

Real of Simply Assembly Line Balancing using Fact-Model

Haeryip Sihombing, Habibullah Akbar, Puvanasvaran Perumal, Mohd. Yuhazri Yaakob, and Jeefferie A. Razak

Abstract—This study is to examine the productivity of the designated production line related to the cycle time, takt time, non-value added activities, and product quantities in which the processing time and the number of operators are having the correlation with assembly line balancing. By using a developed simulation tool, called as Fact-Model; which having facility menus such as the graph of critical path network, working time, and production table, enable users to analyze the line assembly related to idle time and bottleneck as well as to address the unbalancing causes. Fact-Model is also facilitate users to apply their owned pictures (which is taken related to process) in order to depict and map the real characteristic of production flows. Based on the simulation carried out, where the reallocation activities in Main-Board production line are undertaken through the production process and operators reassigned, it shows that productivity is optimum.

Index Terms—Line balancing, productivity, simulation, fact-model.

I. INTRODUCTION

Assembly line balancing or simply line balancing is the problem of assigning operations to workstations along an assembly line, where they should be optimal in some sense [1]. Considering on this, the problem complexity, uncertainty, and constraints will increases as to the number of the processes and products variables increased [2], since the assembly works among the workstation concerned to the allocating task have to evenly-aligned as much as possible without violating any precedence flow and exceeding the cycle time. Based on this reason, the assembly tasks should be, therefore, independently allocated to a specific station towards it needs and/or made up the tasks. First, this is due to in a partition of work among stations are static, unchanging, and generally imperfect [3], especially in the preliminary design stage [4]. Second, when assembly line balancing problem arises, then it has to be solved by redesign and reconfigure the assembly line. In this sense, the workflow must be distributed uniformly on the shop floor to avoid bottlenecks due to its lead to the under-utilization of resources [5].

Hence, the implementation of the assembly line balancing (as a method of sizing production capacity) should allows for better utilization of available resources [6] by reducing the complexity to a simplified model results. This is due to the

method proposed of line balancing for the production problem, so far , are missed out and lack to consider the presence and interrelation of operators against the allocated task and workstation, workshift [3], [7], [8], and the time break.

II. LINE BALANCING

The problem of balancing an assembly line is formally defined through the number of models, their associated tasks, the time for performing each task, and their precedence relationships in which they are as a perplexing problem for all managers, particularly when labor productivity is a primary concern [9] and the distribution of activities among the workstations should be maximum through utilization of human resources and facilities [10].

Traditionally, balancing problem on assembly lines [11] is how to minimize the number of workstations along the production line (in which the goal is interpreted as minimizing the costs of manpower) and how to maximize the rate of production or minimize the cycle time towards a number of fixed workstations. Here, to conduct the balancing an assembly line, therefore, it must constructs a diagram of the tasks involved in assembling the product, their times characteristic, precedence relations as well as a desired demand and a time cycle. This is due to line balancing as a flow-oriented production system need to use of available cycle time as efficiently as possible and allocated the resources in effectively [12], [13], in which as follows:

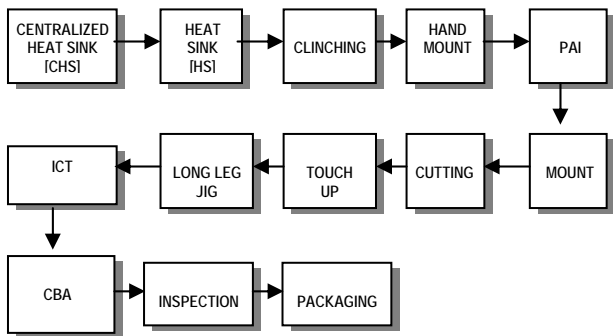
- 1) To optimize the operations in production line for a given number of workstations towards the operators and machines are therefore requires the strategy on how to optimize the line balancing through reducing the cycle time [4]. Particularly, by reducing the cycle (takt) time through equalizing the loads on the workstations [15] where each of stations on the line are ideally should receive an equal amount of work in time units. Here, the resources must be properly used to achieve maximum productivity on the shop floor and properly schedule for efficient use of available resources [15].
- 2) To determine optimum allocation of operations at the workstations in order to minimize the cycle time of the line for a given number of workstations, or to minimize the number of the workstations for a given cycle time need through equalizing the loads on the workstations [4]. Here, the key criteria of the production process measurement related to the number of products finished per period of times and how to allocate a fixed amount of work to the stations of an assembly system in order to maximize throughput is therefore required [16].

