Line Balancing in the Hard Disk Drive Process Using Simulation Techniques

Teerapun Saeheaw, Nivit Charoenchai, and Wichai Chattinnawat

***Abstract*—**Simulation model is an easy way to build up models to represent real life scenarios, to identify bottlenecks and to enhance system performance**.** Using a valid simulation model may give several advantages in creating better manufacturing design in order to improve the system performances. This paper presents result of implementing a simulation model to design hard disk drive manufacturing process by applying line balancing to improve both productivity and quality of hard disk drive process. The line balance efficiency showed 86% decrease in work in process, output was increased by an average of 80%, average time in the system was decreased 86% and waiting time was decreased 90%.

***Keywords*—**line balancing, arena, hard disk drive process, simulation, work in process (WIP)

I. Introduction

DUE to dynamic and uncertainty, the assembly process is an important sector in the manufacturing of hard disk drive. To manage and control the assembly line effectively, as well as reduce the piling up inventory it is necessary to analyze the production system to get optimize outcome. The more realistic simulation representation becomes more essential and effective for designing and testing of large scale engineering system which being increased complexity day by day [1]. Simulation has been commonly used to study behavior of real world manufacturing system to gain better understanding of underlying problems.

Simulation modeling is arguably more widely applied to manufacturing systems in general more than any other application area [2]. Some of the reasons for this are the competitive environment in many industries that has resulted in a greater emphasis on automation to improve productivity and quality. Since automated systems are more complex, they typically can only be analyzed by simulation. Another factor is that the cost of equipment and facilities can be quite large, thus the relatively small expenditure on simulation can reduce the risk of failed implementation. Thus the process industries with their generally high level of automation and capital investment would seem an ideal opportunity to utilize the simulation technique. However despite their widespread occurrence (within the manufacturing sector Novitsky [3] states that approximately 50% of all firms consider themselves to be in the process industries) examples of the use of simulation modeling are few, and those that do occur tend to focus on the analysis of production planning and control issues. Katayama [4] uses simulation to assess a production planning procedure for a multi-item continuous production system in a petrochemical plant. White and Tsai [5] use simulation to analyze the logistics of solvent recovery in a chemical processing plant. Vaidyanathan et al [6] use simulation as a daily production scheduling tool in a coffee manufacturing process. Saraph [7] uses simulation to imitate demand and supply of water in a continuous process biotech manufacturing facility.

Therefore, a simulation model is an easier way to build up models to represent real life scenarios, to identify bottlenecks, to enhance system performance in terms of productivity, queues, resource utilization, cycle times, lead times, etc. A re-configurable assembly line can provide flexibility for high mix low volume manufacturing systems, which can meet growing customer demand.

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 Henry Ford's 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.

In this paper we analyze, evaluate and improve a hard disk drive (HDD) production process by considering the effects of some pre-defined process parameters on the performance of a production line. These parameters include standard operation time at each station and productivity measures at each process element, as well as job description rule, batch sizes. First we employ simulation to evaluate the effects of these factors on the performance of the system and then evaluate the line balance efficiency and throughput of the process. The performance evaluation function is defined in terms of the line balancing efficiency restricted with pre-defined TACT time (the time needed to manufacture one unit of a product) the throughput (average flow time of part through the production line). Arena10.0 simulation software was used to model and analyze the production smoothing process factors.

II. Methodology

A hard disk drive process consists of a series of process in clean room to produce hard disk drive from raw material to finish goods. The hard disk drive is produced by the components of the head stack assembly and hard disk drive which are shown in Figure 1. The head stack assembly (HSA) and hard disc drive assembly (HDE) draw out the raw material from the material warehouse base on the daily going rate schedule by the production control section. The current process has long lead-times (Figure 2) and work in process.

