Journal of Scientific Research and Development 2 (12): 88-94, 2015
Available online at www.jsrad.org
ISSN 1115-7569

Time study of lean manufacturing practices in production floor

T.C. Ng [1, *], C. J. Leong [2]

[1]*Faculty of Engineering and Science, University Tunku Abdul Rahman, Kuala Lumpur, Malaysia*
[1]*Faculty of Engineering, University Putra Malaysia, Serdang, Malaysia*
[2]*Faculty of Engineering and Science, University Tunku Abdul Rahman, Kuala Lumpur, Malaysia*

Abstract: Time study is one of the Lean Tools that helps to analyze the total cycle time used in the production line. With Time Study, the company can gain lead time for flexibility in their operations. Time study is conducted in ABC Sdn. Bhd., to meet the deadline set by the customer when they received massive volume order. Applying Time Study itself does not impact much on the output desired. In Lean, there are many other principles and tools, and all of them play an important role to produce better outcome, in terms of productivity. However, there are never one tool for all solutions. Combinations of related principles are the key to success and improvement in Lean. Thus, layout modifications and 5S are introduced along with Time Study. With all three main principle on the go, the lead time for the operation can be seen significantly after the implementations. The aim of this case study is to create a better and comfort working space for the employees in ABC Sdn Bhd on top of finding a best and effective solution to deliver the finished products smoothly. As a result, a brand new layout and environment is formed in the production floor.

Key words: Lean tools; Time study; Lean; 5S; Cycle time; Layout

1. Introduction

The company that is involved in this study is ABC Sdn Bhd. Untidiness of the environment in the factory area causing delays on identification and placements of tools used. Scattering of various stations within large area leads to unwanted transportations and movements of work in progress which does not add value to it. For instance, the process layouts between stations for the strip brush manufacturing line are far apart among each stations and the material are not flowing in a smooth path.

In this research, the main objective was to identify the total cycle time spent in the production and eliminate the transportation time by re-modify the production layout and eventually reduce the cycle time. The scope of this study involves the areas within the factory focusing on the cleanliness and tidiness criteria, especially the stations for strip brush production, the workshop centre and the machine storage area. Also, this study will focus on the two stations under strip brush production, which are the Stamping station and the Pinnacle stations. The distances between the two stations are far apart from each other which extend the cycle time for the strip brush production as well as the overall transportation distance of work in progress within the production.

2. Literature review

2.1. Elements of 5S

1. Sort - Sorting out all the necessary items including tools and parts to identify what it has, what it uses and what is not needed.
2. Set - Setting all required items in order.
3. Shine - Cleaning, inspection and carry out maintenance for tools and machine in order to perform better.
4. Standardize - Create a standard format and system for everyone to follow to maintain the system
5. Sustain - Execute and follow the system with regular practices

2.2. U-shaped assembly line layouts and their impact on labour productivity

In order to modify an existing assembly line in a manufacturing company, there are 6 steps to take into considerations as a guide to convert the traditional long assembly line into a work effective U-Shaped layout.

1) Step 1: Calculate the desired reduction in number of workstations.
2) Step 2: Calculate the labour productivity level.
3) Step 3: Determine the percent improvement in labour productivity.
4) Step 4: Determine the number of problem instances that experience an improvement in labour productivity.

* Corresponding Author.

5) Step 5: Identify the number of operators that work across both legs (crossovers).
6) Step 6: Determine the percent workstations requiring crossovers.

3. Methodology

3.1. Dimension of the factory layout using footstep method

The distances are recorded based on the numbers of footsteps stacked as shown in Fig. 1. After recording the numbers of footstep, the length of one footstep is measured and the overall factory layout is calculated by multiplication of the length of the footstep with the number of the footstep between two stations. The distance is measured in XY Cartesian coordination instead of diagonally or crooked as travelled by the workers. Thus, in order to travel to another station involving cornering or non-linear direction, the "L" shape Footstep Method in Fig. 2 is applied.

