Line Balancing and Layout Model for Productivity Improvement in Leather Footwear Industry

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Abstract
The government of Ethiopia considers the leather footwear industry as one of the priority sector that is capable of accelerating economic development by creating more employment opportunities. However, the industry’s contribution to the national economy so far is not enjoyable as productivity of the industry is much lower qualitatively, quantitatively and value-wise. The focal constraint against performance of the industry is the existence of bottleneck process in the production line. The major ones are pile up of ‘UPPER’ (i.e. upper part of a shoe) at some points, because of unequal workload distribution among workstations. Accordingly, the main objective of this study is to improve the production line efficiency through line balancing technique that is demonstrated by taking Peacock shoe factory as a case study. The study considered ‘Bades shoe model’ to investigate the production line in the Stitching department. Data were collected through direct data intake from the shop-floor activities and company’s database. A well-prepared templates and stopwatch were used for the data collection. The analysis was carried out through the logic of modular system. This system uses work sharing method in which cross-trained workers perform multiple tasks to eliminate bottleneck processes and balance workloads among workstations. Furthermore, the study proposed a layout model to balance the production line. The results suggest that the production line efficiency is improved from 68.89% to 87.6%, and the labor productivity is increased from 16.67 to 23.44. The findings provide important insights into productivity improvements by creating smooth flow of components in assembly lines.

Keywords: Ethiopia, leather footwear, bottleneck process, line balancing.
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1. Introduction
The tannery operation consists of converting the raw skin (a highly putrescible material) into leather (a stable material). The leather material is used for the manufacturing of a wide range of products like footwear, leather cloth, general goods, etc. The orientation of finishing tanneries has altered over the last few decades. Nowadays, tanneries produce leather material mainly for footwear, garments, general goods, furniture manufacturers and automotive upholstery manufacturers. Of which, the footwear subsector has grown considerably fast. About 65% of the world production of leather is estimated to go into leather footwear production (Netsanet 2014). The production of leather footwear plays a considerable role in the development process of both developing and developed countries (Ulutas and Islier 2015). The total export of leather footwear in the world is US $47 billion. China is the leading exporter of footwear with total market share of 22% followed by Italy, which accounts a value of 15%. Vietnam, Hong Kong, Germany and Belgium follow with footwear export share of 8%, 7.8%, 4.4%, and 3.9%, respectively. On the contrary, Africa’s share of footwear export is mere 1.3% (LIDI 2012). In general, the total production of leather and leather products in Africa is much lower qualitatively, quantitatively and value-wise (Mwinyihija 2014). Seizing the global market opportunities has remained the key challenge, irrespective of having large resource endowment to satisfy raw material needs. Africa contains 21% of the livestock population in the world (UNIDO 2010). Reducing the gap between resources and production is critical for the development of the leather-processing countries in Africa. Ethiopia is one of the leading leather processing countries in Africa (Addis et al. 2019). The leather industry in Ethiopia puts at the forefront of the African leather sector in line with its current comparative advantage for the raw material needs. Availability of large livestock population constituted the country's comparative advantages for the development of leather sector in Ethiopia. Ethiopia has the major comparative advantage to satisfy global raw material requirements (1st in Africa and 10th in the world in livestock population) (UNIDO 2010). The livestock population growth trend (cattle, sheep and goat) also shows potential of the sector to be the main economic source of the country in the future. The livestock population escalated from 54.5 million in 1995/96 to 77.5 million in 2005/06 to 103.5 million in 2012/13 (Leta and Mesele 2014). This resource potential makes the leather industry to be a good candidate for a concerted effort to expand production and achieve competitiveness at the international level.