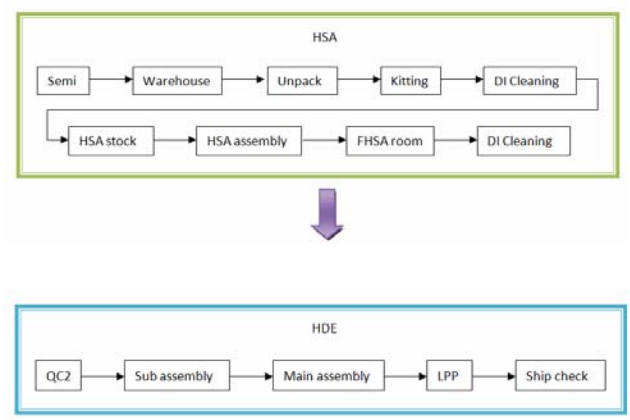

Fig. 1 Departments of hard disk drive process

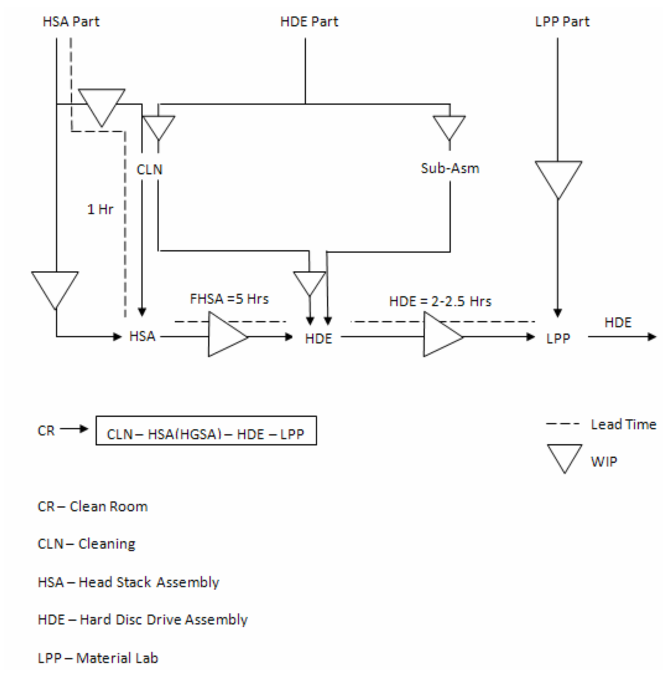

Fig. 2 Lead time and work in process in hard disk drive process

The simulation model was built using Arena® version 10 simulation software. The quantity of resources which are used for each operation are determined by the line balancing. During straight line production each operator uses only one machine/tool.

This study represents discrete-event modeling and the hard disk drive process works for 21 hours in a day.

At the beginning of each order, the production line begins empty. This start-up condition must also be simulated. Statistics during this part of the simulation may negatively bias the final results since the line takes time to "warm up" and begin operating consistently in a steady state. When an entity arrives at a semi store, it waits in a first-in-first-out queue until the resource is available.

The following assumptions are used to define the problem:

- the process line is never starved,
- set up times are not taken into consideration. Because in a real system the setup process is usually accomplished at the end of the working time,
- 21 hours working time does not include breaks,
- no maintenance process is performed during the working period,
- all process times for operations include 'insignificant breakdowns'
- transportation of raw materials is performed by workers who aren't used for operations.