The distance travelled was calculated using Equation 1 as below:

$$\text{1 Footstep (35cm)} \times \text{Number of FootStep Along the Distance} = \text{The Distance Travelled in cm} \quad (1)$$

Fig. 1: The footstep method used to calculate the distance within the factory

Fig. 2: "L" shape footstep method

3.2. Simulated data for travelling time using footstep method

The time spent in each station was recorded in the data sheet. The data travelling time within the factory is simulated by walking along a certain length of distance (450cm) and the time taken is recorded, a set of 6 data is taken in order to obtain a accurate result.

$$\frac{\text{(Average time travel along 450cm)}}{\text{450cm}} = \text{Simulated Travelling Time for 1 cm} \quad (2)$$

$$\text{Simulated Travelling Time for 1 cm} \times \text{Total Distance Travelled} = \text{Total Simulated Travelling Time for Work In Progress} \quad (3)$$

Equation 2 is used to calculate the travelling time estimated for 1 cm travelled whereas Equation 3 is used to calculate the total estimated time travelled by the work in progress within the production line.

4. Results and discussion

4.1. Current material flow in production

Fig. 3 below shows the flow of the current material in the Strip Brush Production Line, from the raw material to the final finished goods and delivered to the customers.

Material Flow in Production Cycle Time:
1) From Raw Material to Strip Brush Machine
2) From Strip Brush Machine to Inventory
3) From Inventory to Stamping Station
4) From Stamping Station to Pinnacle Station
5) From Pinnacle Station to far end Binding Station 1
6) From Binding Station 1 to Binding Station 2
7) From Binding Station 2 to Checking Station
8) From Checking Station to Packing and Trimming Station
9) From Packing and Trimming Station to warehouse.

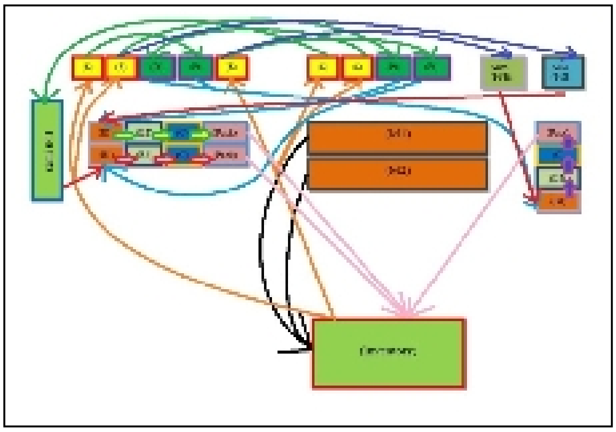

Fig. 3: Full layout of the production floor with material flow

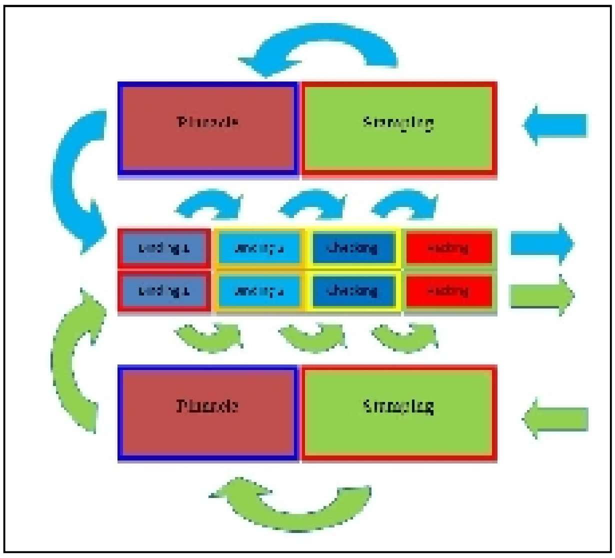

Fig. 4: Layout of suggestion 1

4.1.1. Current total production cycle time in production

The overall Production Cycle Time including the processing time within the each stations and the time taken to transport the work in progress. The transportation time is derived from distance from one station to another and its then multiplied with the simulated time under Footstep Method and added into the process time of each station. Thus, the total production cycle time is obtained by using Equation 4 as shown.

$$(1\ \text{Footstep (25cm)} \times \textit{Number of Footstep Along the Distance} \times \textit{Simulated Time Taken for 1cm}) + \textit{the average time taken for all the 6 stations} = \text{Total Production Cycle Time} \quad (4)$$

The distance for the work in progress to travel are Distance from Strip Brush to Inventory, Distance from Inventory to Stamping, Distance from Stamping to Near Pinnacle (few machine distance), and the Distance from Pinnacle to Far End Binding Station. These distance were calculated and tabulated into the table in the Appendices section under total production cycle time.

Referring to Table 4 in Appendices, the total Production Cycle Time for the current production is 129.898 s.