Despite the above mentioned indigenous resource potentials, the leather industry of Ethiopia is yet to utilize its resources to appreciable extent (Addis 2019). It significantly lags behind many countries that are less abundantly endowed with their indigenous resources (Netsanet 2014). The tannery and footwear producers operate at 44.97% and 47.6% of the daily production capacity, respectively. For the period of 2005-2009, footwear producers
performed, on average, only 27.55% of the planned export value (LIDI 2012). Also, actual average production of the footwear industry is far below the international benchmark standards. For instance, in 2009, the footwear producing companies perform 4 pairs of shoe/day/person, which characterized low operational performance and production efficiency as compared to best practices (i.e. 16 pairs of shoe/day/person) (Cherkos 2011). Studies revealed that the industry faces serious problems, both in the production of raw materials and in the manufacturing stages (Addis et al. 2017b). Addressing constraints downstream to the manufacturing stage is critical, because higher stage of manufacturing activity enable organizations achieve increased level of operational performances (Addis, et al. 2017a). One of the focal constraint against the productivity of footwear industries is bottleneck process in the production line, which results in long production lead times (Addis, et al. 2017a). Bottleneck operations are recognized as having a relentless impact on the operational performance of the footwear manufacturing organizations in Ethiopia. Bottleneck creates a queue and a longer overall cycle time. This study considered Peacock shoe factory as a case study. Peacock shoe factory, one of footwear manufacturer engaged in production of Ladies’ shoes and Men’s shoes, faces problems in the production line. Among many problems, the major ones are pile up of ‘UPPER’ (i.e. upper part of a shoe) at some workstations, because of unequal workload distribution among workstations. There are bottlenecks at some stations and low utilization of the production lines. Moreover, some stations have higher utilization as compared to others. When extra UPPER is piled up at a workstation, the supervisor shifts operators from another workstation to balance the system. This process happens every now and then. To solve the problem, there is a need to optimize the distribution of workloads among workstation, reduce production cycle time and maximize the output/productivity. Accordingly, the main objective of this study is to improve the production line efficiency through line balancing technique that is demonstrated by taking Peacock shoe factory as a case study.

The rest of the paper has been organized as follows. Sections 2 presents the concept of line balancing. Section 3 presents the methodology, followed by data analysis in Section 4. Subsequently, results of the study and conclusions are presented in Section 5 and Section 6, respectively.

2. Line Balancing Concept
A line is defined as a group of operators under the control of production supervisors. Balancing refers to the procedures of adjusting the operation times at work centers to conform as much as possible to the required cycle time and production target. Line balancing is defined as the appointment of sequential work activities into workstations in order to gain a high utilization of labor and equipment and therefore minimize idle time. The line balancing is concerned with assigning the individual work elements so that all workers have an equal amount of work (Kitaw et al. 2010). The objective of line balancing is to balance the workload of each operation to make sure that the flow of work is smooth, that no bottlenecks are created, and operators are able to work at peak performance throughout the day. Line balancing is a way to minimize the workload between workers to achieve the desired output. Balancing may be achieved by rearrangement of the workstations or by adding machines and workers at some of work stations. This process is intended to reduce waiting time to a minimum, and try to equalize standard time of each operation. A balanced process is one where the actual cycle times at every stage are equal. The line balancing is important to enable better production planning and schedule, enable operators to work at optimal pace, and keep inventory cost low (Agarwal et al. 2019).

3. Methodology
Peacock shoe factory manufactures a variety of shoe models. This study has considered a specific type of shoe model, i.e. ‘Bades shoe model’ to investigate the production line. The raw material, mainly leather, is processed in different departments such as cutting, stitching and lasting departments. In this study, the Stitching department is considered as it is the largest and most important department in the footwear production. Operations involved in the stitching department significantly determines the whole speed of the leather components assembly in the company. The study has been conducted by comparing the productivity and efficiency before and after applying the line balancing technique. The time to make each process has been recorded, and standard pitch time and capacity for workstations have been determined. A stopwatch was used to record operation times. To find out the standard allowable minute (SAM) value, process wise capacity has been calculated. In addition, the labor productivity and line efficiency are calculated. The production line has been balanced considering the “bottleneck processes” and “balancing processes”, where the balancing process shared some jobs of the bottleneck process. After balancing, new manpower has been proposed and final capacity of each worker has been reallocated. The study also proposed production layout model that has been modeled with the balanced capacity of each workstation.