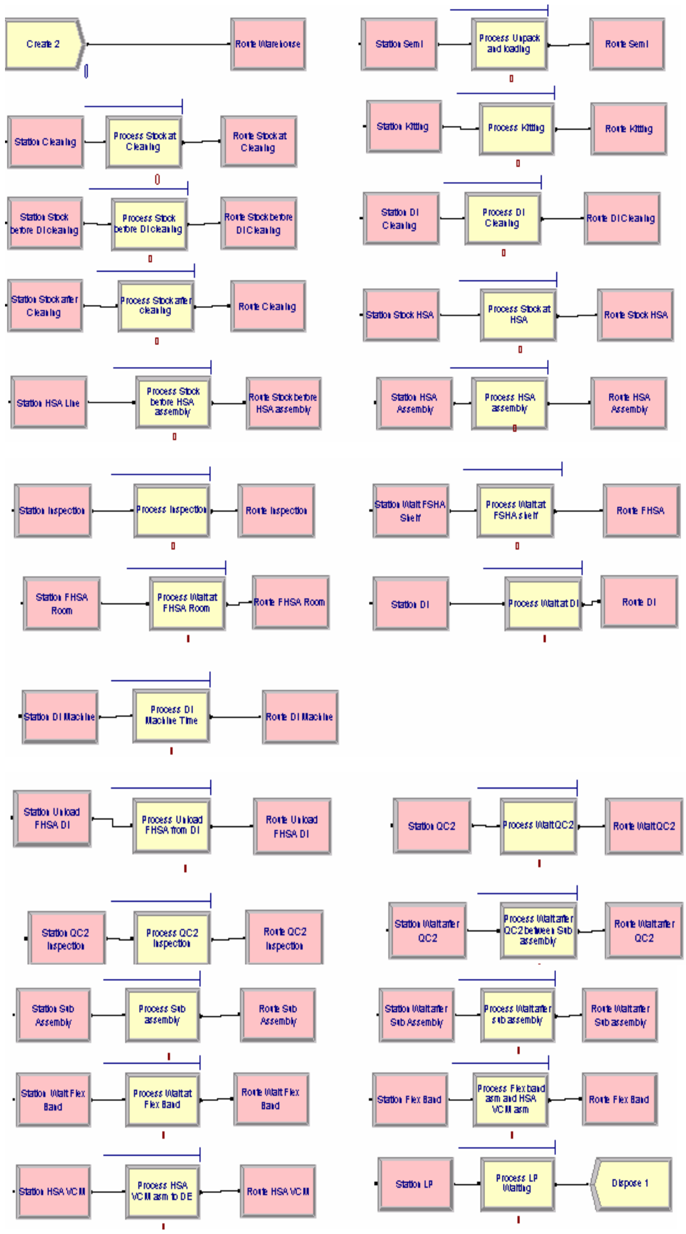

Fig. 3 Arena modeling of the hard disk drive production process

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The model input

During the data collection period, 19 weeks of data are obtained for each operation using time study techniques. As has already been mentioned, in assumptions, insignificant breakdowns are also added to the time study data. All data are evaluated by the Arena Input Analyzer software in order to determine distribution types for every operation (Table 1). The arena model of the process was shown on Figure 3.

TABLE I
DISTRIBUTION TYPES FOR EACH OPERATION IN DEPARTMENTS OF HARD DISK DRIVE PROCESS; UNIT, HOUR.

