Reconfiguration of Assembly Line. Solutions for a Case Study

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Abstract

Needs and market demands are the benchmark against which production processes have to improve both in terms of production capacity and in terms of quality by applying traditional and non-traditional methods of development. This paper will review the existing assembly lines (AL) which must be modified to meet new requirements. The bibliographic research has the role of highlighting the various methods by which one can optimize an assembly line that is complemented by the presentation and analysis of a real case, which aims to enrich the studies done to date in the study area of assembly line balancing problems (ALBP). The aims are to reduce the time of product development and maximizing the use of resources (both machines and workers). By balancing the workload of operators at each station and reducing downtime, the aim is to minimize losses and costs. Balancing the line will allow you to reduce the waiting time and increase the transfer rate.

Keywords: Assembly line balancing (ALB), Configuration of assembly lines, Increase productivity, Simulation.

1. Introduction

The evolution of production processes is constantly adapted to market needs and requirements that are constantly changing. Researches on improving production processes are, mainly oriented, towards identifying and implementing traditional and non traditional development measures. In a typical production environment, performance improvement goals are usually related to improving customer service, reducing product lead times, and maximizing resource use. Since the 1900s when Henry Ford introduces the first assembly lines to increase efficiency and productivity for the famous T-model, so far there are multiple approaches to assembling line analysis and optimization, but the main purpose is to get a optimal configuration for an ideal number of workstations in a certain working time. There are several types of configuration of how to position workstations on the production surface.

We can make the following classification:

- flow lines placed in line or parallel;
- flow lines in the form of U, L, X, Y, V, A;
- flow lines in zigzag and so on;

Traditionally, an assembly line is organized as a serial line, in which case the individual stations are arranged in a straight line along a conveyor belt. Usually the arrangement of stations does not affect how operators work on the product. In terms of how to approach the optimization of assembly lines, there are multiple approaches that can be categorized according to the objective (s) to be pursued.

Nurhan Ali Abu Bakar in "A survey on research objective in the assembly line balancing problem" compares the objectives of 60 reference works published between 2017 and 2018 (Nurhanani and all, 2018).

The objectives were:

1. Minimize number of workstation;
2. Minimize number of mated station
3. Minimize cycle time;
4. Maximize workload smoothness;
5. Minimize line length;
6. Minimize linear area;
7. Minimize cost;
8. Maximize line efficiency;
9. Minimize idle time;
10. Minimize number of position.

From Fig. 1 it follows that the main objective in the analyzed works was to decrease the number of workstations, followed closely by minimizes cycle time. Other two goals that were often pursued were to minimize costs and minimize idle time.

The multitude of problems that may be encountered in assembly lines balancing (ALB) can lead to choosing a single direction to solve the problem or combining two or more objectives. If we analyze the articles proposed for study in the paper "A survey on research objective in the assembly line balancing problem" (Nurhanani and all, 2018), we note that there is no single approach to ALBP.

The fact is that there is no unique and safe formula that can solve.

Figure 1: Number of papers vs. objective (Nurhanani and all, 2018)