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- To achieve the desired balance and to measure the effectiveness of resources (based on the capacities at different stations related to the number of workers and how to allocate the workers between the component stations and the assembly stations) are therefore need to be well-organized planned, especially towards the workstation in sequence where the specific production requirement is required. Besides, the abilities of each worker towards the jobs on designated workstations for high productivity, lower cycle time, and lower rejection rate.

Aforementioned above, the target line is typically needs to be rebalanced rather than balanced [1]. In this sense, line balancing problem is not only related to the problem of line design with nearly equal distribution of tasks among the stations or the adaptation of tasks to the speed of the workers, but also to the stability of the system and the reliability of the production set up [17]. Instead on merely adapting the theoretical solutions, the practical application to real problems should therefore need to be taken as an ultimate consideration since balancing and sequencing have different planning horizons [13] and real-world manufacturing problems contain of nonlinearities, combinatorial relationships, and uncertainties that are too complex to be modelled analytically [18].

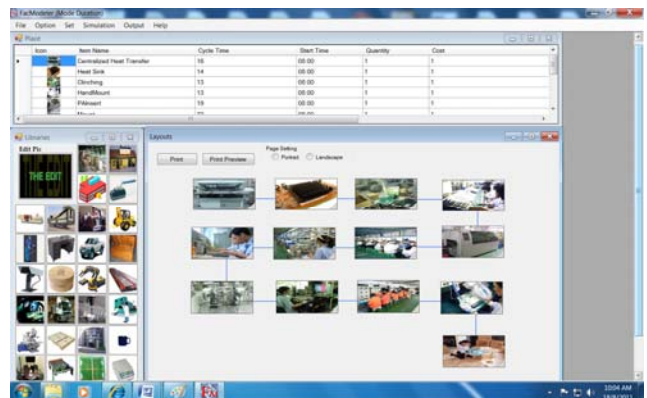


Flow chart of line production

III. SIMULATION FOR PRODUCTIVITY

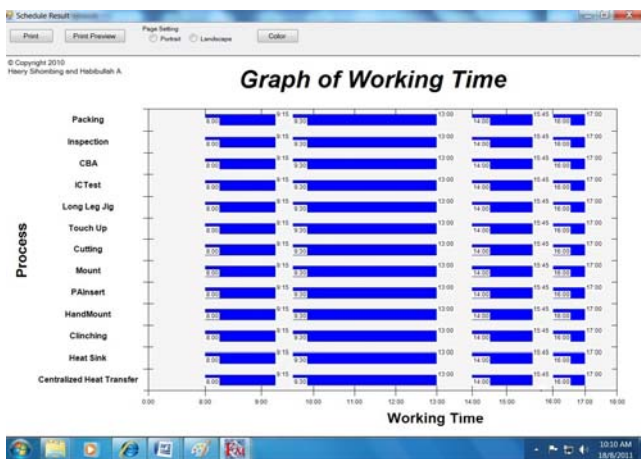
This study discuss the production line to manufacture the electronic component (mainboard) with line balancing requirements. Since the productivity is related to the input and output, factors or variables influenced to the line balancing (i.e. the number of operators, equipment, and machines) will determine the working time consumed for completing one process of product manufactured based on sum of the cycle times taken at every process related. In order to diagnose the current status of the assembly line, the relevant information of line balancing (no. workstation, process sequence, time idleness, efficiency rates, and cycle time) are analyzed through the precedence diagram shown in Fig. 1 and Fig. 2, where the quantity in Table I.

