LINE BALANCING ANALYSIS OF TUNER PRODUCT MANUFACTURING

HAERYIP SIHOMBING

Universiti Teknikal Malaysia Melaka
Melaka, Durian Tunggal 76100, Malaysia
iphaery@utem.edu.my

KANNAN RASSIAH

Politeknik Merlimau Melaka
Melaka, Merlimau 77300, Malaysia
kannan@pmm.edu.my

PARAHSAKTHI CHIDAMBARAM

Politeknik Premier Johor Bahru
Johor Bahru, Pasir Gudang 81700 , Malaysia
parahsak@yahoo.com

Abstract:
The processing time and the number of operators have strong relationship with the productivity of production lines. In the tuner production line, three significant factors related to productivity through using of line balancing method are the number of operator, production tools/equipment, and production process. This study performed the line balancing method through simulation model in order to reduce the line unbalancing causes and relocate the workforce associated to idle time, eliminating the bottleneck, and at the same time maintaining/ improving the productivity. To analyze the production line, we use a develop simulation tool, called Fact-Model, to modeling the production line (with the graph of critical path network and working time) and the works estimated (related to the cycle time, takt time, non-value added activities, quantity, and cost). Fact-Model is facilitated with the features that enable the user to depict the real production flows by using their owned real pictures/photos taken into their simulation model.

Keywords: Line Balancing; Productivity; Fact-Model.

1. Introduction

Line balancing is the problem that related to how the operations designated on the workstations can be optimized through balancing the activities assigned over the workstations (Falkenauaer, 2000). This is due to line balancing as a flow-oriented production system in the operations of an assembly line (to which the work pieces visit the workstation successively) need to use of available cycle time as efficiently as possible, as well as the allocated of resources in effectively (Håkansson *et al.,* 2008; Boysen *et al.,* 2008).

First, to optimize the operations in production line for a given number of workstations towards the operators and machines, the strategy required is against how to optimize the line balancing by reducing the cycle time (Massod, 2006). Particularly, by reducing the cycle (takt) time through equalizing the loads on the workstations (Watanabe *et al.,*1995).

Second, due to the line balancing of assembly works among the workstation concerned to the allocating task and have to evenly-aligned as much as possible without violating any precedence flow and exceeding the cycle time, then the traditional method applied to mass assembly of manufactured items in the large-scale series production were becoming complicated task. Especially, to divide the set of tasks into smaller one and specific assigned of one operator or worker stationed as well as how they performed at each workstation (Becker and Scholl, 2006). Against that reason, Baker *et al*., (1993) previously state that the key criteria design of the production process measurement that 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.

Third, in order to achieve the desired balance and to measure the effectiveness of resources, the capacities at different stations related to the number of workers and how to allocate the workers between the component stations and the assembly station, therefore need well – organized. Especially, towards the workstation in sequence where the specific production requirement was required, besides the abilities of each worker towards the jobs on designated workstations for high productivity, lower cycle time, and lower rejection rate (Stevenson, 2007).

Three reasons above that related to line balancing as productivity, the performance measure were therefore required based on the indication on how effective an assembly line performed based on the output and input. Especially, to the aspects of quality, efficiency, and effectiveness of production lines through the design of workstation, assembly process, equipment, and the number of operators as well as the skill of workers.

2. Simulation for Productivity

This study discusses the production line to manufacture the tuner component with line balancing requirements. Since the productivity is related to the input and output, this study therefore focuses on the input and factors or variables that influence the line balancing, such as the number of operators, equipment, and machines.

By using simulation approaches, this study examines the productivity in terms of input variable in the production line. While, in order to determine the working time consumed for completing one process of product manufactured, the cycle times has to be taken at every process related. In addition, the quantity or volume of production in a certain period can be determined (Figure 1 and Figure 2).

Moreover, a compiled standard operation chart is used to analyze the non-value added at the particular process. In this sense, the efficiency and line balancing ratio are calculated to determine the line balancing and the output of the production line will be decided.

3. Data and Results

3.1 Cycle Time

In order to analyze the line balancing and work-study of the tuner production line, 20 times of cycle time measurement were collected and taken per each workstation. This was merely for getting the average cycle time, since different operators were involved in the production line. Figure 3 shows the flow process of the tuner production, while the cycle times taken to determine each of the 11 workstations quantity or volume assumed per shift are described in Table 1.

