The Improvement for Optimization of Head Stack Assembly (HSA) Assembling Process by Using the Virtual Reality 3D Simulation Model

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Abstract

Currently, a case study in the Head Stack Assembly (HSA) assembling process has an average production rate of 198 units an hour, which inadequates in the future of customer satisfaction. Therefore, this research aims to determine an approach for increasing the production rate by using the Arena program in order to build the simulation model and using the Theory of Constraints (TOC) to improve the assembly process. Moreover, the researchers develops the 3D virtual reality model by using the Arena 3DPlayer program, which assists to support for decision working efficiently and applies the OptQuest for Arena for determine the optimal amounts of the shuttles and flow fixtures.

Keywords: *Simulation, Head Stack Assembly, Virtual Reality*

1 Introduction

Thailand is a production base and export manufacturer of Hard Disk Drive (HDD) and related components, which ranked top of the world in 2007, reaching 500,000 million baht of export value and over 110,000 personnel employed in the industry. The case study of a Head Stack Assembly (HSA) shows the lack of labors, for which each current line has 10 operators and has an average production rate of 198 units per hour (UPH). Besides the low production rate, which is inadequate to the customer needs, it also results in higher production costs. Therefore, this research aims to apply the simulation technique and to use the Theory of Constraints (TOC) to improve the assembly process therefore increasing capacity. However, this cease study has been fixed to the targeted production rate of 280 UPH a line.

2 Literature Reviews

It can be divided into 2 parts, as following:

2.1 *Simulation and Optimization*

According to Kelton et al. (2007), Simulation is a powerful technique can be used to design, analyze and optimize the complex processes that occur in construction projects. As "a broad collection of methods and applications to mimic the behavior of real systems" Pisuchpen (2008) presents that the computer simulation is a useful tool used in order to analyze the work flow or production process before actually producing the product. This computer simulation will help to improve the process and increase efficiency of the process before actual implementation, without disturbing the existing system. Kanchanasuntorn (2007) explains that the theory of simulation optimization technique is for finding the optimization answer because the linear programming (LP) cannot find the optimization answer for complicated system and stochastic data. The OptQuest in the Arena program is a tool that is used to obtain the optimization result by using metaheuristics methods such as scatter search, tabu search and neural network.

2.2 *Virtual Reality and Applying*

Seppanen (2005) studies the movement of the operators in the assembly line by using the Arena program link with Microsoft Excel. Using the visual basic programming to help the connection between easier workflow and Arena 3DPlayer program to show 3D animation of the production line and find the affected numbers of operators with throughput. The production line is designed for 2 - 4 operators. The simulation results conclude that the number of placement between operators, throughput and average production cycle time depend on the number of operators assigned. Korking (2007) applied the Virtual Reality Modeling Language (VRML) to create the virtual simulation model for constructions management, which can be used as a tool to describe the details of the structure to help reduce errors due to reading of the construction drawings, resulting in the increase effectiveness of construction management. Adulbadee and Chutima (2009) researched to solve the problem of product delivery which is unable to respond to customer's requirement on time and production plans are constantly changing. By applying the Theory of Constraints (TOC) to improve the planning of integrated circuit (IC) production. The results from this research found that the problems can be reduced by the variance of cycle time in production and work in process. Sretip et al. (2010) used computer simulation model, Promodel and SimRunner to study the number of shuttles and flow fixtures in the Head Stack Assembly (HSA) manufacturing process and found that the number of shuttles and flow fixtures could be reduced from 17 to 14 without affecting the production rate of the line. From the research, applying of simulation model and the Theory of Constraints (TOC), it is found that it can improve processes and thus increase of efficiency, without changing the actual process and it can also help to find the optimization answers for the probabilistic data.

3 Methodologies

The study can be divided into 7 steps, as shown in Figure 1.