Table I show that thirteen (13) operators are involved in the Main Board manufacturing process, while the total cycle time is 179 sec. To examine the balancing level, the ratio and efficiency of line balancing is calculated (Table 2). Due to the target is not achieved (since the takt time is 18 sec for target 1500 pcs.) cause the Mount and PAI cycle time is 22 sec and 19 sec respectively, in order to make the lines production in balance and at the same time it also reducing the cycle time, the operation therefore need to reallocate the operators. However, prior to reallocate the process, the removing of the non-value added activities are needed against as follows:



Current state of flow chart of line production using fact-model

Fig. 1. Production flow



Production graph of working time 08.00 ~ 17.00



Current state of network path and cycle time

Fig. 2. Working time and network path (current state)

TABLE I: PROCESS VS. CYCLE TIME

Process Name	Op.	Cycle Time	08:00 ~ 09:15	09:30 ~ 13:00	14:00 ~ 15:45	16:00 ~ 17:00	TOTAL		Current State		Future State			
			QTY	QTY	QTY	QTY	W/ hours	QTY		Idle Time	Op.	Cycle Time		Idle Time
Centralized Heat Transfer	1	16	281	788	394	225	7.5	1688	88.89%	11.11%	1	25	138.89%	-38.89%
Heat Sink	1	14	321	900	450	257	7.5	1928	77.78%	22.22%	-	0	0.00%	0.00%
Clinching	1	13	346	969	485	277	7.5	2077	72.22%	27.78%	1	13	72.22%	27.78%
HandMount	1	13	346	969	485	277	7.5	2077	72.22%	27.78%	1	13	72.22%	27.78%
PAInsert	1	19	237	663	332	189	7.5	1421	105.56%	-5.56%	1	19	105.56%	-5.56%
Mount	1	22	205	573	286	164	7.5	1228	122.22%	-22.22%	1	22	122.22%	-22.22%
Cutting	1	10	450	1260	630	360	7.5	2700	55.56%	44.44%	1	10	55.56%	44.44%
Touch Up	1	12	375	1050	525	300	7.5	2250	66.67%	33.33%	1	12	66.67%	33.33%
Long Leg Jig	1	8	562	1575	788	450	7.5	3375	44.44%	55.56%	1	8	44.44%	55.56%
ICTest	1	16	281	788	394	225	7.5	1688	88.89%	11.11%	1	16	88.89%	11.11%
CBA	1	13	346	969	485	277	7.5	2077	72.22%	27.78%	1	13	72.22%	27.78%
Inspection	1	10	450	1260	630	360	7.5	2700	55.56%	44.44%	1	8	44.44%	55.56%
Packing	1	13	346	969	485	277	7.5	2077	72.22%	27.78%	1	13	72.22%	27.78%
Total	13	179							Average	23.5%	12	172	Average	24.79%

TABLE II: THE EFFICIENCY AND RATIO OF CURRENT AND NEW LINE BALANCING

	Current	By removing Heat Sink	New
Line Balancing Ratio	$[179/(13*22)] = 62.59\%$	$[172/(12*25)] = 38.22\%$	$[77.55/(7*16)] = 69.24\%$
Line Balancing Efficiency	$[179/(13*18)] = 76.50\%$	$[172/(12*18)] = 63.70\%$	$[169/(12*18)] = 78.24\%$



Fig. 3. Cycle time graph of main board production line

- Heat Sink. By merging the Heat Sink to Centralized Heat Sink workstation will reduce 1 operator. However, this will affect to the increasing of the Centralized Heat Sink cycle time to 25 sec as well as the ratio and efficiency of line balancing (62.59% and 76.50% respectively). In table 1 shows that the efficiency and ratio of new line balancing is decreased due to the average of idle time and bottleneck is becoming higher (23.50% to 24.79%). Therefore, some of readjustment of new balacing strategy is required to optimize the idle time and bottleneck. Fig. 3 shows that the idle time exhibited at the certain workstations (*i.e.* the Clinching, Handmount, Cutting, Touch-up, etc.) due to its working time finished earlier. To address this fact, the operators who can settle their tasks earlier should, therefore, be replaced or reallocated to other workstations.
- PAI and Mount processes, due to they have the cycle time that higher than takt time. By using why- why analysis, the improvement made is to reduce non-value added by implementing 5S, in which the cycle time of PAI reduced to 17 sec.

