the labor cost would be 8000tk per month then the total cost can increase from 144000tk to 16000tk per month. This improvement could lead to the increment of 129 – 235 pieces per hour (22048 pieces per month) [3]. Kumar et al. (2020b) & Mughal et al. (2020) discussed benefits and applications of Six Sigma (DMAIC) and Lean Six Sigma (LSS) in the productivity improvement of assembly & production lines of various manufacturing industries [27] [28]. Khan et al. (2020c) discussed the benefits and applications lean tool of Value Stream Mapping (VSM) in the productivity improvement of various assembly lines and production lines [29]. Khan et al. (2020d) explored the potential of lean manufacturing practices for the productivity improvement in the assembly & production lines of Pakistani Industry [30]. It is observed that unlike the other developed countries, very few studies are conducted to explore the potential of lean manufacturing practices in the Pakistani Industry. The applications of these lean manufacturing practices in the Pakistani Industry are discussed with the help of suitable examples and related case studies [30]. Zaidi et al. (2021) reviewed the benefits & applications of lean manufacturing practices from eight (8) diverse assembly and production lines of various industries [31].

Two heuristic approaches were applied by Manaye (2019). He conducted an in-depth review of the literature to find the best possible line balancing technique. Accuracy of standard time was focused on time study and the workload was rearranged among the operators through line balancing techniques for solving apparel sewing problems. To conclude, the cycle time, takt time, and several workstations were considered [9]. Lakho et al. (2021) conducted the case study on the production line of heavy engineering industry to evaluate the productivity. Line balancing, time & motion study, Overall Equipment Effectiveness (OEE), TPM & 5S were used to evaluate & analyse the productivity and overall performance. The data of six (6) months was analyzed in MS excel and Minitab. The realignment of housekeeping activities was proposed which can reduce the delay by 33% [24]. Shar et al (2021) conducted the case study at the production line of large pharmaceutical company to evaluate the productivity. The data is gathered from the working plant and analysed by fish bone diagram to find out the potential causes. Pareto chart was used to priorities the problem and descriptive analysis was conducted. The lean tools of TPM, OEE were implemented and and causes were identified. The overall performance of the production line was increased by 11% by the proposed solutions [23]. Virk et al. (2020) & Lakho et al. (2020) reviewed the lean tools of TPM & OEE for the improvement in productivity, profitability and quality in the assembly & production line of manufacturing industry [25] [26].

The Production process of lady pencil skirts was improved by Aung and Tun (2021). Through the reduction of value-added activities, cycle time, and balanced workload at each of the workstations through line balancing, the efficiency of the single model assembly line was improved. Productivity was improved by two approaches i.e. appropriate training and supervision for sewing operations and work-sharing method were used among those workstations on which similar nature jobs were being performed [13]. Bukhsh et al. (2021) conducted the case study at the production line of textile manufacturing unit. Line balancing, time & motion study, standardization, 5S and SMED were implemented in the selected case area of flatbed printing machine [32]. The changeover time was reduced from 142 minutes to 117 minutes which in turn increased the overall productivity of flatbed printing machine [32]. Khan et al. (2021a) explored the applications of Waste Relations Matrix (WRM) in the identification of seven deadly wastes of lean manufacturing in the production lines. The case study of textile production line was also discussed about the investigation of seven Lean Manufacturing wastes i.e. overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion and defect. The wastes were investigated and suggestion were proposed [35]. Khan et al. (2020e) & Khan et al. (2020f) discussed the previous studies related to productivity improvement in the production lines of textile industries by lean practices [33] [34].

Yemani A. (2021) dealt with line balancing (LB) of the BOB T-shirt model by using control limit analysis (CLA), assembly line`s discrete event simulation (DES). The author used CLA for the measurement ofassembly line performance; bottleneck operations were identified at the very first then the LB technique was used for improving the productivity of the model sewing line. BOB T-shirt model was based on 16 operations; thus, the standard minute value of each of the operations was taken out. With the help of CLA and DES, major bottleneck operations were analyzed. Such operations with SMV less than the lower control limit and greater than the upper control limit were named bottlenecks of the sewing section. Moreover, DES and CLA were used for line balancing. Results indicated that production per day increased from 1032 to 1289 pieces. Labor productivity increased from 46.9% to 54.32%; machine productivity improved from 58.59% to 71.61%. The generated profit was also improved from 22704 to 28358birr[40]. Mughal et al. (2021) conducted the case study at the production line of textile stitiching unit where productivity, profitability and quality was investigated [38]. Pareto charts and Fish bone diagrams were used to analyze the defects and skip stitch and stain spot are identified as the most frequent defects. The causes were identified and suggestion were proposed [38]. Khan et al. (2021b), Khan et al. (2020g) & Khan et al. (2018) consired the production line cases of textile industries of Pakistan where productivity, profitability and quality was investigated [36] [37] [39]. The investigation of seven Lean Manufacturing wastes only i.e. overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion and defect was conducted for productivity improvement. The lean practices were proposed for the productivity improvement & reduction of lean wastes in textile industries [36] [37] [39]. Alzoubi et al. (2019) analyzed the tasks required to stitch T-shirt at the apparel unit. Layout planning and line balancing techniques were used in this research to bring about improvement in the current work performance and increment in workers` productivity by decreasing idle time [41].