4. Data Analysis
The study has been conducted by comparing the productivity and efficiency before and after applying the line balancing technique.
4.1. Before Line Balancing

The processing time has been recorded to find out the number of operators, SAM and process wise capacity. Process capacity was determined using the working time available in a day i.e. 8hr or 480min=28800sec. For instance, the ‘Stamping on lining’ operation has a standard time of 13.90 second. Thus, capacity/day is 28800sec/13.90 sec = 2071 units/day. Similarly, the process capacity is determined for all the operations. Process wise capacity of each work station is presented in Annexure 1. Table 1 presents the total output/day, a total number of manpower on the production line and a daily working time with a S.A.M value of 20. The study standardized the benchmark target of 750 pair of shoes/day. The benchmark target was set considering the bottleneck problem that is responsible for the total production line efficiency. From the capacity determination, each workstation is possible to upgrade the target daily production to 750 (see Annexure 1). Observation before the line balancing showed that labor productivity and line efficiency as 16.67 and 69.44%, respectively (see Table 1). Both are calculated using equation (1) and equation (2), respectively. Plotting process wise capacity in a line graph shows the variation of each process from the benchmark target as the upper capacity is 2277 pieces/day and the lower capacity is only 407 pieces/day compare to the benchmark target of 750 pieces/day. The process capacity before the line balancing is shown in Figure 1. It can be revealed from figure 1 that there is an imbalance situation and existence of bottleneck throughout the workstations in the stitching department.

- Labor productivity = Total number of output per day per line/number of workers………………………..(1)
- Line efficiency = Total output/day * S.A.M / (total manpower/line * total working minutes/day)*100%..(2)

4.2. Line Balancing

The processing line has been balanced considering the bottleneck processes and balancing process where the balancing process has shared the excess time to the bottleneck process. The basic objective of line balancing is to achieve efficient utilization of manpower. The classical industrial engineering studies of line balancing considers the logic of modular system that shifts work or workers from one station to another to balance the load (Gel et al. 2002). In the traditional system, one worker is eligible to perform one process. The present study followed the logic of modular system (one worker perform more than one operations). In such cases, a series of skilled cross-trained workers are required to perform multiple tasks and to achieve more productivity. On this occasion, skilled workers are eligible for the production processes and proper training is essential to achieve the optimum improvements on productivity and efficiency.

Bottleneck processes

Variations in the process capacity of the different workstations (WS) have been revealed in Figure 1. WSs with the lower capacity compared to the benchmark target is the bottleneck process as production flow would stuck on these stations. 11 bottleneck WSs have been identified. These are Back seam stitching and Upper quarter stitching, Foam attachment on vamp, lining attaching on upper and lining attaching on apron, Glue app. on quarter lining, lasting margin stitch (vamp), Counter stifener and lining attach, Elastic stitch on quarter, Thread burning and cleaning, Counter molding and Vamp zigzag stitch, Thread burning and cleaning and Strap stitch one. The total production line has been blocked in these 11 WSs and large work-in-process (WIP) are stuck in these bottleneck stations.

Balancing Processes

Balancing method is very essential to make the production flow smoother, by eliminating the bottleneck WSs. The logic of modular system allows workers, who have extra time after completing their works, to help and complete the bottleneck processes. The 11 bottleneck WSs are presented in the left side of Table 2. Worker who is working in Process no. 1 takes 7.38hr to completed his/her daily job and then help process no. 2 for last 22 minutes. Process no. 3 takes 7.39hr to completed his/her daily job and then help process no. 4 for last 21 minutes. Similarly, workers who are working on process no.5, 8, 10, 13, 12, 16, 18, 19, and 22 are required to help process no.7, 6, 9, 11, 15, 17, 14, 21 and 23, respectively. Now, each of WSs has almost a balanced workload through the combination of balancing and bottleneck processes, and operators are able to work at peak performance throughout the day (see Table 2).

