The Effectiveness of Line Balancing on Production Flow Efficiency: An Experimental Study

Batool Ibraheem Jameel
Production and Metallurgy Engineering Department, University ofTechnology/Baghdad.
Email:Batool_alassaf07@yahoo.com

Received on:19/2/2015 & Accepted on:7/5/2015

ABSTRACT

Line balancing problems are well-known applications of industrial engineering in Academic Universities. Effective Line Balancing forms the core of every successful organization as strive to increase productivity without incurring unnecessary costs. Factors contributing to high costs such as excessive overtime and work force, high level of inventory and idle time are all parts of the results of poor line balancing.

Iraqi industries suffer from a strong shock due to high competitive products in the market associated with less cost than can be offered. To survive these industries from collapse and bankruptcy, they need to utilize their sources effectively and efficiently to improve the productivity and reduce loses. One way to achieve that is to adopt the scientific approaches. The research has been applied in one of the important industries based on Baghdad i.e. light Industrial Company assembling Gas Cooker. The assembly line left unbalanced any methodology for balancing the assembly line was not implemented on the assembly line of the company. to implement a scientific methodology production of 20 units/day was employed. When the efficiency of the assembly line analysis found low as 50% from the available efficiency and combined with low productivity. The suggested methodology shows that the production rate can been doubled with same capabilities of resources available and efficiency increased to 92%. Moreover, about 50% reduction in idle time and well-organized of the assembly line by creating 9 workstations . This effect is in addition to increasing productivity , the human factor will be affected positively by raising motivate the morale from one side and distribute the load evenly among them from the other side .

Keywords: Assembly Line Balancing, Efficiency, Productivity, Production Flow.

تأثير موازنة الخط على كفاءة سريان الانتاج :دراسه تحليليه

الخلاصه

ان مشكلة موازنة الخطوط الانتاجيه من التطبيقات المعروفه في علوم الهندسه الصناعيه في الجامعات الاكاديميه . الخط الكفوء يشكل جوهر كل مؤسسة ناجحة تسعى جاهده لزيادة الإنتاجية دون تكبد تكاليف غير ضرورية .

العوامل التي تسهم في ارتفاع التكاليف مثل العمل الإضافي المفرط وقوة العمل ومستوى عال من المخزون والوقت غير المستغل كلها جزء من نتائج موازنة الخط السيء. الصناعات العراقية تعاني من صدمة قوية بسبب التنافس العالي للمنتجات في السوق المصاحبه لكلفة مبيعات أقل مما يمكن أن تقدمها شركاتنا. لانقاذ هذه الصناعات من الانهيار والإفلاس ، فإنها تحتاج إلى استخدام مصادرها بفعالية وكفاءة لتحسين الإنتاجية والحد من الخساره. احدى الطرق للتغلب على ذلك هو اعتماد المناهج العلمية. اعتمد هذا البحث في واحدة من الصناعات الهامة في بغداد الاوهي الشركة العامه للصناعات الخفيفة لتجميع طباخ الغاز. خط التجميع في هذه الشركه لم تطبق عليه اية منهجيه لموازنة الخطوط ولغرض تطبيق المنهجيه العلميه اعتمدت انتاجيه تجميع 20 وحده في اليوم الواحد . وعند تحليل كفاءة خط التجميع وجد بانها منخفضة بنسبة 50٪ عن الطاقه المتاحه و مصاحبه بانخفاض الإنتاجية . وتبين المنهجية المقترحة أن معدل الإنتاج يمكن أن يتضاعف باستخدام نفس القدرات للموارد المتاحة وامكانية رفع الكفاءة الانتاجيه إلى 92 ٪ . وعلاوة على ذلك ، حوالي 50 ٪ تخفيض في الوقت الضائع وتنظيم خط التجميع من خلال إنشاء 9 محطات عمل. تأثير هذا اضافة الى رفع الانتاجيه فان العامل البشري سيتأثر ايجابا من خلال رفع المعنويات من جهه وتوزيع الحمل بالتساوي بينهم من جهه اخرى.