Department	Operation		Distribution type
Semi	COI		LOGN(0.748 , 1.15)
Warehouse	Warehouse to Semi		0.01 + WEIB(0.02, 27.4)
Unpack	Unpack & Loading		0.04 + EXPO(0.0132)
	Semi to Cleaning		0.03 + 0.04 * BETA(15.4, 15.9)
	Stock at Cleaning		0.19 + WEIB(0.0198, 13.7)
Kitting	Kitting		0.03 + EXPO(0.0116)
	Stock Before DI Cleaning		0.01 + 0.31 * BETA(0.866, 1.04)
DI cleaning	DI cleaning		0.5 + WEIB(0.0299, 17.3)
	StockAfter Cleaning		0.09 + LOGN(0.124, 0.0777)
	Cleaning to Stock HSA		NORM(0.0842, 0.0198)
HSA stock	Stock at HSA		0.14 + LOGN(0.144, 0.0998)
	Stock HSA to HSA Line		0.02 + 0.07 * BETA(1.29, 1.77)
	Stock before HSA Assembly	HSA	0.09 + 0.47 * BETA(3.42, 0.974)
HSA Assembly	HSA Assembly		0.31 + LOGN(0.0105, 0.00163)
	Inspection		0.05 + WEIB(0.02, 27.4)
	Wait at FHSA shelf		0.07 + 0.06 * BETA(3.08, 2.98)
	Transfer FHSA to FHSA room		0.26 + LOGN(0.0874, 0.0508)
FHSA room	Wait at FHSA room		TRIA(1.05, 1.25, 1.71)
	Transfer from FHSA room to DI		TRIA(0.1, 0.12, 0.17)
	Wait at DI		TRIA(0.65, 0.776, 1.07)
DI cleaning	DI Machine time		0.53 + LOGN(0.0105, 0.00163)
	Unload FHSA from DI		NORM(0.115, 0.0135)
	Transfer from DI to QC#2		TRIA(0.06, 0.085, 0.11)
	Wait at QC#2		TRIA(0.26, 0.311, 0.43)
QC2	QC#2 Inspection		0.15 + WEIB(0.02, 27.4)
	Wait after QC#2- Sub Asm.		0.38 + LOGN(0.119, 0.0771)
Sub assembly	SUBAsm. Operation		0.32 + WEIB(0.0299, 17.3)
	Waiting after SUB Asm.		TRIA(0.46, 0.55, 0.76)
	Transfer from SUB to Flex band		TRIA(0.06, 0.085, 0.11)
	Wait at flex band		TRIA(0.08, 0.098, 0.14)
	Flex band asm & VCM Asm.		0.12 + EXPO(0.0116)
	HSA/VCM Asm. To DE		0.03 + 0.07 * BETA(3.69, 0.813)
Main assembly	Waiting AF/ DE Inspection		
	Wait at DE by material handling	HDE	
	Transfer from DE ==> QC		
	Wait BF/ QC#3		
	QC#3 Inspection		
	WaitAF/ QC#3		
	Transfer AF/QC#3 to B/STW		
	Waiting at B/STW		
	STW Test		0.62 + 0.31 * BETA(1.64, 1.72)
	Waiting AF/STW		
	Transfer to B/LPP		
	Waiting at LPP line		
LPP	LPP Asm. Time		
	Waiting after LPP		
	Transfer from LPP to check		
	Waiting at B/Ship check		
Ship check	Ship check / sent to Pass box		

Replication Parameters

We specify the Replication Length to be 10 and select the time unit for that to be Hours.

Model validation was accomplished through tests using a throughput with a 95% confidence interval. From initial 10 replications, we have a descriptive statistic as follows (Table 2).

TABLE II
DESCRIPTIVE STATISTIC FOR 10 REPLICATIONS

Mean	82.2
Standard Error	0.29
Standard Deviation	0.92
Sample Variance	0.84
Median	82
Mode	82
Kurtosis	0.40
Skewness	0.60
Range	3
Minimum	81
Maximum	84
Sum	822
Count	10

The appropriate number of replication, N solve for
z at 95% confidence interval = 1.96
δ = standard deviation = 91.89
$\bar{x}$ = mean = 82.2

$$N = \frac{z^2 \delta^2}{\bar{x}^2} \qquad (1)$$

We will get N = 4.8. So, the appropriate number of replication is 5 times.

Output Analyzer

To make a plot of WIP vs. time in the Output Analyzer, we created a new data group and added the file Total WIP History.dat to it. Figure 4 shows the resulting plot of WIP across the simulations. From this plot, it seems clear that as far as the WIP output is concerned, the run length of 100 hours is enough for the model to have settled out, and also it seems fairly clear that the model isn't "exploding" with entities.