4.3. Proposed Layout

The proposed layout model in Figure 2 shows that the processes in the production line are almost balanced through the combination of balancing and bottleneck processes. The Proposed layout model followed the logic of modular system (one worker works more than one processes who is skilled on all processes and these combination of skilled workers finish their work in piece flow production). The blue arrow on the center table indicates the production flow through the process no. and green arrow shows the sharing of works in between balancing and bottleneck processes. First column on both side of center table shows the WSs and then followed by process no. process name, S.A.M value, previous capacity and capacity after balancing. After the first process, i.e. stamping on lining and re-
enf. attachment on counter, bundle of leather components come to process no. 2, i.e. Back seam stitching and Upper quarter stitching, then the bundle passes horizontally to process no. 3 and so on. From process no. 1 to 2 and process no. 8 to 6, work flows vertically with short distance for balancing out the possible processes of no. 2 and 6. Similarly, for balancing 11 stations, the short possible distance can be used that makes the total production time minimum.

5. Result
Changing from traditional layout to balanced layout model results in improvements in manpower utilization and the total production efficiency. The total number of workers in stitching department were reduced from 42 to 32 (see Annexure 1), labor productivity has been increased from 16.67 to 23.44 and has been improved from 68.89% to 87.6%. The production capacity can be boost up to 750/day with manpower of 32 (see Table 3). After balancing the process flow, figure- 3: shows less variation of each process from the benchmark target. It reflects a balanced flow in the production line.

6. Conclusion
In this study, the aim was to improve the productivity of a leather footwear manufacturing company by using a line balancing technique and standardization of work through a layout model. The real problem is identified and it is found to be associated with the line balancing and standardization. Line balancing was conducted and process flow is analyzed thoroughly. The production line has been balanced considering the 'bottleneck processes' and 'balancing process', where the balancing process shared the excess time to the bottleneck process. The layout model also provided efficient arrangement of workstations to create smooth flow of components in the production line. The results showed that the production line efficiency of the company is improved from 68.89% to 87.6%, and the labor productivity is increased from 16.67 to 23.44. It is also revealed that the total number of workers were reduced from 42 to 32.

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### Annexure 1: Capacity determination for stitching department