INTRODUCTION

As a part of manufacturing systems, the assembly line has become one of the most valuable researches to accomplish the real world problems related to them. Many efforts have been made to seek the best techniques in optimizing assembly lines. Line balancing is a classic Operations Research (OR) optimization problem, have been tackled by OR over several decades. Many algorithms have been proposed for the problem. Line balancing is an effective tool to improve the throughput of assembly lines while reducing work force requirements and costs. Assembly Line Balancing, or simply Line Balancing (LB), is the problem of assigning operations to workstations along an assembly line, in such a way that the assignment be optimal in some sense. Ever since the introduction of assembly lines, LB has been an optimization problem of significant industrial importance. The efficiency difference between an optimal and a sub-optimal assignment can yield economies (or waste) reaching millions of dollars per year [Garg 2010].

The production lines are consisting of a group of stations, work pieces are moved along the line from station to other, while each one performs a number of repeated operations necessary to manufacture a desired final product [Basheer 2009; Meredith & Shafer2013] Production line must be arranging the individual processing or assembly tasks at the workstations in a way that facilitates the flow materials or parts from a workstation to another. So that assembly line is a flow oriented production system consists of a set of workstations arranged in a linear fashion, a station is considered any point on the assembly line in which a task is performed on the part. The time it takes to complete a task at each operation is known as the process time. The cycle time of an assembly line is predetermined by a desired production rate. This production rate is set so that the desired amount of end product is produced within a certain time period [Grzechca 2008]. The total time required at each workstation is approximately the same. Improper line balancing is defined on distribution of workloads are not equal along the production line, there will one station that has maximum time to perform a task so that the production flow different in one station to others . This station is called bottleneck station [Norman2002;Nearchou2006].

Balancing method is very essential to make the production flow almost smoother. Line balancing is a tool that can be used to optimize the workstation or production line throughput. This tool will assist in the reduction of the production time and maximizing the output or minimizing imbalance between stations in order to achieve required run rate to max production flow. This can be done by equalizing the amount of work in each station[Slack 2004;Grzechca 2008].

There are different versions of assembly line balancing classified between single model, multi model to mixed model line balance depends on the different types of product required to be assembled on the same production line[Nearchou2006;Hapaz 2008]

Literature Review

In view of the importance of integrated line balancing, many researchers have worked on this problem from very beginning of industrial revolution .Some of them are referred here.

[Liu 2008]focused on the use of exact algorithms for solving simple assembly line balancing problem which is required an assignment of tasks to workstations in order to minimize the number of workstations needed for a given cycle time. precedence relations between tasks are not violated, and one or more objectives are optimized using branch-and-bound algorithms for solving the simple assembly line balancing.

[Shumon et al 2010]discussed and comparing the output and efficiency before and after applying the balancing technique. One production line is selected from the sewing floor and comparing total output of each process then identified the bottleneck station. Standard allowable minutes has been calculated of each station and then imbalance situation in the line and bottleneck condition has been identified. Balancing process has shared the excess time after the benchmark production in the bottleneck process Maximum outputs have been increased and line efficiency increased by 58%.

[Rashid et al 2011]concentrated on several soft computing approaches using different techniques to solve Assembly Sequence Planning (ASP) and ALB. Although these approaches do not guarantee the optimum solution, they have been successfully applied in many ASP and ALB optimization research works .current research trend shows that ASP and ALB are progressing to a more complicated problem by increment in the number of papers that works on multi objective optimization . Besides that, growth in usage of relatively new algorithm like Particle swarm optimization (PSO) shows that the researchers tend to explore and develop algorithm which manage to handle more complex problems.

For more detail concerning state of art for assembly line balancing can be referred to [Scholl & Becker 2006; Boysen et 2008].

The Aim of The study

Iraqi industries are suffering from lack of adopting proper scientific approaches that result in low volume of throughput. This can reflect of increasing costs and reducing efficiencies of production as well as increasing of idle times . As a result , fail to compete in high competitive markets.

This study will focus of applying line balance concept on a single production line at

Light Industrial Company assembling Gas Cooker based at Baghdad. The study will go through developing line balance methodology with view to increase the throughput effecting by using the same available constraints of resources such as times, workers and equipments.