4.2. Suggestions for strip brush production line

There are a few suggestions proposed by the author in order to overcome the current problem faced by the company under Strip Brush Production Line. A total of three suggestions were proposed and the suggestions were mainly focusing on the material flow in the production line.

4.2.1. Suggestion 1 strip brush production line

<u>Material Flow in Production Line</u>:

1) From Raw Material to Strip Brush Machine
2) From Strip Brush Machine to Inventory
3) From Inventory to Stamping Station
4) From Stamping Station to Pinnacle Station (arranged side by side)
5) From Pinnacle Station to Binding Station 1 (with nearest distance)
6) From Binding Station 1 to Binding Station 2
7) From Binding Station 2 to Checking Station
8) From Checking Station to Packing and Trimming Station
9) From Packing and Trimming Station to warehouse.

Referring to Table 5 in Appendices, the total Production Cycle Time for the Suggestion 1 Layout is 98.981s.

4.2.2. Suggestion 2 for strip brush production line

<u>Material Flow in Production Line:</u>

1) From Raw Material to Strip Brush Machine
2) From Strip Brush Machine to Inventory
3) From Inventory to Stamping Station
4) From Stamping Station to Pinnacle Station (arranged side by side)
5) From Pinnacle Station to Binding Station 1 via sliding in Slider
6) From Binding Station 1 to Binding Station 2
7) From Binding Station 2 to Checking Station
8) From Checking Station to Packing and Trimming Station
9) From Packing and Trimming Station to warehouse

Referring to Table 6 in Appendices, the total Production Cycle Time for the Suggestion 2 Layout is 98.848 s.

4.2.1. Suggestion 1 Strip Brush Production Line

<u>Material Flow in Production Line:</u>

1) From Raw Material to Strip Brush Machine
2) From Strip Brush Machine to Near Inventory
3) From Near Inventory to Stamping Station
4) From Stamping Station to Pinnacle Station (arranged side by side)
5) From Pinnacle Station to Binding Station 1 via sliding in Slider
6) From Binding Station 1 to Binding Station 2
7) From Binding Station 2 to Checking Station
8) From Checking Station to Packing and Trimming Station
9) From Packing and Trimming Station to warehouse.

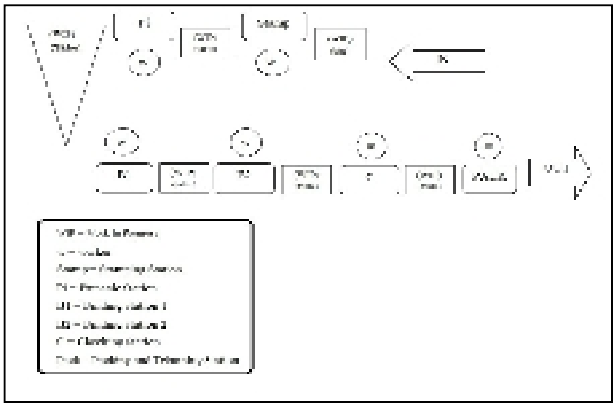

Fig. 5: Layout of suggestion 2

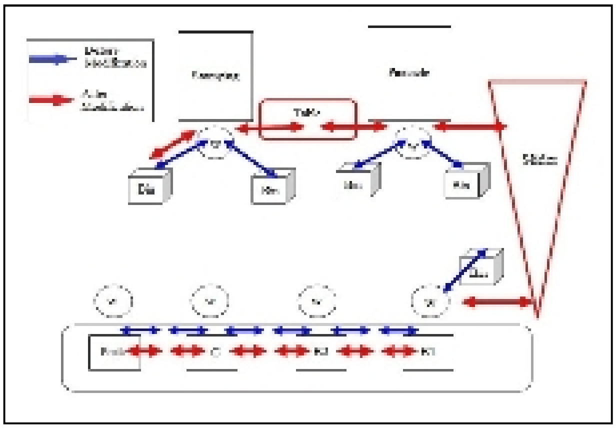

Fig. 6: Elemental task modification of Suggestion 2

Referring to Table 7, the total Production Cycle Time for the Suggestion 3 Layout is 47.436 s.

4.3. Final analysis on suggestion selection and implementations

4.3.1. ANOVA analysis on current production cycle time

The current situation and the total production cycle time data from Table 1 were analyzed by ANOVA. The p value and the F critical value are 6.35E-35 and 2.007792 respectively.