To ensure that the cycle time limit is appropriate to the production volume assigned, the takt time can be determined by calculating the demand of the product versus the working hours in the normal production capacity condition, that is 1905/shift and 7.5 hours respectively. To calculate the takt time, the formula is as follow:

$$T = \frac{Ta}{Td}$$

Where,

T = **T**akt time

T_a = Net **T**ime **a**vailable to work

T_d = **T**ime **d**emand (customer demand).

In Table 1 shows that each of the three (3) operators were involved in Hand-Mount and UV workstation processes respectively, while the total cycle time was 105.10sec. Figure 4 shows that Cover B has the highest cycle time, that is 14.32sec. Since the takt time is 14.17sec, this means that Cover B workstation is exceeding 0.15sec against the takt time. Therefore, in order to make the lines production in balance and at the same time also reduce the cycle time, the compiled standard operation chart is used to identify and remove the non-value added activities.

Furthermore, in order to examine the balancing level, then the calculation for the ratio and efficiency of line balancing is as follows:

- Line Balancing Ratio $= \dfrac{Total\ Cycle\ Time}{No.of\ Workstation\ X\ Longest\ Operation} = \dfrac{105.10\ sec}{11\ X\ 14.32\ sec}$ X 100% = 67%

- Line Balancing Efficiency = $\frac{\textit{Total Cycle Time}}{\textit{Manpower X Takt Time}} = \frac{105.10 \text{ sec}}{13 \text{ X } 14.17 \text{ sec}} \text{ X } 100\ \% = 57\%$

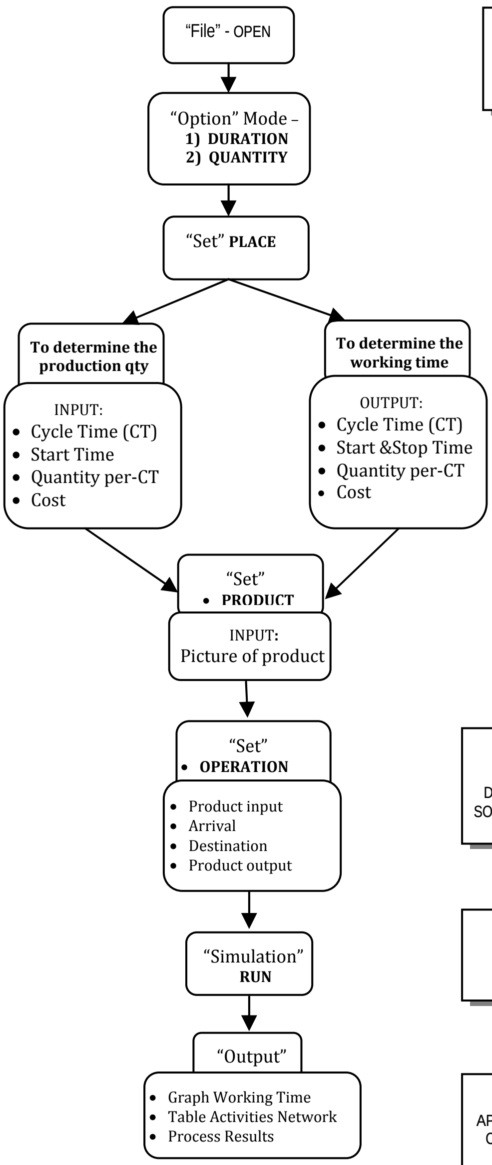


Figure 1: Simulation Tool-Fact Model
(see in Appendix about the result)