Objectives of Line Balancing

From the literature (2,10), the researcher is summarizing the following objectives of line balancing:

1. Minimize the total amount of unassigned or idle times at the workstations.
2. Eliminate bottlenecks, ensuring a smoother flow of production.
3. Determine the optimal number of workstation and operations in each station.
4. Maintain the morale of workers since the work content of the different workers will not be of great difference.
5. Maximize the work force utilization by minimizing the idle times of the operators.
6. Minimize the intermediate stock or work-in-progress.
7. Improve the quality and productivity of the assembled products.
8. Reduce waste of production and delay**.**

The Methodology

The methodology adopted in this study to achieve the aim by exploring the steps below. The processing time to perform each work element is derived from the actual work measurement carried out during the study process.

1.Construct a "characteristic table" that specifies the number of tasks, description of each task, predecessor task, and the processing time for each task.

2.Construct the precedence diagram to specify the sequential relationships among tasks.

3.Determine the cycle time required(C_t) which is the time interval between parts moving from station to another Also it reflects the time between parts coming off the line [Fendi 2009 & Greasley 2013].

$$C_t = \frac{A}{R} \quad \text{....(1)}$$

Where:

A= Effective production time per period (day).

R=Required output in units per period (day).

4.Determine the theoretical minimum number of work stations required (N).This number. of work stations reflects the minimum required because it affected by the task times with possibility of not be able to assign task to specified work station[Kriengkorakot and Pianthong 2007;Greasley2013].

$$N = \frac{\sum_{i=1}^{n} ti}{Ct} \quad \text{..... (2)}$$

Where:

N= is the minimum number of work stations.

t_i= is the processing time of task i, for i = 1....n

5.Select heuristic method such as Kilbridge &Wester method or the Rank Positional Weights Method to allocate task elements to each workstation.
6.Each workstation time should not exceed the cycle time.
7.Ensure that the sequencing is in order, even for the task elements in each station.
8.Calculate the efficiency (η) which means of measuring the degree of balance for each process time in a flow line operation. It is the percentage of available workstations time that is used productively.

$$\eta = \frac{\sum_{i=1}^{n} ti}{Ct * N} * 100\% \qquad \ldots(3)$$

9. Calculate the idle times (IT) which is unproductive time, and hence the balancing loss/ delay (B)is found. Balancing delay/loss is the measure of line inefficiency results from idle time due to imperfect allocation of work among stations [Roya,2010].

$$IT = (N * C_t) - \sum_{i=1}^{n} ti \qquad \ldots(4)$$

$$B = 100\% - \eta \qquad \ldots(5)$$

10.Analyze the balanced flow line to improve efficiency and to reduce idle times. An efficient balance will minimize the amount of idle time.

Rank Positional Weights Method (RPW)

This method is suggested to be used in this study as it's more convenient to the assembly line under study than other line balancing problems. The following steps are used to find RPW:[Heizer and Render 2011]:
Step 1: Calculate the RPW for each element by summing the task elements time together task element time values for all the elements that follow it in the arrow chain of the precedence diagram.
Step 2: List the elements in the order of their RPW, largest RPW at the top of the list. For include the task time value and immediate predecessors for each element.
Step 3: Assign elements to stations according to RPW, avoiding precedence constraint and time cycle violations.

Methodology Application

The mentioned methodology for assembly line balancing is applied to the single assembly production line at the light Industrial Company assembling Gas Cooker which suffering from low production rate comparing with elevated cost. The Result, fail to compete in the Iraqi open market. The investigated production line is concerned with assembling one product type i.e. a Saloon Gas Cookers. The Company. is not following any method of line balancing which causes reduction in efficiencies and bad reputation and moral between workers, as some of them are working with full capacity while others enjoying of high rate of idle time.

According to The annual planning, the company is planning to assemble 20 units per day, which is the maximum aspiration. The assembly production line operates (8 hours) per day and if not achieving the required output they will go for overtime. The total number of task elements is (24). Each task element is considering as one workstation. So that there are 24 work station. Gas cookers consist of (24)parts required for assembling one Gas cooker.