Table 1: ANOVA on Current Production Cycle Time

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Row 1	6	0.45	0.075	0		
Row 2	6	126.0844	21.01407	1.60224		
Row 3	6	210.9966	35.1661	4.65991		
Row 4	6	20.4	3.4	[illegible]		
Row 5	6	[illegible]	13.84[illegible]	[illegible]		
Row 6	6	17.15	2.858333	0.555537		
Row 7	6	119.2071	19.86785	[illegible]		
Row 8	6	48.64	8.106667	2.827107		
Row 9	6	35.86	5.976667	0.258467		
Row 10	6	66.38	11.06333	34.39691		
Row 11	6	51.14	8.523333	4.928467		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6231.822	10	623.1822	134.165	6.35E-35	2.007792
Within Groups	256.9087	55	4.671022			
Total	6488.731	65				

4.3.2. ANOVA analysis on suggestion 3 production cycle time

The data of the total production cycle time for Suggestion 3 from Table 2 is analyzed by ANOVA. The p value and the F critical value are 1.69E-12 and 2.073351 respectively.

From all four analysis, Suggestion 3 has the shortest production cycle time even though the p value, 1.69E-12, is slightly higher than the current situation's p value of 6.35E-35. As long the production cycle time is the shortest among the three suggestions and the p value is less than 0.05. The null hypothesis is rejected and the solution in Suggestion 3 is valid.

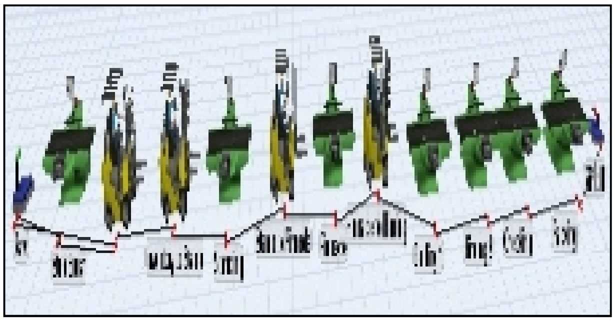

Fig. 8: Current process layout in FlexSim

Table 2: ANOVA on Suggestion 3 Production Cycle Time

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Row 1	6	0.45	0.075	0		
Row 2	6	10.54574	1.757624	0.01[illegible]		
Row 3	6	18.06446	3.010743	0.032889		
Row 4	6	19.326	3.221	0.09916		
Row 5	6	16.15	2.691667	0.129573		
Row 6	6	18	3	0		
Row 7	6	48.64	8.106667	2.827107		
Row 8	6	35.86	5.976667	0.258467		
Row 9	6	66.38	11.06333	34.39691		
Row 10	6	51.14	8.523333	4.928467		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	661.1565	9	73.46183	17.23224	1.69E-12	2.073351
Within Groups	213.3787	50	4.267575			
Total	875.3374	59				

4.4. Cost Saved and Profit Earned in 1 unit produced

The cost and profit earned in the production is mainly the interest of the company. The profit of a unit produced is assumed to be RM1 under both situation, current and the final solution. With the final solution provided, using Suggestion 3, in Table 4.15 shows the differences between both situations, before and after implementation in terms of profit earned by the company.

The ratio of the production before and after is approximately 1 to 4, which means under the same production time; the company earned additional RM 3 under the final solution.

Therefore, from the simple estimation, the time taken to produce 1 unit of finished product from the current situation is approximately four times more as compared to the final solution. Thus, by applying the solution, the company can earn approximately RM 183040 instead of RM 45760, which have the difference of RM 137280 for 1 year production.

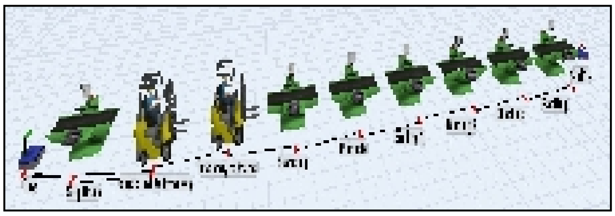

Fig. 9: Suggestion 3 process layout in Flexsim

4.5. Verification of Layout using FlexiSim

Both the picture below (Fig. 8 & 9) were obtained from FlexSim and the simulation is executed which supports the implementation of Suggestion 3 into the Strip Brush Production Line. Fig. 8 is the simulated process layout of the current situation whereas the Fig. 9 is the simulated process layout for Suggestion 3.