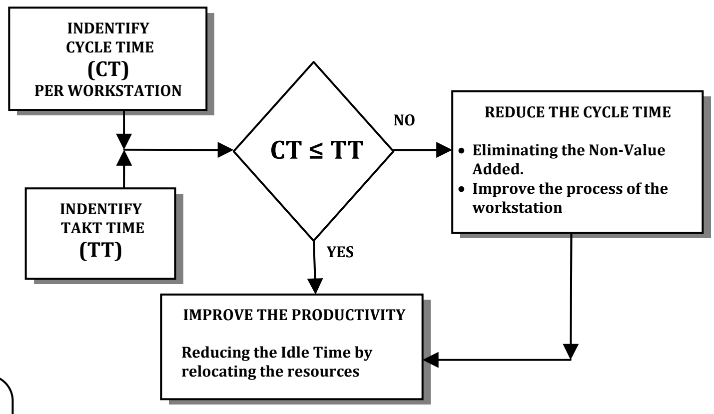


Figure 2: Simulation Model

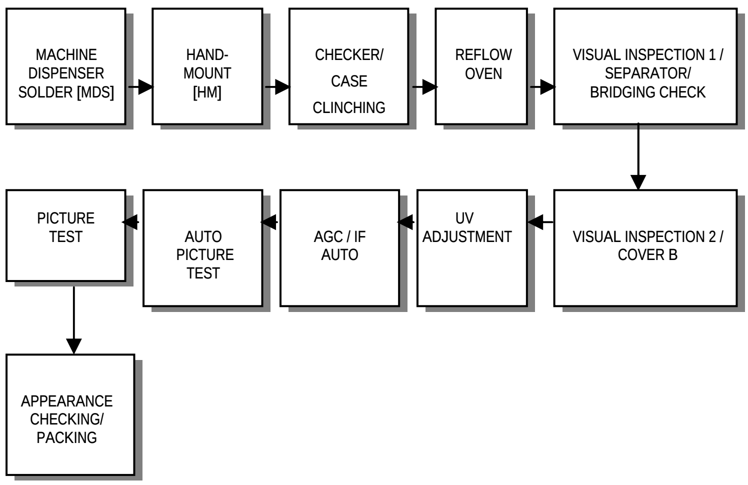


Figure 3: Tuner Production Flows
(see in Appendix: "Process Flow Diagram" for real picture/photo of production flow and "Path Network Diagram" for critical path network using Fact-Model)

Table 1: Process vs. Cycle Time and Quantity

NO.	PROCES	ACTIVITIES/ FUNCTION	OPERATOR	CYCLE TIME (Average)		Assumption of Quantity produced Working Time / Cycle Time
1	**Machine Dispenser Solder (MDS)**	This machine performs the printing of solder on the Printed Wiring Board (PWB), where operator will mount coils and other related parts on the board. This MDS machine will sweep liquid solder on the board by using panel plat which is especially created for each different tuners model	1	6.34		4259
2	**Handmount Station**	Every flows of PWB from MDS will proceed to Handmount station for mounting coil and other electronic components. In this section, operators need to mount the parts on the board according to the specification.	1	*15.59*	5.33	5066
			1	*16.01*		
			1	*16.39*		
3	**Clinching**	The operator in this station has to check if the mounted items are correctly attached according to the specification. Their jobs are to detect and avoid any missed mounted, no mount, and reverse polarity of component. They also install the casing in order to separate PWB into smaller pieces.	1	3.30		8182
4	**Reflow Oven**	This machine is functioned to dry off the solder at PWB after the processes of Handmount and checker are performed. This oven has 5 parts which each of them had their level of warmth; the level of warmth has to set according to suitability of the temperatures bearable by components on PWB	0	12.00		2250
5	**Visual Inspection I / Separator/ Bridging check**	To ensure there are no defectives such as loose soldering, solder bridge, solder ball & spike, and no solder, the operator has to re-check the quality of tuner product. This division is very important to ensure the quality of soldering.	1	12.22		2210
6	**Visual Inspection II / Cover B**	In this station, the operator has to install the cover or casing on the mount side by pushing 2 buttons simultaneously. The jig used in this process is pneumatic mechanism.	1	14.32		1885
7	**UV Adjustment**	In this station, the operator has to setting the frequency of VL, VH and VHL for each tuner according to the recommended specification. The method of this adjustment is using UV jig to move the coil adjustment and control instrument in order to ease operator to read, recognize the graph and calculate for the value on the screen.	1	*22.7*	7.71	3502
			1	*23.39*		
			1	*23.30*		
8	**AGC / IF AUTO**	In this station, IF auto jig (Intermediate Frequency Auto Checker) will identify the AFT (Auto Frequency Tuning) justification and AGC (Auto Gain Control) recommended justification	1	8.50		8.50
9	**Auto Picture test**	In this process, the operator has to insert the product to Auto Picture Test Jig and then pass to picture test in order to examine whether the display and sound is in good condition or not. The picture produced can be examined by watching the on the television display in front of the operator.	0	10.61		2545
10	**Picture test**		1	13.42		2012
11	**Appearance Check/ Packing**	Finally, the operator has to arrange the completed tuner product into the carton. In order to avoid the mixing products with actual production planning, the operator also needs to count the amount of the tuner by using provided stick wood.	1	11.35		2379
		TOTAL	13	105.10		

3.2 Working Time Analysis

Due to the normal working time per shift is 9 hours and the rest time designated is 1.5 hours, it consequently means that the effective working time is 7.5 hours. In addition, the actual tuner product demand is 1905 parts per shift and the operators are having 7.5 hours in order to finish the product based on the demand or product volume designated. However, the company is normally setting the actual production output assumed to the demand, that is 2000 parts per shift, in order to the backup against the reject and scrap about 5%.