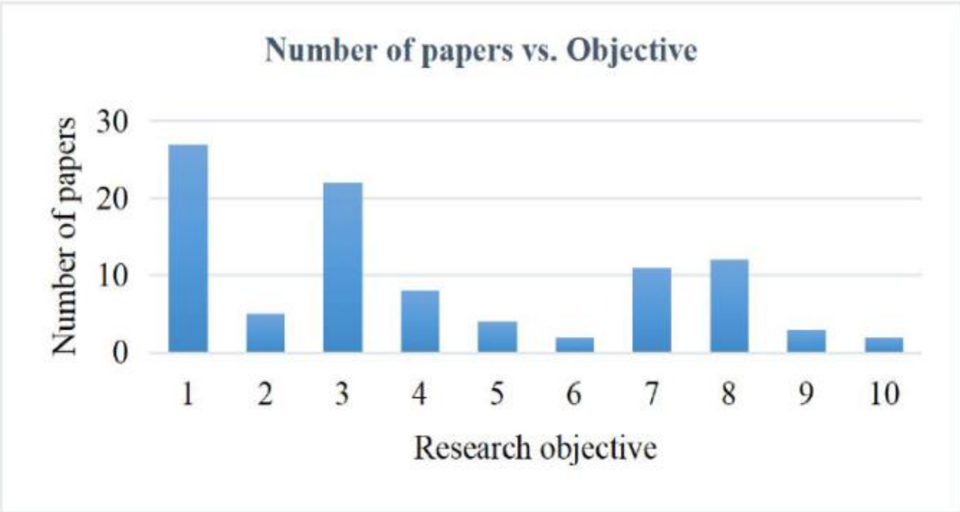


Table 1: Two objectives succeeded in researches to solve ALB

OBJECTIVES	Minimize number of mated station	Minimize cycle time	Maximize workload smoothness	Minimize line length	Minimize linear area	Minimize cost	Maximize line efficiency	Minimize idle time	Minimize number of position	REFERENCES
Minimize number of workstation										(Hamzadayi, 2018) (Tang et al, 2017)
										(Ritt et al., 2018) (Dou et al., 2017)
										(Yuan et al., 2018)
										(Gansterer et al., 2017)
										(Chica et al., 2018)
										(Sivasankaran et al., 2017)
										(Delice et al., 2017)
Minimize cycle time										(Wang et al., 2018)
										(Dong et al., 2018) , (Zhang et al., 2018) (Toroudi et al., 2017) (Rane et al., 2017)
Maximize workload smoothness										(Babazadeh et al., 2018) (Hu et al., 2018)
Minimize cost										(Tiacci, 2017)
Maximize line efficiency										(Oksuz et al., 2017) (Krenczyk et al. 2017)

Table 2: Three objectives succeeded in researches to solve ALB

OBJECTIVES	2. Minimize number of mated station	3. Minimize cycle time	4. Maximize workload smoothness	5. Minimize line length	6. Minimize linear area	7. Minimize cost	8. Maximize line efficiency	9. Minimize idle time	10. Minimize number of position	REFERENCES
1. Minimize number of workstation				■		■				(Defersha et al, 2018)
	■			■						(Delice et al., 2017), (Gansterer et al., 2017)
						■	■			(Hamzas et al.2017)
			■				■			(Razali et al. 2017) (Haq et al., 2017)
		■					■	■		(Belassiria et al., 2017)
	■		■							(Li et al., 2017)

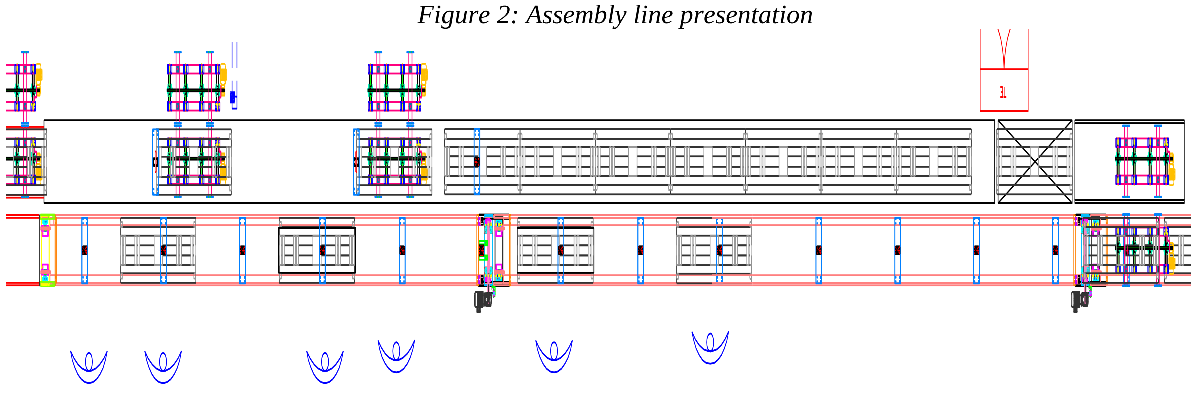
Usually, in solving the problems related to ALB, it starts from a main objective. Solving this goal may often lead to other secondary objectives as can be seen from Table 1 and Table 2.

On an existing system, simulations can be made to assess the real situation in order to propose new solutions which can be compared in terms of performance. This stage is an analytical one that provides for the implementation of some chosen solutions**.**

2. Initial problem evaluation

The study that we will achieve is for an existing assembly line on which is assembled only one type of product. The assembly line is positioned in the right line, the feed is continuous and the operators are placed on one side Fig.2. The operations are done manually and automatically.