The Practical Results

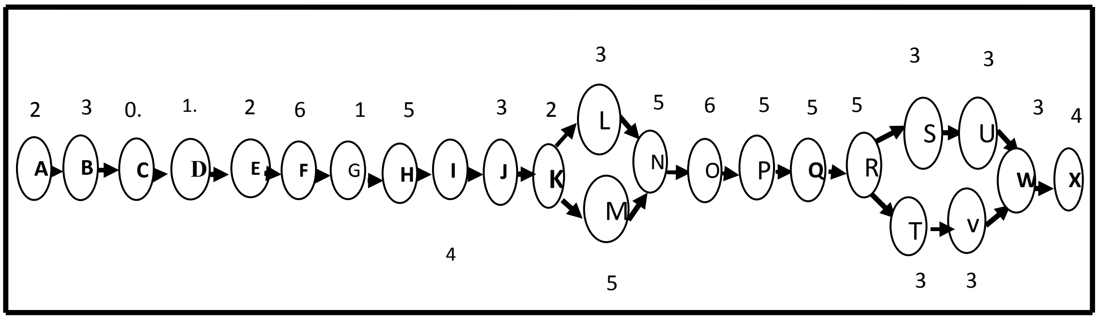
The assigned steps of the referred methodology are carrying out at the assembly line for Gas Cooker production and are given below .Thereafter, the practical discussion will follow through eight cases. Each case reflects one sitation which can be applied to the production assembly line. Starting with case 0 which is represents the current used state:
1-Tasks"characteristic table" and RPW are constructed and developed respectively as shown in table(1).

Table(1): Tasks characteristic &RPW calculations

Task Number	Task Name	Task Description	Tasks that must predecessor	RPW	Time (min)
1	A	Assembly upper roasting device for oven		83.5	2.5
2	B	Assembly lower roasting device for oven	A	81	3
3	C	Place oven frame on conveyor	B	78	0.5
4	D	Attach upper roasting device	C	77.5	1.5
5	E	Attach lower roasting device	D	76	2
6	F	Attach thermal insulator around oven frame	E	74	6
7	G	Put oven frame on oven die	F	68	1
8	H	Attach two sided and adjustable base to oven frame	G	67	5
9	I	place and attach the front panel and electrical system	H	62	4
10	J	attached Ignition System	I	58	3
11	K	Attach oven burners	J	55	2
12	L	Assembly and attached the lower oven door	K	48	3
13	M	Assembly and attach gas pipes	K	50	5
14	N	Preliminary inspection of the gas	M,L	45	5
15	O	Attach gas nozzle and upper panel	N	40	6
16	P	Final gas inspection	O	34	5

17	Q	Electrical inspection	P	29	5
18	R	Assembly and attach back	Q	24	5
19	S	assembling class cover	R	13	3
20	T	assembling the double class oven door	R	13	3
21	U	attach class cover	S	10	3
22	V	attach oven door	T	10	3
23	W	support the accessories	V,U	7	3
24	X	Packaging	W	4	4

2-The sequential relationships among tasks with processing time using a precedence diagram are shown in figure(1)



Figure(1) precedence diagram

The samples calculations for the essential parts of the methodology are carred out below:

Case 0 (The current procedure)

Actually, this is the case used by the company in the assembly line at present time. The current procedure is used as there are no distinguished workstations. Parts are flow through from one place to another at the assembly line not taking any consideration about balancing. The max processing time (C_t)occurs at task no. 6 with processing time 6 min (table 1). The production efficiency and all other relevant values can be found from equations(3, 4 &5). Given The production rate = 20 units, and $\sum_{i=1}^{n} ti$ =83.5, Then:

Efficiency η= 83.5 / 24*7 = 49.5% ; idle time IT = 24*6 - 83.5 = 60.5 min, and
Balance Delay B = 100% - 49.5% = 50.5%

The above figures show the degree of badness of the assembly line construction. The efficiency is about 50%.

<u>Case 1</u>

In this case the same production rate of 20 product per day is used with the developed methodology to find the efficiency and all others relevant figures.