Table 2 shows the actual working time, while the completion time required by operator at each workstation to complete the task is shown in Table 3. According to the working time graph (Figure 5), there is idle time exhibited at certain workstations due to its working time finishing earlier. In order to eliminate and avoid the idle time, then the operators who can settle their tasks earlier will therefore be replaced or relocated to other workstations.

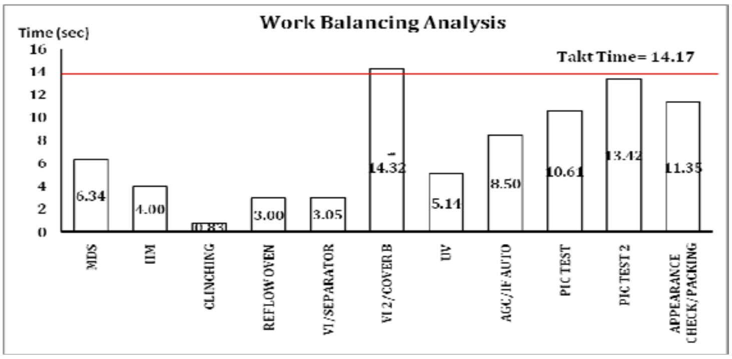


Figure 4: Cycle Time Graph of Tuner Production Line

Table 2: Working Time

WORKING HOUR	REST TIME
6.15am~8.15am	8.16am~8~30am (15 minutes)
8.31am~11.15am	11.16am~11.30am (15 minutes)
11.31pm~1.00pm	1.01pm~2.00pm (1Hour)
2.01pm~3.16pm	3.16pm (End working hour)

There is only the process of Cover B, which completed the product exceeding the working time (15.15pm) that is at 15.42 pm. It seems that the operators need to take the over time in order to meet the target designated in which can cause the cost to be increased. Therefore, the strategy required to overcome the facts are as follows:

1. To find solutions in order to avoid the overtime through the analysis to the higher cycle time whether non-value added activity existed. Here, the Compiled Standard Operation Chart is used in order to analyze every step of the processes from start to finish, there were “mark” and “put to conveyor” as non-value added that will be removed (Figure 6).
   a) Reduce the cycle time by changing the way to mark the product from writing a letter or number as mark to just simply mark by dot. Different operators can use different colours of marker pens to mark (doing dots). Hence, the cycle time will be reduced to 0.2sec.
   b) Reduce the cycle time by reducing the height of the conveyor stand from 103mm to 94mm. Here, the activity of operators to load the tuner product on the conveyor is reduced to 0.4sec. As consequences, the cycle time of Cover B workstation can be reduced to 13.72sec.

2. For the Handmount (HM) process, the current operators used are three (3) operators, whereas the Clinching process is only one (1) operator. On the other hand, at UV process there were three (3) operators designated. Therefore, by relocating and removing the operators from the current workstation to another workstation, it can eliminate 3 operators simultaneously. Figure 7 and Figure 8 showed the scenario to illustrate the relocating activities.
   a) The operator at clinching process and another 2 operators at UV process can be reduced. Those operators who had been removed from their tasks after completing their task will then replace the operators for HM process. Here, while HM are doing their tasks until the end, clinching process has not started the process yet because the products had still not arrived at clinching workstation. After HM operators had finished their tasks within 3.5 hours, which is until 10.00pm, one of them will be allocated to the clinching workstation and another 2 of them will be moved to the UV process. After 1.50 hours (which is until 12.05pm) clinching operator will finish his task and will be moved to the UV process so that in UV process there will be 4 operators and they will finish at 14.07pm.

b) The idle time, waiting time, and bottleneck will occur if HM immediately do their tasks while clinching did not execute their tasks due to the clinching operator being eliminated and replaced by the HM operator after their completed HM tasks. To avoid such situation, HM and Clinching therefore must work a day before to produce the inventory in order to make the production line run smoothly.