Figure 2: Assembly line presentation



On the assembly line there are 6 workstations (OP) in which operators are placed who perform a set of tasks within a certain timeframe. The time required to perform the operations is not the same from one OP to another, it varies according to the time required to complete each task. For avoidance of bottlenecks on the assembly line would be ideal type there are no differences from one workstation to another.

The company works in three shifts of 8 hours each.

Operators are entitled to three working breaks of which:

- 30 minutes of meal break,
- two intermediate pauses of 10 minutes.

The actual working time is 7 h and 10 min.

For measuring the working time in each OP, three sets of measurements were made for each exchange and considered as study value their arithmetic mean.

The values obtained can be seen in Fig. 3, which highlights the time needed to perform the operations in each OP. As we can see in Fig. 3 for the studied assembly line there is a major difference between OP3 and the other workstations.

Figure 3: Assembly line OP takt time

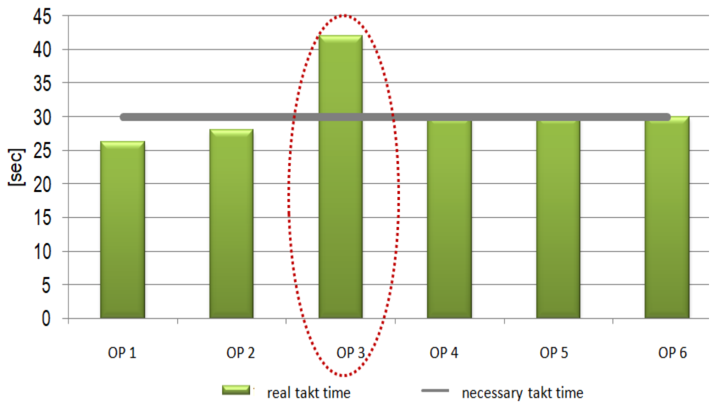


Table 3: Operator task analyze

OPERATOR TASK	Periode of time [sec]		TASK - PERIODE OF TIME																																									
	Manualy	Automatically	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
OT1	2																																											
OT2	4																																											
OT3		32																																										
OT4	13																																											
OT5	4																																											

In this case it is necessary to balance the operations on the assembly line so that the tact of the studied line will reach 30 sec. We will analyze OP 3 workstations that are performed manual and automatic operations (OT). This dissemination is necessary to understand the way OT takes place over the measured time interval. In Table 3, we can see how they are arranged tasks that must be performed on the operator in the range of 42 seconds.

From the table it follows that in 42 seconds the operator has to make 4 successive types of operations that have different time intervals depending on their complexity.

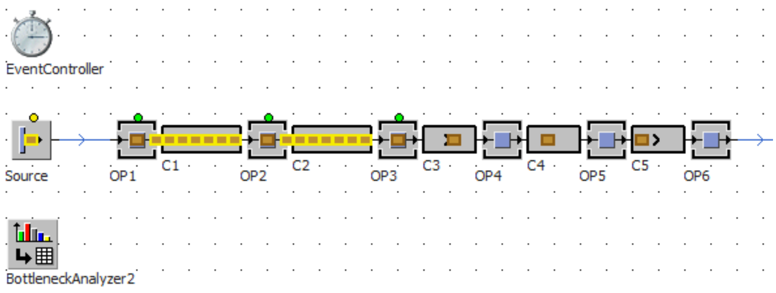
We can also see that there is an operation that is performed automatically - OT3 - and in parallel with this the operator must perform the OT 4 which is like the duration of 19 seconds less than the operation that is performed automatically.

Which means that the 19 seconds in the operator does not have any other surgery to accomplish, there are lost times in the work.

To compensate for this time frame, it can be chosen that in parallel with the OT3 task, the operator OP3 can performs parallel operations that do not take longer than 19 seconds, but taking into account that operations who precede and succeed OP3 do not exceeds 30 sec. this option is out of computation.

The main goal is to balance the assembly line by reducing takt time for OP3.

Fig. 4. Initial situation simulation



Knowing the initial situation, a simulation of the assembly line was carried out to validate the following models to be proposed for analysis.

The simulated model corresponds to the reality, in Table4 we can see a small variation in the number of products made.