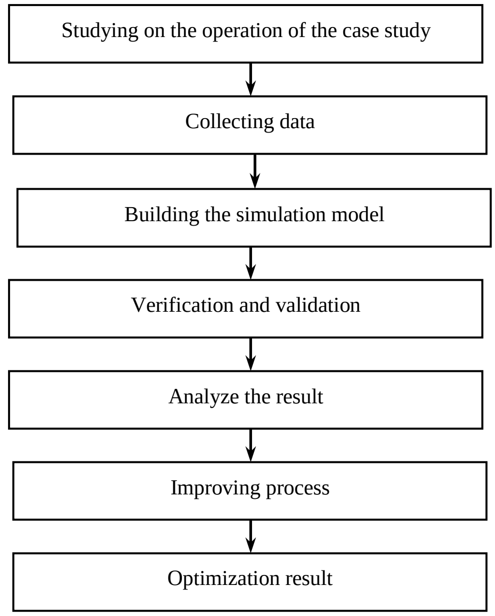

Figure 1: Steps in the study

3.1 *Studying on the operation of the case study*

The company's product is Head Stack Assembly (HSA). Head Gimbal Assembly (HGA) is the combination of the slider and the suspension. When the HGA assembles with the Actuator Pivot Flex Assembly (APFA), that will be the HSA, as shown in Figure 2.

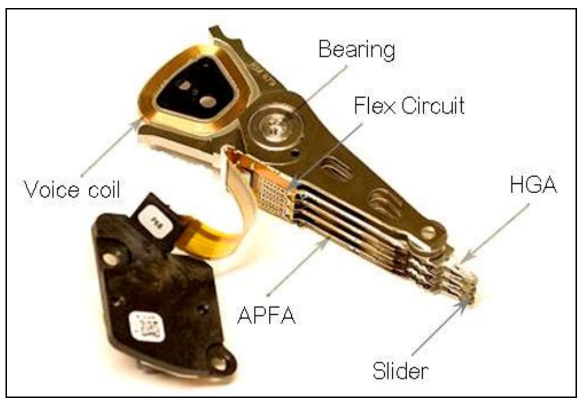

Figure 2: Head Stack Assembly (HSA)

The HSA assembling flow process chart is divided into 7 steps, shown in Figure 3.

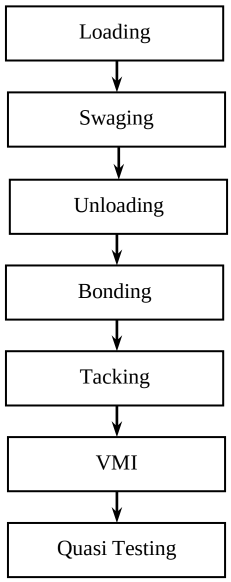

Figure 3: HSA assembling flow process chart

The flow process chart of the HSA assembling can be explained as following:

1. Loading; The APFA assembly of HGA which is fixed to the shuttles by using 2 operators.
2. Swaging; The shooting the ball steel for binding the HGA and the APFA together.
3. Unloading; To take the HSA out of the shuttles. After that the HSA has been fixed into the flow fixture by using 2 operators.
4. Bonding; The electrical cable has been connected between the HGA and the flexible circuit on the APFA by using 2 operators.
5. Tacking; The enough epoxy glue has been dropped in order to hold between the long tail of HGA and the slot of the APFA by using 2 operators.
6. VMI; The inspection for quality is to detect any physical defects of HSA by using an operator.
7. Quasi Testing; The test for electrical performance of the HSA has been operated by an operator.

From the flow process chart of HSA assembling process in the current consist of 10 operators and have 6 shuttles and 8 flow fixtures per one production line.

3.2 *Collecting data*

The researcher collects the variable data of the HSA assembling process for the building of the model, as following:

1. Data of HSA assembling flow process chart
2. Data of HSA Layout process
3. Data of cycle time for each element process
4. Data of conveyor, including the length and speed
5. Data of resource downtime, including the uptime and downtime

Next, to analyze the data to find the data distribution by using the Input Analyzer tool in the Arena program, as shown in Figure 4.