| Sr. No. | Operations in sequence | Std. time | Capacity/day | No. of worker | Remark | Proposed capacity and no. of workers (Target 750) |
|---------|------------------------|-----------|--------------|---------------|--------|-----------------------------------------------|
| 1       | Stamping on lining     | 13.90     | 2071         | 1             | Club together and assist operation 2 | 1 | Stamping on lining and Re-enf. attachment on counter | 0.588 | 1 | 753 |
| 2       | Re-enf. attachment on counter | 23.89 | 1205 | 1 | Club together | 2 | Back seam stitching and Upper quarter stitching | 0.667 | 1 | 753 |
| 3       | Back seam stitching    | 20.21     | 1425         | 1             | Club together | 3 | Lining quarter stitching and Hammering | 0.572 | 1 | 775 |
| 4       | Upper quarter stitching| 20.24     | 1423         | 1             | Club together | 4 | Foam attachment on vamp | 0.645 | 2 | 760 |
| 5       | Lining quarter stitching| 18.77   | 1534         | 1             | Club together and assist operation 7 | 5 | Foam attaching on apron | 0.591 | 2 | 760 |
| 6       | Hammering              | 17.71     | 1626         | 1             | Club together | 6 | Glue app. on quarter lining | 0.654 | 2 | 751 |
| 7       | Foam attachment on vamp| 79.12     | 728          | 2             | Club together and assisted from operation 8 | 7 | Lining attaching on upper and lining attaching on apron | 0.654 | 1 | 755 |
| 8       | Foam attaching on apron| 74.2      | 776          | 2             | Club together and assisted from operation 9 | 8 | Vamp re-cut and Apron re-cut | 0.586 | 1 | 756 |
| 9       | Glue app. on quarter lining | 80.24 | 718 | 2 | Club together and assisted from operation 10 | 9 | Lining attaching on upper and lining attaching on apron | 0.661 | 1 | 760 |
| 10      | Lining attaching on upper | 15.07   | 1911         | 1             | Club together and assisted from operation 11 | 10 | Marking on vamp | 0.582 | 1 | 760 |
| 11      | Lining attaching on apron | 14.72   | 1957         | 1             | Club together and assisted from operation 12 | 11 | Counter stiffener and lining attach | 0.653 | 1 | 757 |
| 12      | Vamp re-cut            | 19.04     | 1513         | 1             | Club together and assist operation 13 | 12 | Counter stitch with vamp | 0.571 | 2 | 760 |
| 13      | Apron re-cut           | 17.38     | 1657         | 1             | Club together and assisted from operation 14 | 13 | Trimming | 0.585 | 1 | 764 |
| 14      | Lining attaching on upper | 39.71   | 725          | 1             | Club together and assisted from operation 15 | 14 | Counter molding and Vamp zigzag stitch | 0.654 | 1 | 756 |
| 15      | Lining attaching on apron | 14.72   | 1957         | 1             | Club together and assisted from operation 16 | 15 | Counter molding and Vamp zigzag stitch | 0.683 | 1 | 755 |
| 16      | Vamp re-cut            | 39.21     | 734          | 2             | Club together and assisted from operation 17 | 16 | Counter stitch with vamp | 0.567 | 1 | 755 |
| 17      | Apron re-cut           | 17.38     | 1657         | 1             | Club together and assisted from operation 18 | 17 | Thread burning and cleaning | 0.669 | 2 | 751 |
| 18      | Vamp zigzag stitch     | 39.21     | 734          | 2             | Club together and assisted from operation 19 | 18 | Bind tape attaching | 0.587 | 1 | 761 |
| 19      | Vamp re-cut            | 14.72     | 1957         | 1             | Club together and assisted from operation 20 | 19 | Vamp re-cut and Apron re-cut | 0.586 | 1 | 756 |
| 20      | Apron re-cut           | 17.38     | 1657         | 1             | Club together and assisted from operation 21 | 20 | Apron stitch | 0.567 | 1 | 755 |
| 21      | Vamp zigzag stitch     | 39.21     | 734          | 2             | Club together and assisted from operation 22 | 21 | Thread burning and cleaning | 0.669 | 2 | 751 |
| 22      | Apron re-cut           | 39.21     | 734          | 2             | Club together and assisted from operation 23 | 22 | Bind tape attaching | 0.587 | 1 | 761 |
| 23      | Vamp re-cut            | 14.72     | 1957         | 1             | Club together and assisted from operation 24 | 23 | Vamp re-cut and Apron re-cut | 0.586 | 1 | 756 |
| 24      | Apron re-cut           | 17.38     | 1657         | 1             | Club together and assisted from operation 25 | 24 | Apron stitch | 0.567 | 1 | 755 |
| 25      | Vamp zigzag stitch     | 39.21     | 734          | 2             | Club together and assisted from operation 26 | 25 | Vamp re-cut and Apron re-cut | 0.586 | 1 | 756 |
| 26      | Apron re-cut           | 39.21     | 734          | 2             | Club together and assisted from operation 27 | 26 | Apron stitch | 0.567 | 1 | 755 |
## Actual capacity and actual no. of workers

| Sr. No. | Operations in sequence | Std. time  | Capacity/day | No. of worker | Remark |
|---------|------------------------|------------|--------------|---------------|--------|
| 27      | Thread burning and cleaning | 23.11      | 1246         | 2             |        |
| 28      | Strap Folding          | 35.98      | 820          | 1             | Assist operation 29 |
| 29      | Strap stitch one       | 42.01      | 685          | 1             |        |
| 30      | Strap attachment       | 17.72      | 1625         | 1             | Club together |
| 31      | Strap stitch two       | 18.77      | 1534         | 1             | Club together |
| 32      | Jewelry attach         | 13.78      | 2090         | 1             |        |
| 33      | Foam attaching         | 24.30      | 1185         | 1             |        |
| 34      | Socks stitching        | 16.49      | 1747         | 1             | Club together |
| 35      | Inspection             | 12.65      | 2277         | 1             |        |
| Total   |                        |            |              | 42            |        |