Table 4: Model validation

	Realty	Simulation
Capcity/h	67	73
Capcity/Sch	593	609

Figure 5: Simulation results

Object	Working	Set-up	Waiting	Blocked	Portion
OP1	63.31%	0.00%	0.00%	36.69%	
OP2	69.72%	0.00%	0.16%	30.12%	
OP3	99.67%	0.00%	0.33%	0.00%	
OP4	71.05%	0.00%	28.95%	0.00%	
OP5	70.93%	0.00%	29.07%	0.00%	
OP6	70.81%	0.00%	29.19%	0.00%	

Material Flow 609

3. Solutions proposed

With the aim of balancing the assembly line and considering the increase in the number of products made in the same time, two solutions were proposed for analysis.

Solution 1:

The first proposed solution is to divide the tasks from OP3 into two consecutive workstations. Analyzing the tasks performed in the OP3 station, it was concluded that the operation that is performed automatically can be divided into two separate operations of 13sec or 19sec respectively.

Table 4: Task for OP31 and OP32

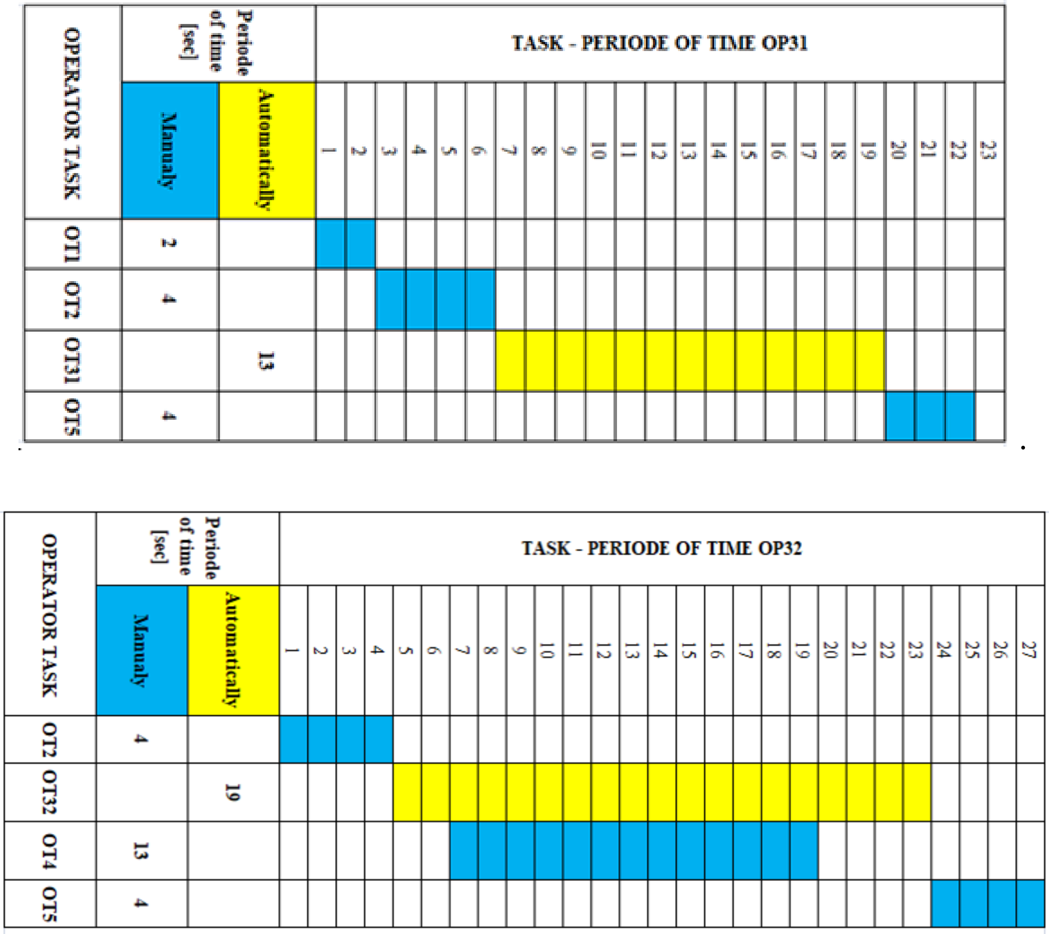


Figure 6: Simulation for Solution 1

Object	Working	Set-up	Waiting	Blocked	Portion
OP1	88.94%	0.00%	0.00%	11.06%	
OP2	98.30%	0.00%	0.14%	1.56%	
OP4	99.40%	0.00%	0.60%	0.00%	
OP5	99.24%	0.00%	0.76%	0.00%	
OP6	99.09%	0.00%	0.91%	0.00%	
OP31	77.27%	0.00%	6.71%	16.01%	
OP32	90.08%	0.00%	1.47%	8.45%	