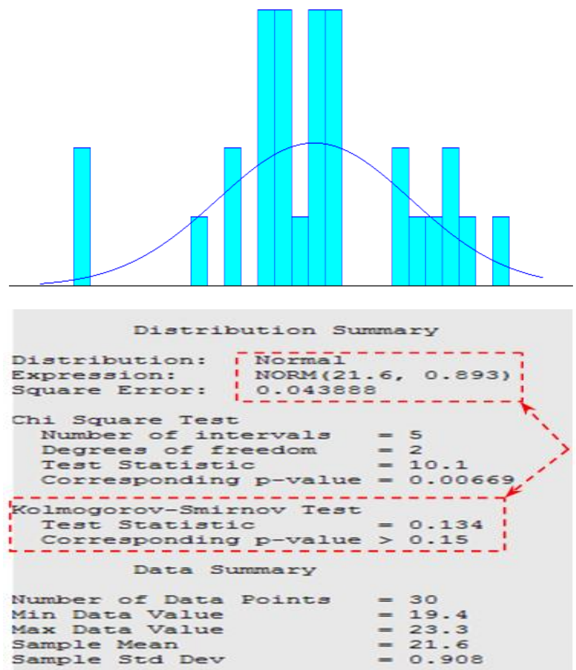

Figure 4: Analyzing data by Input Analyzer

Figure 4 shows the cycle time data analysis of the tacking process from the data is less than 50, accordingly, Kolmogorov-Smirnov testing is used. The result shows statistical testing equals 1.134 and P-Value at 0.15 which is more than the significant (0.05). The above can be summarized that the input data is a normal distribution which average 21.6 seconds. Standard deviation is 0.893 seconds with a square error of 0.043. The cycle time data distribution in HSA assembling process, shown in Table 1.

Table 1: The cycle time data distribution in HSA assembling process

Process	Distribution (Sec)
Loading (P1)	TRIA (23, 26.6, 28.8)
Loading (P2)	23 + WEIB (3.46, 2.36)
Unloading (P1)	5.28 + ERLA(0.132, 5)
Swaging	Constant (13.00)
Unloading (P2)	11.2 + ERLA (0.378, 6)
Bonding (P1)	TRIA (20, 24.1, 25)
Bonding (P2)	20.5 + WEIB (2.87, 2.63)
Tacking (P1)	NORM (21.6, 0.893)
Tacking (P2)	NORM (21.5, 1.15)
VMI (P1)	TRIA(11.1, 11.61, 11.9)
Quasi Testing (P1)	11.3 + 2.49 * BETA (2.92, 3.35)

3.3 *Building the simulation model*

To take the above data to build the HSA assembling process model by using Arena program, as shown in Figure 5.

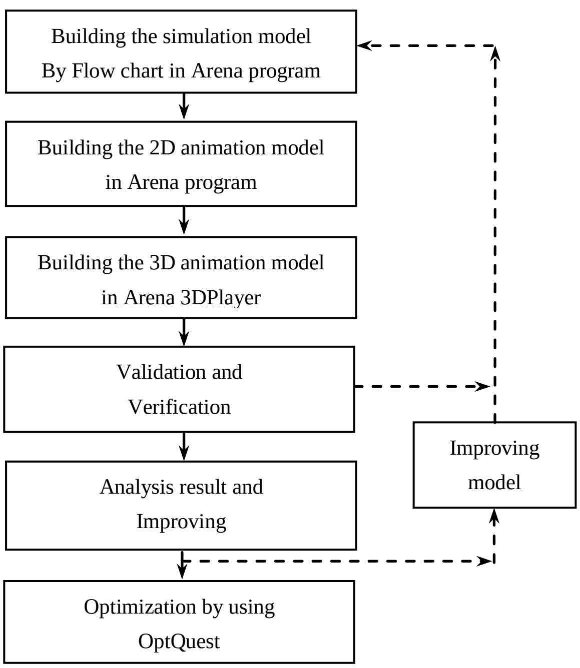

Figure 5: The steps of building the simulation model

3.4 *Verification and validation of the model*

It can be divided into 2 steps, as following:

1. Verification is to check the simulation model which was built by the Arena program must be able to run without any errors and bugs.
2. Validation is to check the accuracy of the results by the simulation model, by comparing between the results real data. Thereafter, the validation is divided into 2 methods that include the statistical hypothesis testing and the animation model.

- Hypothesis average tests the real data average output (μ_0) against the simulation average output (μ_1). The result is shown in Figure 6.