Table 3: Process Time

Process	No Operator	Cycle Time	Completion Time *(hour)*	Process Time	Hour	Minute	Clock	Clock *(Include Rest)*	Assume Demand
MDS	1	6.34	3.5	3.3	3	30	9.45 [am]	10.00 [am]	2000
H/M	3	5.33	2.96	2.58	2	57.6	9.13 [am]	9.28 [am]	2000
Clinching	1	3.3	1.83	1.5	1	49.8	8.05 [am]	8.05 [am]	2000
R/Oven	0	12	6.67	6.4	6	40.2	12.55 [pm]	14.25 [pm]	2000
Separator	1	12.22	6.78	6.47	6	46.8	13.02 [pm]	14.32 [pm]	2000
Cover B	1	14.32	7.95	7.57	7	57	14.12 [pm]	15.42 [pm]	2000
UV	3	7.71	4.3	4.18	4	18	10.48 [pm]	10.48 [pm]	2000
AGC	1	8.5	4.72	4.43	4	43.2	10.58 [pm]	11.13 [pm]	2000
Auto Picture Test	0	10.61	5.89	5.53	5	53.4	12.08 [pm]	12.38 [pm]	2000
Picture Test	1	13.42	7.45	7.27	7	27	13.42 [pm]	15.12 [pm]	2000
Packing	1	11.35	6.3	6.18	6	18	12.33 [pm]	14.03 [pm]	2000
Total	**13**	**105.1**	**58.35**						

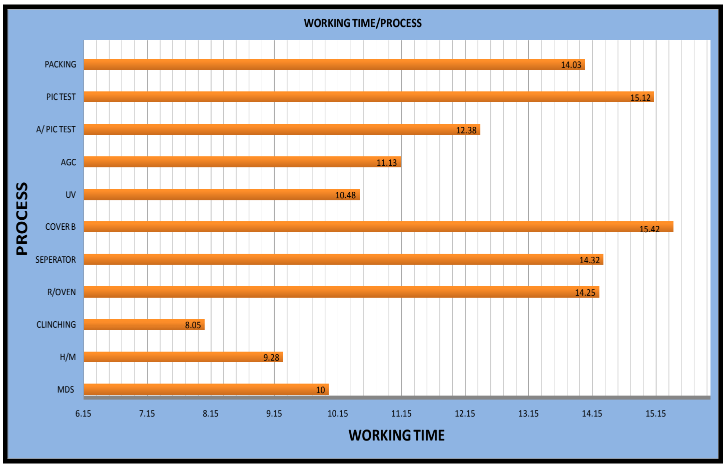


Figure 5: Graph of Working Time (before improvement)