Material Flow 853

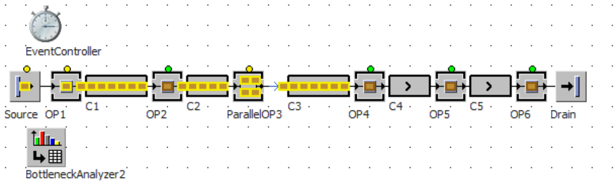
As can be seen in Table 4, dividing operations to create a new workstation leads to additional handling. It can be seen that the OT2 and OT5 tasks are repeated by the two operators, leading to multiple manipulations.

As a result of the simulations, it can be noticed that for this variant, there is no blockage, which means that one of the objectives was reached. With the removal of this bottleneck, the number of products increased from 609 products obtained for real simulation to 853 products, which means a 14% increase in production.

Solution 2:

The second proposed solution is that in OP3 it should be placed in parallel two workstations that will simultaneously perform the tasks specific to this post.

Fig. 7. Model simulation situation 2



Object	Working	Set-up	Waiting	Blocked	Portion
OP1	88.88%	0.00%	0.00%	11.12%	
OP2	98.24%	0.00%	0.14%	1.62%	
OP4	99.65%	0.00%	0.35%	0.00%	
OP5	99.49%	0.00%	0.51%	0.00%	
OP6	99.34%	0.00%	0.66%	0.00%	
ParallelOP3	70.65%	0.00%	9.59%	19.76%	

Material Flow 855

As in the previous case, there is a significant increase in the number of products made over the same time by eliminating bottlenecks and balancing the assembly line.

4. Conclusion

Balancing the assembly lines is not a new problem, but it remains permanently up to date because of the need to have advanced assembly lines that can be used at maximum capacity under minimal cost conditions.

The bibliographic study revealed that in the last few years the main objective of the researches was to reduce the number of operators.

In this study, a real case has been analyzed, for which two solutions have been proposed.

In order to achieve the main objectives of balancing the assembly line and increasing productivity, both solutions proposed the introduction of an additional workstation either in a straight line or in parallel.

If we compare the two variants for which simulations have been made, there is no significant difference from the point of view of the number of products that can be achieved.

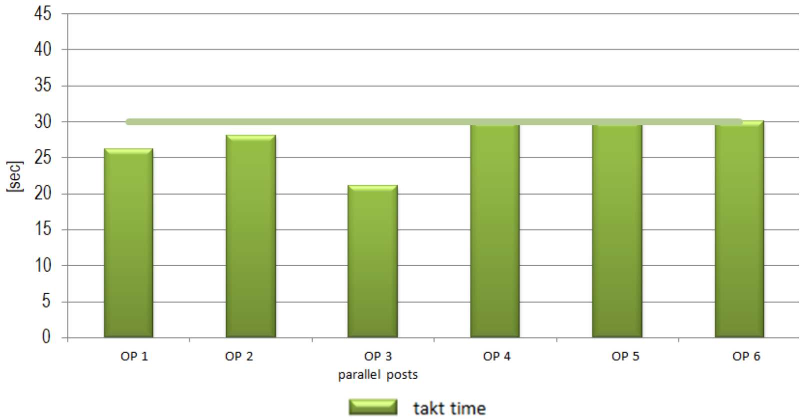
Concerning the bottlenecks on the assembly line for solution 1, the sum of the percentages of the bottlenecks is 37.8%, and in the case of Solution 2 the amount of the blockages is 32.5%.

The total percent of expectations of the assembly line for Solution 1 is 10.59% and for Solution 2 the total amount is 11.25%.

Table 4 highlights the tasks that operators must perform in OP31 and OP34 and we notice that the two operators have to repeat their OT2 and OT5 task in their posts, which means Solution 1 involves introducing additional manipulations that do not bring value to the final product.

Following the results obtained, the viable solution to be implemented is Solution 2.

Fig. 8. New assembly line takt time



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