The hypothesis, as following:

$$H_0 : \mu_0 = \mu_1$$
$$H_1 : \mu_0 \neq \mu_1$$

```
Two-Sample T-Test and CI: Current Line, Simulation

Two-sample T for Current Line vs Simulation

              N    Mean  StDev  SE Mean
Current Line  8  197.63   3.34      1.2
Simulation    8  200.35   1.70     0.60


Difference = mu (Current Line) - mu (Simulation)
Estimate for difference:  -2.72625
95% CI for difference:  (-5.67703, 0.22453)
T-Test of difference = 0 (vs not =): T-Value = -2.06  P-Value = 0.067  DF = 10
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Figure 6: The hypothesis testing results

Figure 6, the average of hypothesis testing results found that P-Value at 0.067 which is more than significant (0.05) to accept the null hypothesis (H_0) the above can be summarized that real data average output (μ_0) is not different from the simulation average output (μ_1). Thus the simulation model, which was built, can be taken to analyze the real system.

- The accuracy of HSA assembling process has been checked by using animation of Arena 3DPlayer program. It can be compared between motion of the simulation model and the real system, shown in Figure 7.

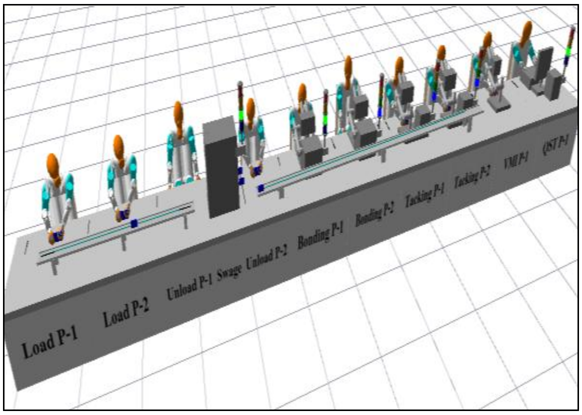

Figure 7: Simulation model accuracy checking of the current line by using the Arena 3DPlayer

3.5 *Analysis result*

This step explains about the results of the simulation model of the HSA assembling process in current line for analyzing the bottleneck is summarized, as shown in Table 2.

Table 2: Simulation results of current line

Process	Average waiting time (Sec)	Utilization	
		Machines	Operator
Loading (P1)	12.06	-	0.9217
Loading (P2)	59.65	-	0.9339
Unloading (P3)	5.94	-	0.5156
Swaging	11.59	0.7176	-
Unloading (P4)	42.40	-	0.7425
Bonding (P5)	7.00	0.6349	0.8649
Bonding (P6)		0.6352	0.8622
Tacking (P7)	62.44	0.5950	0.6377
Tacking (P8)		0.5927	0.6362
VMI (P9)	9.31	0.6340	0.7939
Quasi Testing (P10)	95.37	0.6847	0.8933

After analyzing Table 1, cycle times distribution and Table 2 the results of the simulation model of the HSA assembling process in current line, it is found that Loading (P1) and Loading (P2) have the highest cycle times which affected the utilization. The highest are 0.9217 and 0.9339 respectively. To conclude, Loading (P1) and Loading (P2) are the bottleneck of the HSA assembling process in current line.

3.6 *Improvement process*

To improve the HSA assembling process, the Theory of Constraints (TOC) is defined into 5 improvement steps.

1. Identifying the constraint which has the most cycle time when the capacity of production to be compare with the improving target (280 UPH), found that the HSA assembling process in current line has constraint process more than a process, as shown in Table 3.

Table 3: Capacity of production

Process	Current capacity (UPH)	Target (UPH)
Loading	218	280
Swaging + Unloading	224	
Bonding	230	
Tacking	263	
VMI	249	
Quasi Testing	220	

2. The constraint process is improved in order to increase the effectiveness that can be described as following:

- The work instruction of constraint process are improved which can be divided into 2 processes in order to reduce the cycle time.
- The motion of shuttles and flow fixtures are improved in each process that the assembly line are adapted by using the conveyor in order to replace the operators