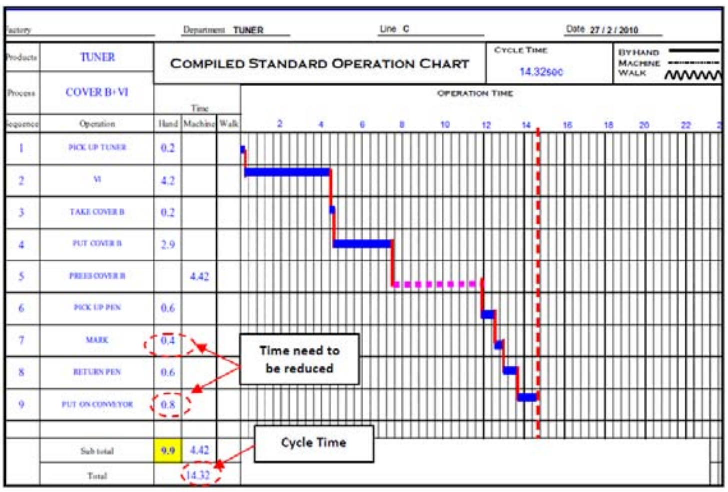


Figure 6: Compile Standard Operation Chart of Cover B

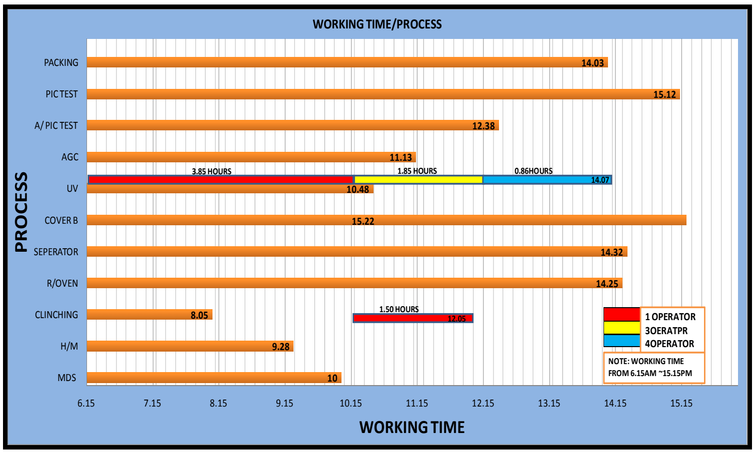


Figure 7: Graph of New working time

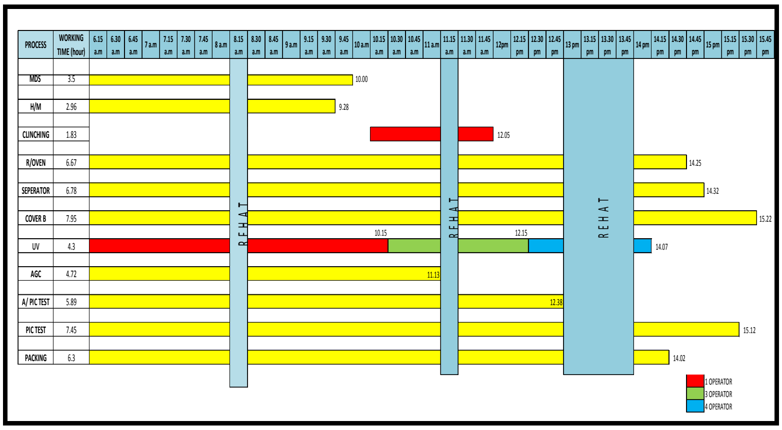


Figure 8: Graph of New Working Time Including Rest Time (After Improvement)

4. Conclusion

In this study, the problem regarding line unbalancing situation in the tuner production are solved by removing the non-value added at Cover B workstation. In addition, the total number of operators also can be reduced from 13 to 10 persons by relocating the manpower of UV and Clinching workstation. This amounts to an increase of manpower productivity by about 25%. By such improvement, the line balancing ratio is increased from 67% to 69%, while the efficiency is increased to about 17%, from 57% to 74%.

Since the increment of productivity considered in this study is in terms of the output (by performing the reduction of the total worker numbers and the cycle times, while at the same time the outputs maintained), there are actually some of other improvement aspects still required to carry out for productivity activities in the turner production line. Therefore, the further study towards the issues in the tuner production line (such as quality product, layout design, and ergonomic) should be taken into account to increase the tuner production productivity. This is due to the quality product resulted of each workstation, layout design, and ergonomic factors are also related to production line balancing.

Acknowledgment

Fact-Model is a simulation tool created by Haeryip Sihombing and Habbibullah Akbar. The authors would like to thank CRIM-UTeM. This project is supported by CRIM through PJP /2010/FKP (5A) S663.

References

[1] Falkenauer , E. (2000): Line Balancing in the Real World. Proceedings of the International Conference on Product Lifecycle Management PLM´05, 360 – 370

[2] Håkansson, J.; Skoog, E.; Eriksson, K. (2008): A Review of Assembly Line Balancing and Sequencing including Line Layouts. Proceedings of PLANs forsknings- och tillämpningskonferens, Chalmers Technical University, Gothenburg, Sweden

[3] Boysen, N.; Fliedner, M.; Scholl, A. (2008) : Assembly Line Balancing: Which Model to Use When? Int. J. Production Economics, **111**,pp. 509–528

[4] Masood, S. (2006): Line Balancing and Simulation of an Automated Production Transfer Line. Assembly Automation, **26(**1), pp. 69-74.

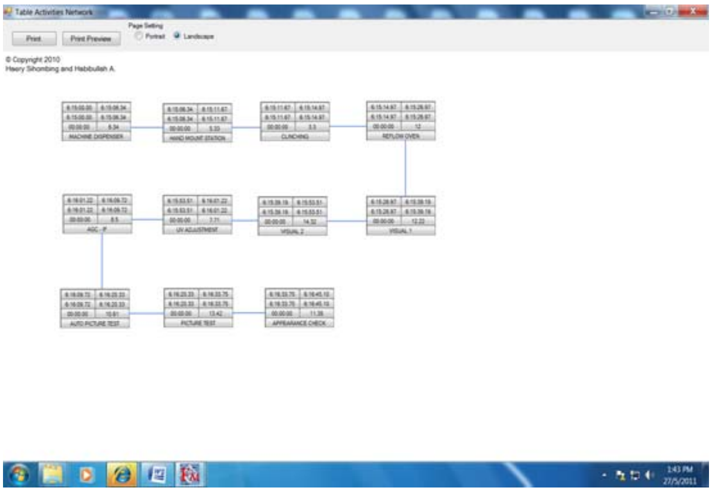
[5] Watanabe, T.; Hashimoto, Y.; Nishikawa, I.; Tokumaru, H. (1995): Line Balancing Using A Genetic Evolution Model, Control Eng. Practice, **3**(1), pp. 69-765

[6] Becker, C.; Scholl, A. (2006): A Survey on Problems and Methods in Generalized Assembly Line Balancing. European Journal of Operational Research, **168**(3), pp.694-715.