Moreover, due to the cycle time of Centralized Heat Sink and PAI is higher than the takt time, the reallocating the operators to others workstation are therefore required (Table

3), as follows:

- The operator at workstation of the Clinching, Handmount, and Packing are reallocated to support Centralized Heat Sink workstation at 08.00am till 09.30am, so as the total operator is 4 people. The total product resulted is 864 pcs, in 1.5 hours (before 1st time break). While, the rest of the volume product (648 pcs.) is then made by 1 operator started at 09.45 to 15.15 (09.45am to 03.15pm) with considering the 2nd time break (13.00 to 14.00).
- The operator of the Clinching and Handmount workstation will start his /her activities at 09.45am (after 1st time break). Each of them will produce the total demand of product (1500 pcs.) with the working hours finished at 16.30 (04.30pm) (1523 pcs.) with considering the 2nd time break (13.00 to 14.00) and 3rd time break (15.45 to 16.00).
- An operator of the Packing workstation will start his her activities at 09.45am. He or she will produce total demand of product (1500 pcs.) with the working hours finished at 15.45 (03.45pm) before 3rd time break.

Furthermore, the operator at Touch-up and Long Leg Jig workstation are allocated to support Mount operation at 08.00 am to 09.30am, so as the total operator is 3 people. The

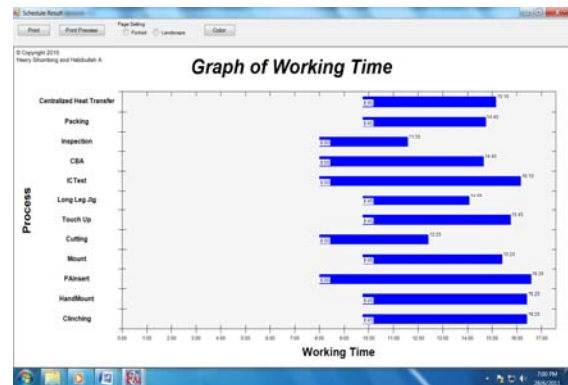
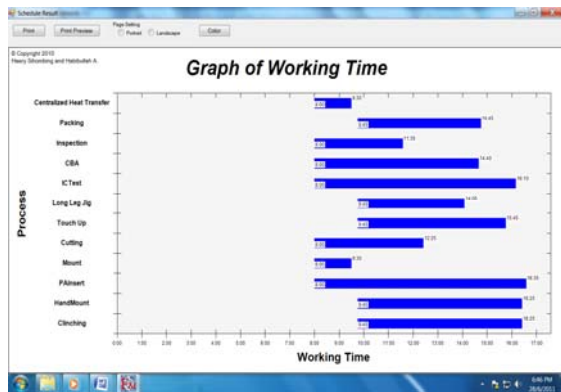
total product resulted is 736pcs in 1.5 hours (before 1st time break). While, the rest of volume product (777 pcs.) is then made by 1 operator started at 09.45am to 03.30pm. Here, the operators of Touch-up and Long Leg Jig workstation will start his /her activities at 09.45am (after 1st time break). He/she will produce 1500 pcs. (the total demand of product) with the working hours finished at 03.45pm and 02.15pm respectively (1500pcs and 1575 pcs. respectively).

Since the inspection workstation is handled by an operator who having a crucial role to check and inspect the product (that need to be independently and avoided from the job interference from production line interest), reallocating of

inspection operator to other workstation is prohibited even though the cycle time of inspection activities were the lowest one (8 sec). In addition, because of the Cutting process is finished earlier (12.30pm), but how to reallocate the operator of this process therefore need further arrangement, beside re-layout where it will effect to other workstation. For the temporary, the company let the process like that, until the process of Mount operation is stable and the TPM programs carried out to improve their efficiency are successful.