Cycle time (C_t) is $\frac{8*0.85*60}{20}$= 20.4 min, then

Min no. of workstations from equation(2): N= $\frac{83.5}{20.4}$ =4.9≈5, and

The efficiency η= $\frac{83.5}{5*20.4}$ =82%

And hence idle timeIT is 18.5min with balance delay B = 18%.

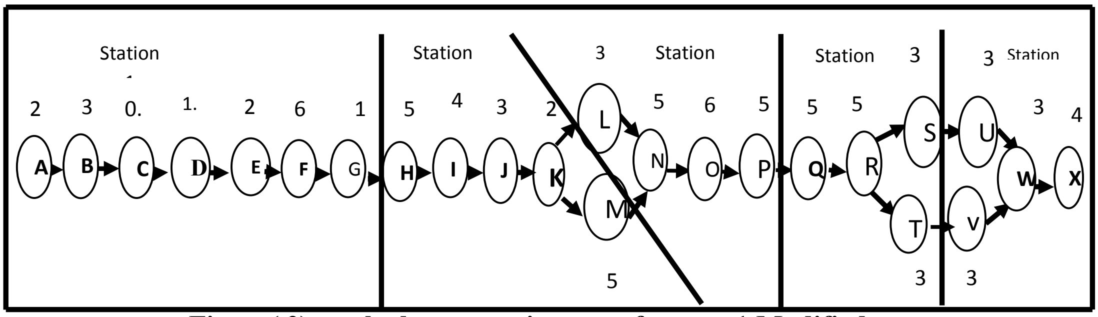
Case 1 M (modified)

Refeering to case 1 and figure 2, the maximum process time is 19 although the cycle time is 20.4. Accordingly, the line could be operated at a cycle time 19 rather than 20.4. So that the production rate can be incread by 1.07 unit per cycle, which is deduced as follow:

Increase the Production rate = 20.4/19 = 1.07 unit/ cycle

Then total production rate per day increased to 21.43 (i.e. 1.07 * 20)

is will modify the efficiency and it becomes 87% (i.e. $\frac{83.5}{5*19}$), while idle time IT becomes 11.5 min (5*19-83.5) with balance delay 13%.



Figure(2) work element assignment for case 1 Modified

The results of the remaining other cases (6 cases) from Case2 to case 4M are summarized in table (2). the procedure followed on these cases are concetrited on the effects of icreasing production rate on the number of workstations promising the changes in efficiencies at the direction better utilazation, keeping in mind using the same avaliable resources .

Table (2): Comparsion results of all studying cases

Cases	Production Rate	Increase In Production	No. Ws	Ct min	η %	B%	IT min
Case0	20		24	7	49.5	50.5	60.5
Case 1	20		5	20.4	82	18	18.5
Case 1M	21.47	1.07	5	19	87	13	11.5
Case 2	25		6	16.32	85	15	14.42

Case 2M	25.5	1.02	6	16	86	14	12.5
Case 3	30		7	13.6	87	13	11.7
Case 3M	31.2	1.04	7	13	91	9	7.5
Case 4	40		9	10.3	90	10	8.3
Case 4M	40.8	1.02	9	10	92	8	6.5

DISCUSSION

Referring to table 2, the first case is reflect the actual statement of the company where the assembly line is working without consideration any techniques, results in low output efficiency which is about 50%. This means losses about 50% of available resources utilization. When this case compared with case 1 which uses the developed methodology of line balance, creating workstations and uses cycle time idea with the same production rate of 20 units, five workstations and cycle time 20.4. The efficiency of assembly line increased to 82%. This case is more robust and more confidents between workers. Actually, the maximum cycle time is19 min instead of 20.4 the theoretical one. So that, case 1 can be modified and use 19 min as C_t instead of 20.4. The result will increase the throughput by 1.07 per cycle. The total production rate becomes 21.47 (case 1M). Using the same resources and facilities, the production rate can be increased to 25 unit (i.e. 20% increased in production) with 6 workstations and cycle time 16.32(case 2), and to (16) with modified version of case 2 (case 2 M). Case 3 dealing with production rate of 30 unit, that is increases by 50% of original, with same resources and capabilities but with 7 work stations, and to (31.2) with modified case 3(case 3M). The production rate even though can be increase to 40 units, i.e. 100% increases when rearranging the assembly line with 9 Ws and C_t10.3(case4), and even to 40.8 units and to 92 % efficiency with modified case (case 4M). However, the efficiency now reached to 92%,which is a very efficient figure. the decision maker can select any case with the required efficiency to cope with and for his criteria about the idle time required. According the workstations with all work elements are promised.