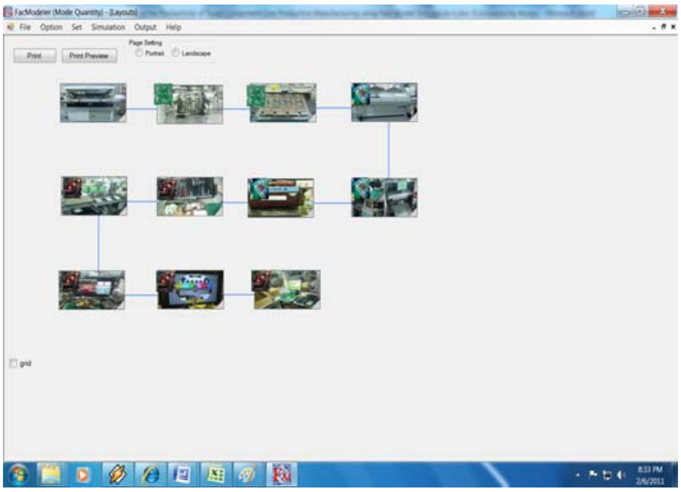
[7] Baker, K.R.; Powell, S.G.; Pyke D.K. (1993): Optimal Allocation in Assembly Systems. Management Science, **39**(1), pp.101-106

[8] Stevenson, W.J. (2007). *Operation Management*, 9th Edition, New York: McGraw-Hill, pp55.

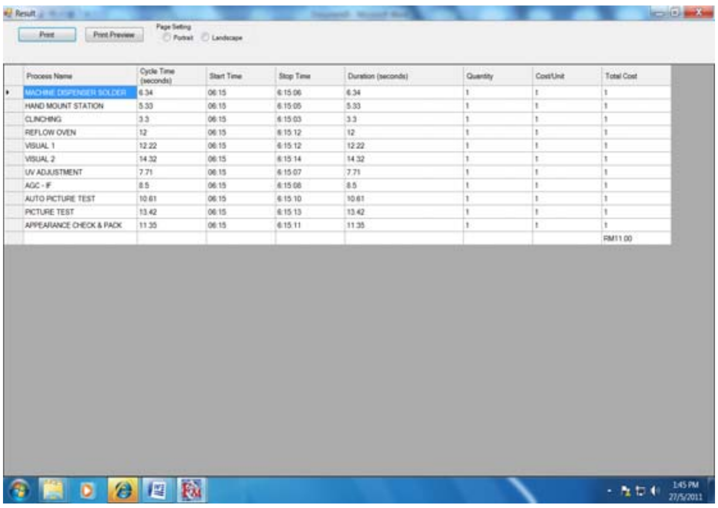
APPENDIX:



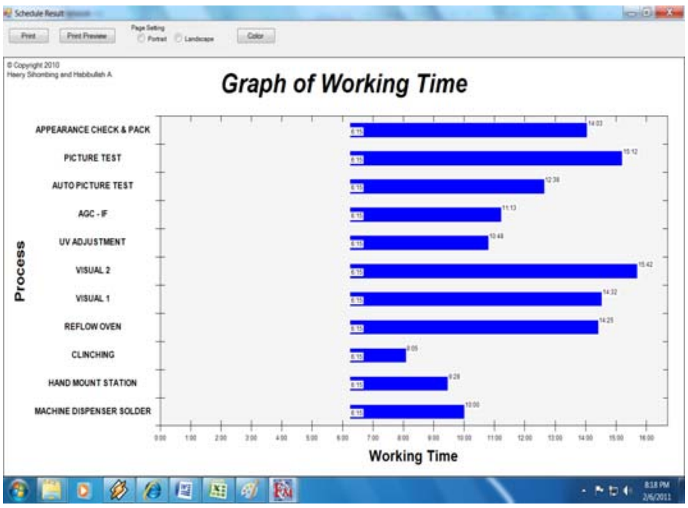
Path Network Diagram [Time]