The selection of lean tools for productivity improvement improvement in assembly lines varies from industry to industry but basic tools were found common in most of the industries. The identified lean tools applied in the selected industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry for productivity improvement in assembly lines are mentioned in Table.2.

Table 1. Lean Tools applied for productivity improvement in assembly lines

Type of Industry	Lean Tools for productivity improvement in assembly lines
Textile & Garments Industry Footwear Industry Automobile Industry Pharmaceutical Industry Heavy Engineering Industry General Industry	Line Balancing, Time & Motion Study, Takt time, Single minute die exchange (SMED), Andon, Jidoka, 5S, Poka yoke, Division of Labour, Mathematical Modeling & Simulation, Automation, Bottleneck Analysis, Root cause analysis, Kaizen, Kanban, Total productive maintenance (TPM), Six sigma (DMAIC), Total quality management (TQM), Ishikawa diagram, Pareto analysis, Lean six sigma (LSS), Facility planning & layout, Standardized work, Workstation, Just in time (JIT), Overall equipment effectiveness (OEE), Waste relations matrix (WRM), Value stream mapping (VSM), Visual Conbtrol.

III. RESEARCH AIM AND OBJECTIVES

This research aimed to present the applications of major lean manufacturing tools for the productivity improvement in the assembly lines of diverse manufacturing industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry along with the effectiveness, impacts and their useful outcomes after implementation.

- To discuss the applications of lean manufacturing tools in the assembly lines of manufacturing industries
- To highlight the effectiveness of applied lean manufacturing tools in the productivity improvement

IV. RESEARCH METHODOLOGY

A narrative literature review was conducted to put the detailed and broader picture of the major lean manufacturing tools for the productivity improvement in assembly lines of selected manufacturing industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry in terms of their implementation in industrial world. For the analysis of literature, narrative review is used and it enables an extensive understanding of problems and controversies associated with the use of technology and at the same time, it helps to take out the key success factors of adopting and using technologies [45]. By this method, researchers conduct analysis of debates and outcomes of already conducted research; moreover, it helps in figuring out the research gap and future implications [44]. Present research paper, summarizes the data and evidences as collected from the previously conducted research on the implementation of major lean manufacturing tools for the productivity improvement in assembly lines of selected manufacturing industries.

Data Collection & Analysis

This narrative research was based on the secondary data which was collected from the previously conducted empirical studies, case studies and literature reviews. Research papers on the implementation of mentioned lean tools were downloaded and most suitable research papers on the major lean manufacturing tools for the productivity improvement in assembly lines of selected manufacturing industries were considered for the literature review. The data was extracted from those papers and was organized, analysed and discussed. The six (6) industry segmenents mentioned in Table.1 i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry are catered in our research.

Table 2. Types of selected Industries

S. No.	**Type of Industry**
1	Textile & Garments Industry
2	Footwear Industry
3	Automobile Industry
4	Pharmaceutical Industry
5	Heavy Engineering Industry
6	Generalised Industries