CONCLUSIONS

Iraqi industries under threats due to lack of using scientific approaches which were developed and extensively used by all over the world. The research explored the benefits gain from using technique of assembly line balance and highlighted the benefit reactions as the production can be doubled with same facilities and resources. The efficiency of assembly line increased from about 50% , which means a lot of losses due to bad utilization of available resources, to 92% which reflects a good management of using resources. In other words in economic sense a reasonable reduction in production costs. This will motivate to go further for more research in order to cope with advance methodologies. And this is the only way to survive and compete with imported merchandises in the market nowadays. Also, increases the confidence among works and shareholders.

REFERENCES

[1]. Garg , P. (2010). " Production And Operations Management".1st Edition, S.K. Kataria & Sons.

[2].Basheer, B.(2009)." Integrating Assembly Planning and Line Balancing Using Precedence Diagram" .Eng.&Tech.Journal,Vol.27,No.5.

[3]. Meredith, J & Shafer, S. (2013). "Operations Management".5th Edition, John Wiley & Sons Singapore, Pte . Ltd Publication.

[4].Grzechca, W. (2008). "Estimation Of Time And Cost Oriented Assembly Line Balancing Problem".The Silesian University Technology,.

[5]. Gaither, N .(2001). "Operations Management with POM Software CD-ROM ". 9th Edition, South - Western

[6]. Nearchou, A .(2006) . "Balancing Large Assembly Lines By A New Heuristic Based On Differential Evolution Method".Int J Adv Manu Techno 34:1016–1029 Springer-Verlag London Limited, www.ivsl.org.

[7].Slack, N.,Chambers, S & Johnston, R. (2004). "Operations Management". 4th Edition; Prentice Hall.

[8]. Hapaz, H. (2008). Productivity Improvement Through Line Balancing". University Malaysia Pahang ,Malaysia mpir.ump.edu.my/198/1/Project_Hazmil_Hapaz.pdf.

[9]. Liu, S & Ong, K. (2008). "Branch-And-Bound Algorithms For Simple Assembly Line Balancing Problem" . Springer-Verlag London Limited , 36:169–177.

[10].Shumon, R., Zaman, K & Rahman, A. (2010). "Productivity Improvement Through Line Balancing In Apparel Industries". International Conference On Industrial Engineering And Operations Management. Dhaka, Bangladesh,

[11].Rashid, M., Hutabarat, W & Tiwari, A. (2011). "A Review On Assembly Sequence Planning And Assembly Line Balancing Optimization Using Soft Computing Approaches". Int J Adv Manuf Technol, Vol 59,I1- 4, PP 335-349 Springer-Verlag London Limited, www.ivsl.org.

[12]. Scholl, B.(2006)."State-of-the-art exact and heuristic solution procedures for simple assembly line balancing". European Journal of Operational Research, 168, 666-693.

[13].Boysen, N., Fliedner, M., & Scholl, A. (2008). "Assembly line balancing: which model to use when", International Journal of Production Economics, 111(2), 509-528.

[14].Fendi,J.(2009). "An Automated Assembly Sequence Planning System". Eng.&Tech.Journal,Vol.27,No.14 .

[15]. Greasley, A. (2013). "Operations Management", 2nd Edition, John Wiley & Sons, Ltd, Publication .

[16]. Kriengkorakot,N & Pianthong ,N.(2007)." The Assembly Line Balancing Problem :Review articles".KKU Engineering Journal Vol. 34, No .2 ,133 – 140.

[17].Roy,D & khan,D.(2010)."Integrated model for line balancing with workstation inventory management".International Journal of Industrial Engineering Computations 139 –146

[18].Heizer, J & Render,B.(2011). "Operations Management".10th Edition, Prentice Hall.