Table 3: Profit Earned in Producing 1 Unit of Strip Brush

	Before	After	Absolute Difference
Total production cycle for 1 unit produced (in sec)	129.909	47.418	82.491
Ratio of production per unit	1.000	3.000	2.000
Profit earned for 1 unit produced (assumption)	1.000	1.000	0.000
Total units produced in 3 minute(180 sec) (in sec)	1.385	3.794	2.409
Ratio	1.000	4.000	3.000
Total profit earned in 3 minutes	RM 1.00	RM 4.00	RM 3.00
Total profit earned in 1 hour (60 minutes)	RM20.00	RM 80.00	RM 60.00
Total profit earned in 1 shift/day (8 Hours working time)	RM 160.00	RM 640.00	RM 480.00
Total profit earned in a week (5.5 working days = 44 hours)	RM 880.00	RM 3520.00	RM 2640.00
Total profit earned in a year (52 weeks)	RM 45760.00	RM 183040.00	RM 137280.00

4.6. Using solid works for process layout

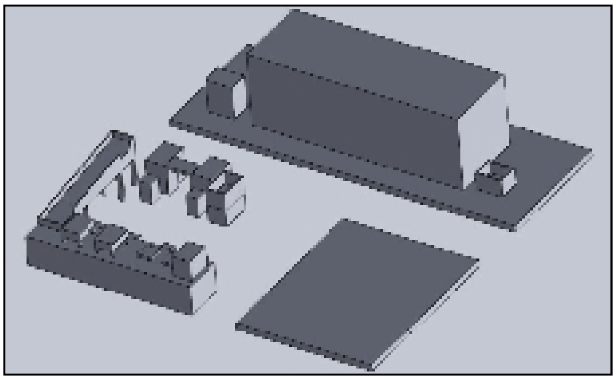

Fig. 11: Isometric view of the suggestion 3

4.7. 5. Simulation implementations

In order to maintain the cleanliness and tidiness of the environment around the factory, 5S, (sort, set, shine, standardized and sustain), were implemented to the company in a few areas.

Fig. 12: At the recycle cartoon box area (before)

Fig. 13: At the recycle cartoon box area (after)

Fig. 14: At the tools center (before

Also, at the tools center, the initial situation as shown in Fig. 14 was messy and not oriented. The worker seems to have a hard time finding the tools and profile required easily and fast. Thus, after the implementation with additional of labeling on it, the situation seems to be more organized (Fig. 15).

At the Head Brush Assembly Station as well as the Strip Brush Station at the final stage under quality checking, visualized labels are placed at a observable location in order to guide and remind the workers to check the quality of the product produced with the simple visual of how is a pass product and how is a not pass product. This is to prevent the finished goods that are defect to be send to the customer else, the company has to bear the losses for breach of the contract. Fig. 18 to 22 is the labeling done to the respective stations as indicator to the workers.

Fig. 15: At the tools center (before)

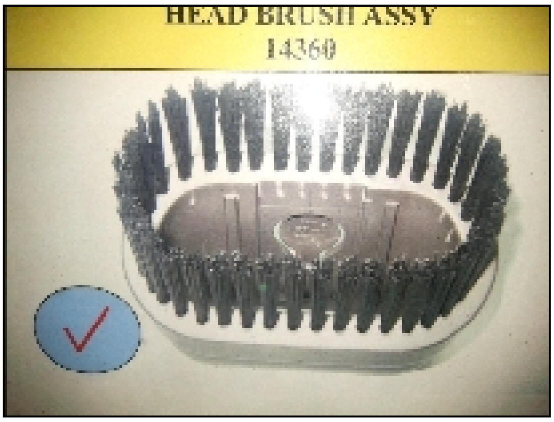

Fig. 16: Pass product (with no defect product)

Fig. 17: Not pass product (defect product)