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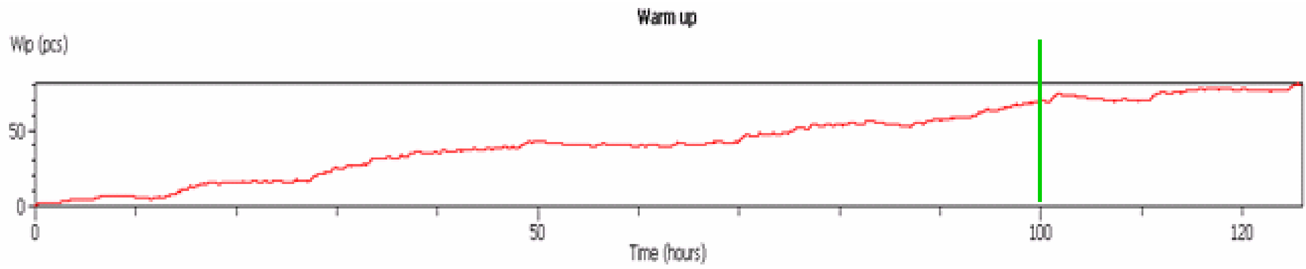

Fig. 4 Within-Run WIP Plots

Verification/Validation

We examined the process and ran the simulation model to verify and validate the model. The comparison between simulation results and pre-historical records show the consistent throughput. After validation of the simulation model, the solution of improvements was generated by concurrently considering the practical changes in production operations and work constraints.

Process Analyzer

After running the model, the simulation results coincide with the historical records showing that the process Wait at FHSA room posses highest work in process. Because we have to add operators for suitable operations in order to decrease the bottleneck in the production line. The production line balancing has been investigated extensively in the literature, i.e., [8], [9]. Both exact and heuristic procedures and more recently, meta-heuristic procedures have been developed to solve this problem, [10]. With more than two scenarios to compare, the problems are evaluating many scenarios with the Process Analyzer (PAN).

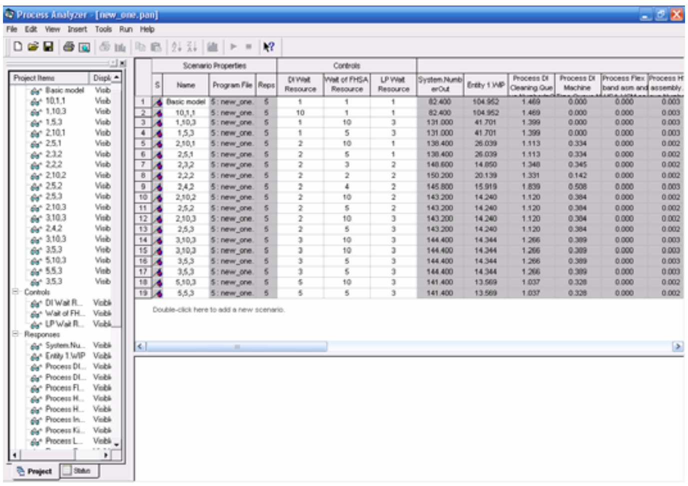

Fig. 5 Process Analyzer of the hard disk drive production process

III. RESULT

After the validation process was done, we found that entity WIP was 104.95, output was 82.4 and waiting time was 72.33. From Resource scheduled utilization showed Wait of FHSA resource is a bottleneck (Figure 6). Since Wait of FHSA resource related with both DI wait resource and LP wait resource, we adopted Process Analyzer to find optimal solution. Different decision options were evaluated for the design or reconfiguration of the production line. Skilled operators were added for suitable operations in order to decrease the bottleneck in the production line. The queue length and the utilization of each resource were also observed.