- If the constraint process cannot be improved inside the work instruction, it has to increase the machines or the operators in the bottleneck in order to balance the production line.

3. The improving process in step 2 are created the working standard so the assembling process is designed to be semi-auto HSA assembling process and can create the simulation model by using the Arena 3DPlayer that can be shown in Figure 8 and 9.

Note. Rockwell Automation (2004) mentioned that Arena 3DPlayer is a powerful post-process tool that provides the ability to create and view 3D animations of the Arena models.

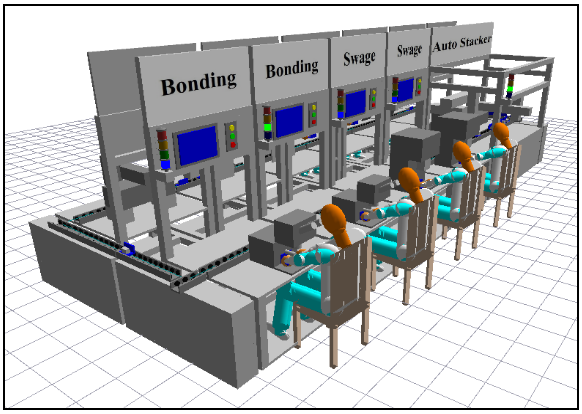

Figure 8: Front view of the semi-auto line

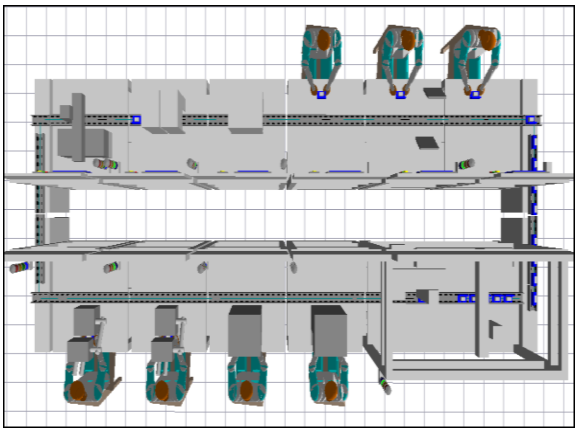

Figure 9: Top view of the semi-auto line

4. The raw materials for HSA assembling are controlled in order to make sure that the constraint machine does not work with poor raw material. This step is to increase the maximum capacity for the constraint process.
5. If the HSA assembling process cannot be improved to the target, the researchers have to return to the first step until the result is on target.

3.7 *Optimization result*

Rockwell Automation (2006) described the optimization model, a model that seeks to maximize or minimize some quantity, such as profit or cost, have three major elements: controls, constraints and an objective. Glover, Kelly and Laguna (1996), The OptQuest is a general-purpose optimizer developed by using the scatter search methodology. The OptQuest is a tool in the Arena program used to build mathematics model to find the optimized amount of shuttles and flow fixtures, it can be shown in Figure 10.

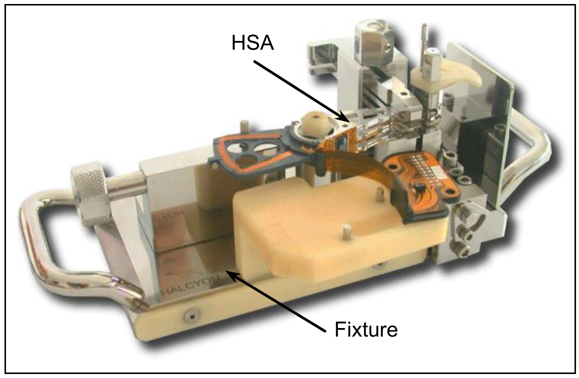

Figure 10: Fixture of the HSA assembling process

1. Calculating the optimization of shuttles and flow fixtures in the HSA assembling process in current according to the objective function and constraints can be shown in the Equation (2)-(7):

Objective function:

$$\textit{Maximize Number Out} \qquad (1)$$

Subject to:

$$\textit{Number Shuttle} <= 12 \qquad (2)$$

$$\textit{Number Flow Fixture} <= 15 \qquad (3)$$

$$\textit{Wait for Loading } (P1) <= 2 \qquad (4)$$

$$\textit{Wait for Loading } (P2) <= 2 \qquad (5)$$

$$\textit{Wait for Assembly Flow Fixture} <= 3 \qquad (6)$$

The Equation (1) is the objective function to maximize among the completed HSA, in current line. While Equation (2) has the constraint that shuttles used are less than 12 sets, Equation (3) is that the usage of flow fixtures are less than 15 sets, Equation (4) is number waiting of shuttles before in to the Loading (P1) are less than 2 sets, Equation (5) is number waiting of shuttles before in to the Loading (P2) are less than 2 sets and Equation (6) is number waiting of flow fixtures before getting into the Unloading (P4) are less than 3 sets. The results from the OptQuest from Arena, as shown in Figure 11-12.

Best Solutions   Optimal solution found.

Sele	Simulation	Objective Value	Status	Number_Flow Fixtur	Number_Shuttle
☐	89	4657.400000	Infeasibl	13	10
☐	90	4656.700000	Infeasibl	13	11
☐	91	2437.900000	Feasible	3	2
☐	92	1316.000000	Feasible	3	1
☐	93	3830.600000	Feasible	4	10
☐	94	4653.500000	Infeasibl	15	8
☐	95	1936.300000	Feasible	2	2
☐	96	1942.900000	Feasible	2	7
☐	97	4658.300000	Infeasibl	14	9
☐	98	976.500000	Feasible	1	8