## Proposed capacity and no. of workers (Target 750)

| Sr. No. | Operations in sequence | S.A.M  | No. of worker | Capacity/day |
|---------|------------------------|--------|---------------|--------------|
| 21      | Thread burning and cleaning | 0.632  | 1             | 760          |
| 22      | Strap Folding          | 0.568  | 1             | 751          |
| 23      | Strap stitch one       | 0.7    | 1             | 754          |
| 24      | Strap attachment and Strap stitch two | 0.608  | 1             | 789          |
| 25      | Jewelry attach and Foam attaching | 0.635  | 1             | 756          |
| 26      | Socks stitching and Inspection | 0.585  | 1             | 800          |

### Figure 1. Variations in process capacity with respect to the benchmark target (i.e. 750 pieces/day)
Figure 2. Proposed layout model to balance the bottleneck processes.

Figure 3. Variation in each process capacity per day compare to benchmark target per day.
Table 1. Line Efficiency and Labor productivity for Bades shoe model

| Total Output Per Day | 700 |
|----------------------|-----|
| Total Manpower =     | 42  |
| Working Time =       | 480 Minute |
| S.A.M =              | 20min |
| Target /day =        | 750 |
| Labor Productivity = | 16.67 |
| Line Efficiency % =  | 68.89 |

Table 2. Balancing Processes to equalize the bottleneck process

| S.No. | Bottleneck process | Balanced process |
|-------|--------------------|------------------|
|       | Process Name       | Process No. | Cap/hr | Balanced Capacity | Process Name | Process No. | Cap/hr | Balanced Capacity |
| 1     | Back seam stitching and Upper quarter stitching | 2          | 720    | 753              | Stamping on lining and Re-enf. attachment on counter | 1          | 786    | 753              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 2     | Foam attachment on vamp | 4          | 728    | 760              | Lining quarter stitching and Hammering | 3          | 807    | 775              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 3     | Lining attaching on upper and lining attaching on apron | 7          | 739    | 755              | Foam attaching on apron | 5          | 776    | 760              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 4     | Glue app. on quarter lining | 6          | 718    | 751              | Vamp re-cut and Apron | 8          | 789    | 756              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 5     | Lasting margin stitch (vamp) | 9          | 725    | 760              | Marking on vamp | 10         | 795    | 760              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 6     | Counter stiffener and lining attach | 11         | 734    | 757              | Trimming      | 13         | 787    | 764              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 7     | Elastic stitch on quarter | 15         | 701    | 755              | Counter stitch with vamp | 12         | 814    | 760              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 8     | Thread burning and cleaning | 17         | 684    | 751              | Apron stitch | 16         | 822    | 755              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 9     | Counter molding and Vamp zigzag stitch | 14         | 733    | 756              | Bind tape attaching | 18         | 784    | 761              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 10    | Thread burning and cleaning | 21         | 720    | 760              | Bind stitching | 19         | 810    | 770              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |
| 11    | Strap stitch one   | 23         | 685    | 754              | Strap Folding | 22         | 820    | 751              |
|       | Remarks:           |             |        |                  | Remarks:      |             |        |                  |

Table 3. Labor productivity and Line Efficiency after line balancing.

| Total Output Per Day | 750 |
|----------------------|-----|
| Total Manpower =     | 32  |
| Working Time =       | 480Minutes |
| S.A.M =              | 20  |
| Labor Productivity = | 23.44 |
| Line Efficiency % =  | 87.6 |

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