TABLE III: PROCESS TIME AND GRAPH OF WORKING TIME

No	Workstation	Op.	Cycle Time (s)	Process Time [w/rest time]	Hrs	Min'	QTY	Start	End	End [time scale]	QTY [real]	Activities End [Efficiency]
1	Centralized Heat Sink & HeatSink	1	25	10.42	10	25	1500	08:00	19:55	20:00	1512	15:15 [80.0%]
		4	6.25	1.50	1	30	864	08:00	09:30	09:30	864	
		1	25	4.42	4	25	636	09:45	15:10	15:15	648	
2	Clinching	1	13	5.42	5	25	1500	08:00	14:40	14:45	1523	16:30 [93.33%]
							09:45	16:25	16:30	1523		
3	Handmount	1	13	5.42	5	25	1500	08:00	14:40	14:45	1523	16:30 [93.33%]
								09:45	16:25	16:30	1523	
4	PAI	1	17	7.08	7	5	1500	08:00	16:35	16:45	1535	16:45 [96.67%]
5	Mount Operation	1	22	9.17	9	10	1500	08:00	18:40	18:45	1514	15:30 [83.37%]
		3	7.3	1.50	1	30	736	08:00	09:30	09:30	736	
		1	22	4.67	4	40	764	09:45	15:25	15:30	777	
6	Cutting	1	10	4.17	4	10	1500	08:00	12:25	12:30	1530	12:30 [56.67%]
7	Touch Up	1	12	5.00	5	0	1500	08:00	14:15	14:15	1500	15:45 [86.67%]
								09:45	15:45	15:45	1500	
8	Long Leg Jig	1	8	3.33	3	20	1500	08:00	11:35	11:45	1575	14:15 [66.67%]
								09:45	14:05	14:15	1575	
9	ICT	1	16	6.67	6	40	1500	08:00	16:10	16:15	1519	16:15 [90.0%]
10	CBA	1	13	5.42	5	25	1500	08:00	14:40	14:45	1523	14:45 [73.33%]
11	Inspection	1	8	3.33	3	20	1500	08:00	11:35	11:45	1575	11:45 [46.67%]
12	Packing	1	12	5.00	5	0	1500	08:00	14:15	14:15	1500	15:45 [86.67%]
								09:45	14:45	15:45	1500	



- The operator at Clinching, Hand mount, and Packing are reallocated to support Centralized Heat Sink workstation at 08.00am till 09.30am.
- The operator at Touch-up and Long Leg Jig workstation are allocated to support Mount operation at 08.00 am to 09.30am

- The operator of Clinching and Handmount workstation will start his /her activities at 09.45am
- An operator of Packing workstation will start his /her activities at 09.45am

IV. CONCLUSION

In this study, due to the Centralized Heat Sink and Heat Sink workstation are merged into 1 workstation (in which then only 1 operator required), the total number of operators was reduced from 13 to 12 persons. However, this strategy was actually reducing the line balancing ratio from 62.59% to 38.22% and the efficiency from 76.50% to 63.70%. Although by merging such workstation will increase the

efficiency of operator involved, the average of bottleneck and idle time is, however, increased by 1.29%. This is not as what required for line balancing purpose. Therefore, the problem of line unbalancing situation in the Main Board production line is not only requiring the reallocation of operators of Clinching, Handmount, and Packing to the Centralized Heat Sink, but also the removal of the non-value added (through implementing 5S at PAI workstation). By this strategy, the

efficiency average calculated of the working time from 12 workstations is 79.44% (Table 3), while the new of line balancing ratio and efficiency is increased to 69.24% and 78.24% respectively (Table 2). Here, the Fact-Model is used to help the simulation by mapping it through graph of the working time related to quantity and network path.

Since the increment of productivity considered in this study is in terms of the output that related to quality of product, by performing the reduction of the total worker numbers and the cycle times as well as reallocating the operator (while at the same time the outputs maintained) are, therefore, need to consider the time interchange of the jobs. This is to avoid the possibility of reject product occurred due to the confusion of operator for doing the tasks. In this study, the reallocating of operators were, therefore, undertaken to before or after the break time.

However, there are some of other improvement aspects still required to carry out productivity activities against line balancing through rebalancing the lines, especially related to the buffer stock and WIP. Besides, the further study toward the issues in the production line (that is related to quality product, layout design, and ergonomic) in order to increase the production productivities and line balancing.

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