☐	99	4465.100000	Feasible	5	11
☐	100	1946.800000	Feasible	2	11
☐	101	2451.900000	Feasible	5	2
☐	102	3475.200000	Feasible	5	3
☐	103	4657.800000	Infeasibl	15	7
☑	104	4602.100000	Feasible	8	6
☐	105	4610.700000	Infeasibl	9	6
☐	106	4611.000000	Infeasibl	8	8
☐	107	4600.000000	Infeasibl	7	8
☐	108	2515.700000	Infeasibl	13	2
☐	109	4629.800000	Infeasibl	8	12
☐	110	2486.800000	Infeasibl	9	2
☐	111	4625.000000	Infeasibl	11	7

Figure 11: The results from the OptQuest of the current line

Optimization   Completed Optimal solution found.

Total simulations: 180

Maximize	Objective Value	Status
Best Value	4602.100000	Feasible
Current Value		

Best Simulation 104

Control Name	Best Value	Current Value
Number_Flow Fixture	8	
Number_Shuttle	6	

Constraint Name	Type	Status
Constraint1	Linear	Feasible
Constraint2	Linear	Feasible
Constraint3	Non Linear	Feasible
Constraint4	Non Linear	Feasible
Constraint5	Non Linear	Feasible

Figure 12: Optimization result of current line

2. Calculating the optimization of shuttles in the HSA assembling for the semi-auto line according to the objective function and constraints can be shown in the Equation (8)-(10):

Objective function:

$$Maximize\ Number\ Out \qquad (7)$$

Subject to:

$$Number\ Shuttle <= 55 \qquad (8)$$

$$Wait\ for\ Loading <= 2 \qquad (9)$$

The Equation (7) is the objective function to maximize among the completed HSA in semi-auto line. While Equation (8) has the constraint that the amount of shuttles is less than 55 sets and Equation (9) is the number of waiting shuttles before getting into the Loading are less than 2 sets. The results as shown in Figure 13-14.

Best Solutions   Optimal solution found.

Sele	Simulation	Objective Value	Status	Number_Shuttle
☐	26	6576.500000	Infeasib	34
☐	27	4146.400000	Feasible	8
☐	28	6570.200000	Infeasib	44
☐	29	6563.200000	Feasible	25
☐	30	6571.500000	Feasible	33
☐	31	6554.500000	Feasible	17
☐	32	6563.500000	Feasible	24
☐	33	6559.400000	Feasible	18
☐	34	6578.000000	Infeasib	37
☑	35	6576.000000	Feasible	31
☐	36	6572.300000	Feasible	32
☐	37	6574.900000	Infeasib	39
☐	38	6561.400000	Infeasib	53
☐	39	3633.300000	Feasible	7
☐	40	6564.600000	Feasible	22
☐	41	6558.700000	Feasible	21
☐	42	6567.400000	Infeasib	46
☐	43	5166.700000	Feasible	10
☐	44	6568.400000	Infeasib	42
☐	45	6561.800000	Infeasib	48
☐	46	5646.300000	Feasible	11
☐	47	6574.600000	Infeasib	35
☐	48	6561.900000	Infeasib	54

Figure 13: The results from the OptQuest of the semi-auto line

Optimization   Completed Optimal solution found.

Total simulations: 55

Maximize	Objective Value	Status
Best Value	6576.000000	Feasible
Current Value		

Best Simulation 35

Control Name	Best Value	Current Value
Number_Shuttle	31	

Constraint Name	Type	Status
Constraint1	Linear	Feasible
Constraint2	Non Linear	Feasible

Figure 14: Optimization result of current line

In conclusion, finding the optimized amount of shuttles and flow fixtures required, as shown in Table 4.

Table 4: Optimization result summary

HSA assembling process	Optimization result		Average of production rate (UPH)
	Shuttles	Flow fixtures	
Current line	6	8	200.35
Semi-auto line	31	-	289.69

In Table 4, it explains that the current line has the optimal amount of 6 shuttles and 8 flow fixtures and average in a production rate of 200.35 UPH. The semi-auto line has the optimal amount of 30 shuttles and average in a production rate of 289.69 UPH.