V. DISCUSSION

Kathem et al. (2021) reduced non-value added activities by 36%, production cycle time by 31%, and increased productivity by 43% by using the concepts of lean manufacturing and line balancing [2]. Haque et al. (2018) decreased 2 workers by suggesting a new sewing layout by using the ALB technique; the number of pieces produced per hour was suggested to increase from 129-to 235 (22048 pieces per month) [3]. Line balancing, frequent time & motion study, periodic takt time, TPM programs and OEE were also suggested among the other lean manufacturing practices for the improvement in productivity, profitability and quality of the assembly and production lines of Automobile Industry [20] [18] [19]. Yemani A. (2021) dealt with line balancing (LB) of the BOB T-shirt model by using control limit analysis (CLA), assembly line`s discrete event simulation (DES). Results indicated that production per day increased from 1032 to 1289 pieces. Labor productivity increased from 46.9% to 54.32%; machine productivity improved from 58.59% to 71.61%. The generated profit was also improved from 22704 to 28358birr[40]. Line balancing and frequent time & motion study were found popular and suitable among the other lean manufacturing practices for the improvement in productivity, profitability and quality of assembly & production lines of pharmaceutical industry [21], [23], [22]. Line balancing, time & motion study, 5 whys, 5S, cause & effect analysis were also recommended as the essential tools with TPM & OEE for the improvement in productivity, profitability and quality in the assembly & production line of manufacturing industry [23] [24] [25] [26]. The Production process of lady pencil skirts was improved by Aung and Tun (2021). Through the reduction of value-added activities, cycle time, and balanced workload at each of the workstations through line balancing, the efficiency of the single model assembly line was improved. Productivity was improved by two approaches i.e. appropriate training and supervision for sewing operations and work-sharing method were used among those workstations on which similar nature jobs were being performed [13]. Line balancing, time & motion study were also recommended as the essential tools with other lean tools i.e. Six Sigma (DMAIC), Lean Six Sigma (LSS) and Value Stream Mapping (VSM) for the improvement in productivity, profitability and quality in the assembly & production lines of various manufacturing industries [27] [28] [29] [30] [31]. The greater reduction in the cycle time needs larger investments in terms of machines or an expensive technology; however, approaches i.e. line balancing help companies to allocate resources efficiently and improve productivity [41]. The line balancing, time & motion study, WRM, Andon, root cause analysis, SMED and 5S were recommended as the most suitable lean practices among the other lean manufacturing practices for the improvement in productivity, profitability and quality of textile industry [32] [33] [34] [35]. The line balancing, time & motion study, root cause analysis, six sigma (DMAIC), lean six sigma (LSS), TPM and OEE were recommended as the most suitable lean practices among the other lean manufacturing practices for the improvement in productivity, profitability and quality of textile industry [37][36]. The development of user-friendly computer software with embedded solutions for line balancing would be a supportive step for the implementation of this technique in the industry for real-time [17]. The line balancing, time & motion study, Andon, jidoka, poka yoke, standardized work, root cause analysis, six sigma (DMAIC) and lean six sigma (LSS) were recommended as the most suitable lean practices among the other lean manufacturing practices for the improvement in productivity, profitability and quality of textile industry [37] [38] [39]. Alzoubi et al. (2019) improved workers` efficiency by the application of layout planning and line balancing techniques. It was found the logistic time of the product decreased dramatically without huge investments in machines and the latest technology [41].

VI. CONCLUSION

Line balancing leads to the optimal use of resources (manpower, time, and machines). Literature review was conducted on the major lean manufacturing tools for the productivity improvement in assembly lines of diverse manufacturing industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry. Most of the manufacturing industries are aware of lean manufacturing tools and many have initiated the implementation lean manufacturing tools for the productivity improvement in assembly lines. The six (6) industry segmenents i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry are catered in our research. We have identified twenty nine (29) major lean manufacturing which were being implemented successfully for the productivity improvement in the assembly lines of selected manufacturing industries. Organizations who have implemented lean philosophy have received less attention in developing countries [42]. Due to the lack of awareness about the effectiveness and impact of lean tools, the companies are reluctant to adopt this approach. At the other hand, resistance from employees and top management are also the main hindrances in the way to this change. In this regard, one of the researcher have suggested that the employees must be taught for proper lean tools implementation from the bottom to the top in the execution [43].

VII. LIMITATIONS AND FUTURE WORK

In the present paper, major lean manufacturing tools for the productivity improvement in assembly lines of six (6) diverse manufacturing industries i.e. Textile & Garments Industry, Footwear Industry, Automobile Industry, Pharmaceutical Industry, Heavy Engineering Industry and General Industry are discussed. We have identified twenty nine (29) major lean manufacturing which were being implemented successfully for the productivity improvement in the assembly lines of selected manufacturing industries. In the future research, other lean tools can be discussed in the context of same and/or other manufacturing industries in order to put more clear and broad picture of effectiveness and loopholes. More research papers can be considered in order to draw better and effective conclusion.

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VIII. CONFLICT OF INTERESTS

There was no conflict of interest among the authors of the present research paper.

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