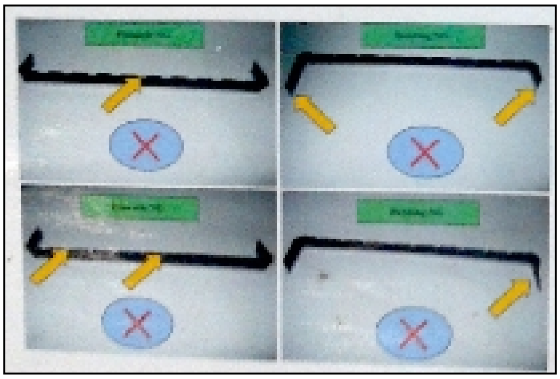

Fig. 18: Front view of the pass product

5. Conclusion

In the current situation, the average processing time for Stamping is 3.4s, Pinnacle is 2.8583s, Binding 1 is 8.1067s, Binding 2 is 5.9767s, Checking is 11.0633s, and Packing is 8.5233s. Total average processing time is 35.5283s without including any transportation time for the work in progress. The current total production cycle time is found to be 129.898s which is approximately 4 times of the Suggestion 3 which is the final implemented solution with the total production cycle time of 47.436s.

It was found that the p value and the F Critical value of the current production cycle time are 6.35E-35 and 2.007792 respectively. This somehow proved that the production line is considered in a good situation as the p value is less than 0.05. However, the p value and the F Critical value of the final implementation's production cycle time are 1.69E-12 and 2.073351. Thus, the implemented solution is four times much more efficient than the current situation even though both p values are less than 0.05.

The profit earned under the final solution is four times as to the current situation within the same production time. By implementing the final solution, the company will manage to earn additional RM 3 with the same amount of production time, cost of the utilities and capital cost. Thus, the solution under Suggestion 3 managed to gain profit for the company with the application of Lean theory.

Fig. 19: Rear view of the pass product

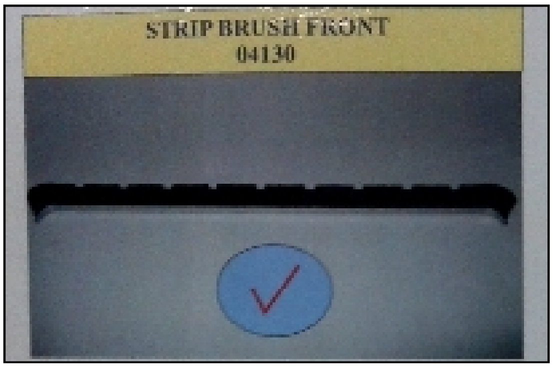

Fig. 20: Not pass product (defect product)

5.1. Further improvements

It is recommended for the company to import new and better machines especially semi-automated or fully automated machines so that the production flow can be balanced up as the strip brush machine is twice the speed of the manual job shop machines. The practices of 5S is mostly implemented in the factory but sustaining the 5S system is the last and curial factor in order to have a clean, tidy and lean production. Thus, the company should focus more on maintaining and sustaining the system after the implementation of 5S.

The suggested methods and layouts in this research and also the final solution can be expand and spread throughout the whole company even though the process might defer a little. In this research, the author has developed a simple system on applying lean into manufacturing line and the company can follow the procedure and apply the system to other areas in the company for better and greater impact of lean manufacturing.

References

K. S. Al-Saleh (2011). Productivity Improvement of A Motor Vehicle Inspection Station Using Motion And Time Study Techniques. Journal of King Saud University – Engineering Sciences, vol. 23, pp. 33-41, 2011.

M. A. Khalaf, A. A. L., A. E. E. (2011). An Investigation Into The Relationship Between The Implementation Of Lean. Australian Journal Of Basic And Applied Sciences, 5(12), pp. 1886-1896., 2011

Ofd19974, (2010). http://www.docstoc.com. [Online] Available at: http://www.docstoc.com/docs/29851815/Student-time-sheet-work-study---Excel [Accessed 6 April 2013].

R. A. Al-Aomar (2011). Applying 5S Lean Technology: An Infrastructure for Continuous Process Improvement. World Academy of Science, Engineering and Technology 59, 2011.

R. Gerald Aase, J. R. ,M. J. (2004). U-Shaped Assembly Line Layouts and Their Impact On Labor Productivity: An Experimental Study. European Journal of Operational Research, vol 156, p. 698–711, 2004.

S. Aguado, R. A., R. D. (2012). Model of Efficient and Sustainable Improvements in a Lean Production System Through Processes of Environmental Innovation. Journal Of Cleaner Production, pp. 1-8, 2012.

Ş. Özgürler,et al (2010). Designing A Simple U-Shaped Production Line And Analysis of Effectiveness. 14th International Research/Expert Conference, September 2010