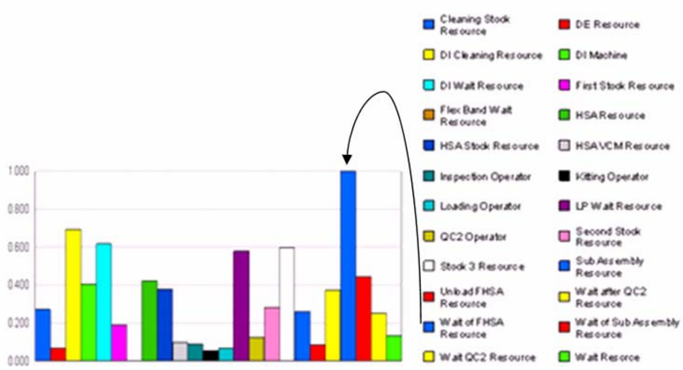

Fig. 6 Resource scheduled utilization in current process

	Scenario Properties				Controls			Responses		
	S	Name	Program File	Reps	DI Wait Resource	Wait of FHSA Resource	LP Wait Resource	System.NumberOut	Entity 1.WIP	Entity 1.WaitTime
1		Basic model	5 : new_one.	5	1	1	1	82.400	104.952	72.327
2		10,1,1	5 : new_one.	5	10	1	1	82.400	104.952	72.327
3		1,10,3	5 : new_one.	5	1	10	3	131.000	41.701	26.451
4		1,5,3	5 : new_one.	5	1	5	3	131.000	41.701	26.451
5		2,10,1	5 : new_one.	5	2	10	1	138.400	26.039	16.319
6		2,5,1	5 : new_one.	5	2	5	1	138.400	26.039	16.319
7		2,3,2	5 : new_one.	5	2	3	2	148.600	14.850	7.008
8		2,2,2	5 : new_one.	5	2	2	2	150.200	20.139	10.883
9		2,4,2	5 : new_one.	5	2	4	2	145.800	15.919	7.697
10		2,10,2	5 : new_one.	5	2	10	2	143.200	14.240	6.922
11		2,5,2	5 : new_one.	5	2	5	2	143.200	14.240	6.922
12		2,10,3	5 : new_one.	5	2	10	3	143.200	14.240	6.922
13		2,5,3	5 : new_one.	5	2	5	3	143.200	14.240	6.922
14		3,10,3	5 : new_one.	5	3	10	3	144.400	14.344	6.991
15		3,10,3	5 : new_one.	5	3	10	3	144.400	14.344	6.991
16		3,5,3	5 : new_one.	5	3	5	3	144.400	14.344	6.991
17		3,5,3	5 : new_one.	5	3	5	3	144.400	14.344	6.991
18		5,10,3	5 : new_one.	5	5	10	3	141.400	13.569	6.724
19		5,5,3	5 : new_one.	5	5	5	3	141.400	13.569	6.724

Fig. 7 Quantity of optimal resources before and after line balancing

Results of simulation are presented in Figure 7. The optimal quantity of resources in both LP wait resource and DI wait resource was 2 operators. Wait of FHSA resource was 3 operators. The line balance efficiency showed 86% decrease in work in process, output was increased by an average of 80%, average time in the system was decreased from 76.25 to 10.94 and waiting time was decreased 90%.

IV. DISCUSSION

This simulation research for hard disk drive process had adopted line balancing to improve the productivity and quality of the process. The results showed that the productivity was increased, line balancing efficiency was dramatically improved, and work in process was reduced as well as the improvement in quality. According to the restriction and constraints, work cells cannot be totally balanced. The overall results still fulfill the need of the process manager to increase the utilization of production line.

V. CONCLUSION

A simulation model is an easier way to build up models to represent real life scenarios, to identify bottlenecks, to enhance system performance in terms of productivity, queues, resource utilization, cycle times, lead times, etc. Discrete-event simulation has proven to be a good tool to evaluate performances of different optimization methods. Good results were obtained in the case of various basic scheduling policies, allowing comparison between different options. The model could be used to develop intelligent optimization methods through links with external software. Among others, genetic algorithms have been considered as a possible choice. Any heuristically based method would benefit greatly of the ability that discrete-event simulation has to mimic real processes.

The models can be applied in a real system to analyze the system performance more efficiently and effectively. The modeling environments can easily be used for line balancing and assessing the behavior of a line. Thus, managers can prevent any unexpected situations by analyzing results using the simulation model.

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