4 Results

4.1 *Simulation results*

HSA assembling process is the terminating system which does not have warm-up period. By the simulation length at 24 hours or working times a day and 8 replications. The result of simulation model is shown in Table 5.

Table 5: The simulation result

HSA assembling process	Optimization result (Shuttles and Flow fixtures)	Average of production rate (UPH)	Takt time (Sec)	Operator (person)
Current line	6 Shuttles and 8 Flow fixtures	200.35	18.58	10
Semi-auto line	31 Shuttles	289.69	12.99	7
Percentage (%)	-	44.59	30.09	30.0

In Table 5, it can be explained, as following:

1. Current line has the optimal amount of 6 shuttles and 8 flow fixtures, average in a production rate of 200.35 UPH, Takt time at 18.58 second and usage of 10 operators.
2. Semi-auto line has the optimal amount of 30 shuttles, average in a production rate of 289.69 UPH, Takt time at 12.99 second and usage of 7 operators. Regarding the average of production rate, Takt times and number of operator in the semi-auto line are better than the current line because the average of production rate is on target.

4.2 *Sensitivity analysis result*

The simulation results in Table 6 of the appendix can be analyzed in order to define the relationship of throughput, yield and downtime by using the Multiple Linear Regression (MLR). The result of this step can be created the forecasting model, which can be formulated in equation (10).

$$\text{Throughput (UPD)} = 369.16 + 65.91 \times \text{Yield (\%)} - 37.16 \times \text{Downtime (\%)} \qquad (10)$$

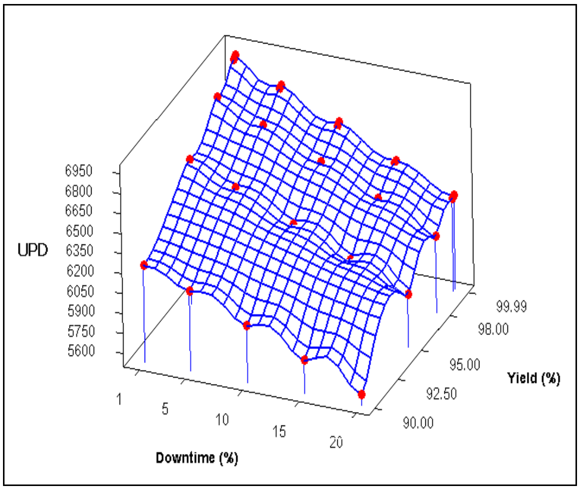

Figure 15: Reposes surface

In Figure 15, the response surface can be described the yield at 99.99 % and downtime of machine 1 %, which it has been occurred the unit per day (UPD) at 6,934.30.This value is the maximum throughput of the semi-auto line. If we want to forecast the throughput of other yield and downtime, we can apply the equation (10) for calculating.

5 Conclusions and Recommendations

5.1 *Conclusions*

In this case study of the HSA assembling process whereby we apply simulation technique, we can conclude that. When the current line and semi-auto line are compared, it is found that the semi-auto line has an average production rate increased of 44.59 %, Takt time is decreased by 30.09 % and the operators is decreased by 30.00 %. The aim of this case study shows that we can achieve the target.

5.2 *Advantages* and *Disadvantages*

1. The advantage of this research is to support for feasibility study in order to improve the HSA assembling process. Moreover, it can determine the optimal amount of the shuttles and flow fixtures by using the OptQuest in Arena. The optimal amount of fixtures affect to the increasing of the average of production rate and to reduce the cost of fixture.
2. For disadvantage, creating of the simulation models, the designer should clearly know about simulation software and statistical knowledge in order to analyze the results from the simulation models accurately.

5.3 *Limitation of research*

The limitation of this paper is to calculate the optimization of the shuttles and the flow fixtures in the current line and semi-auto line that have not considered the investment cost of fixtures. The cycle times data of semi-auto line is approximated by designer which depends on the experience, therefore if the inputs data are inaccurate, it cannot generate accurate results, however the error of results can be corrected by the operator.

5.4 *Recommendations*

1. This case can be further studied to analyze the sensitivity by studying factors that affect the production rate by calculating the breakeven point and the payback period, for analyzing whether to invest in the improvement of the HSA assembling process.
2. The result of case study has been simulated in the simulation model so the HSA assembling process in semi-auto line is created completely. The researchers should take the real data in order to reanalyze by using the simulation technique.

6 Acknowledgments

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7 References

[1] Adulbadee M. and Chutima P., 2009. Application of Theory of Constraints for The Improvement of Planning Process of Integrated Circuit Manufacturing. *Proceedings of the 7th PSU Engineering Conference*, Songkhla, Thailand.

[2] Glover F., Kelly J.P. and Laguna M., 1996. New Advances and Applications of Combining Simulation and Optimization. *Proceedings of the 1996 Winter Simulation Conference*, J.M. Charnes D.J. Morrice D.T. Brunner and J.J. Swain, 144-152.

[3] Kanchanasuntorn K., 2007. Simulation - Optimisation Technique. *University of the Thai Chamber of Commerce Journal*, 27(1), January-April.

[4] Kelton W.D., Sadowski R.P. and Sturrock D.T., 2010. *Simulation with ARENA*, 5th Edition, McGraw-Hill, New York, USA.

[5] Korking Y., 2007. Virtual Reality Modeling for Construction Management. *Proceedings of the National Civil Engineering Conference 12th*, Phitsanuloke, Thailand.

[6] Pisuchpen R., 2008. *Arena Simulation*. Se-education, Bangkok, Thailand.

[7] Rockwell Software., 2004. *Arena 3DPLAYER User’s Guide*. Rockwell Software Inc, USA.

[8] Rockwell Software., 2006. *OptQuest for Arena User’s Guide*. Rockwell Software Inc, USA.

[9] Seppanen M.S., 2005. Operator-paced assembly line simulation. *Proceedings of the 2005 Winter Simulation Conference*, 1343-1349.

[10] Sretip S., Sirivongpaisal N. and Suthummanon S., 2010. Reducing the number of tooling in Head Stack Assembly process using computer simulation. *Proceedings of the 8th PSU Engineering Conference*, Songkhla, Thailand.

Appendix

The results from simulation in each scenario are analyzed the sensitivity which it can be shown in the Table 6. In analysis, the researchers define 31 shuttles which it is optimal.

Table 6: Simulation results for sensitivity analysis

Scenario	Yield (%)	Downtime (%)	Defect (UPD)	Throughput (UPD)
1	90.00	1	705.60	6,232.10
2	90.00	5	677.80	6,109.10
3	90.00	10	660.90	5,930.50
4	90.00	15	645.60	5,754.60
5	90.00	20	622.30	5,581.40
6	95.00	1	349.20	6,588.30
7	95.00	5	339.70	6,445.50
8	95.00	10	326.30	6,257.00
9	95.00	15	327.50	6,076.60
10	95.00	20	308.10	5,899.60
11	98.00	1	143.40	6,794.40
12	98.00	5	133.60	6,651.20
13	98.00	10	131.90	6,459.40
14	98.00	15	126.00	6,271.00
15	98.00	20	124.50	6,076.30
16	99.80	1	12.30	6,923.50
17	99.80	5	13.10	6,769.70
18	99.80	10	12.50	6,576.00
19	99.80	15	12.10	6,379.50
20	99.80	20	12.80	6,197.70
21	99.99*	1*	0.80	6,934.50*
22	99.99	5	1.00	6,782.70
23	99.99	10	0.70	6,586.60
24	99.99	15	0.50	6,385.40
25	99.99	20	0.60	6,204.40

Remark: * The maximum throughput of the semi-auto line