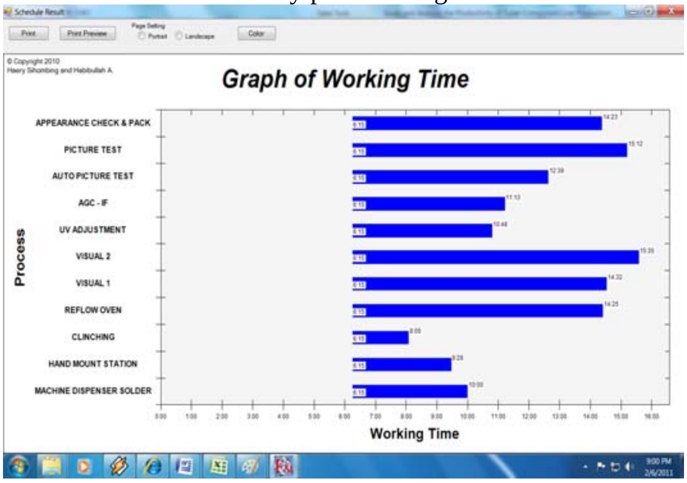
Process Flow Diagram [Simulation Run]



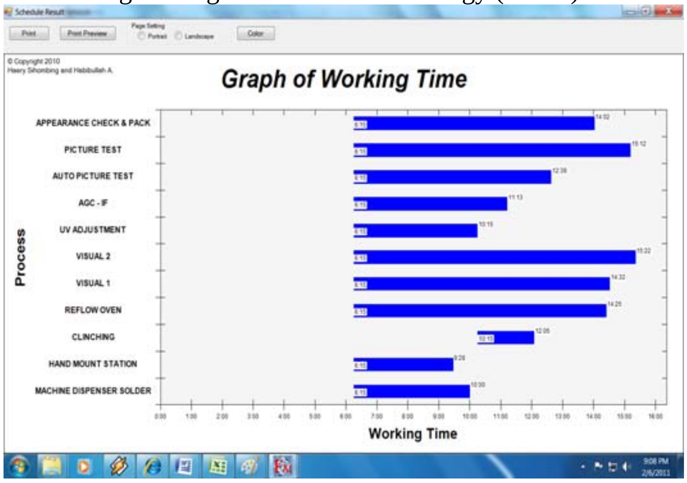
Total Cycle Time



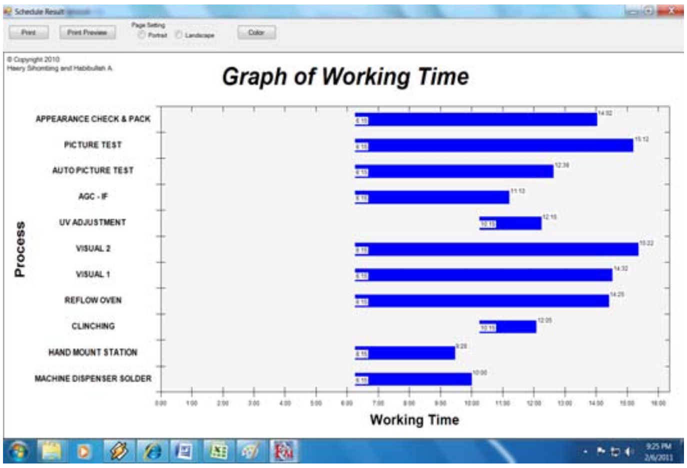
Working Hours [duration for 2000 pcs]



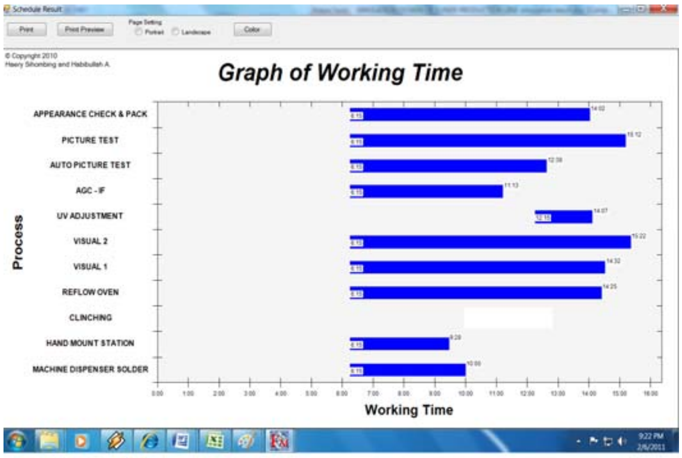
Working Hours w/ UV Cycle Time = 13.72
[duration for 2000 pcs]



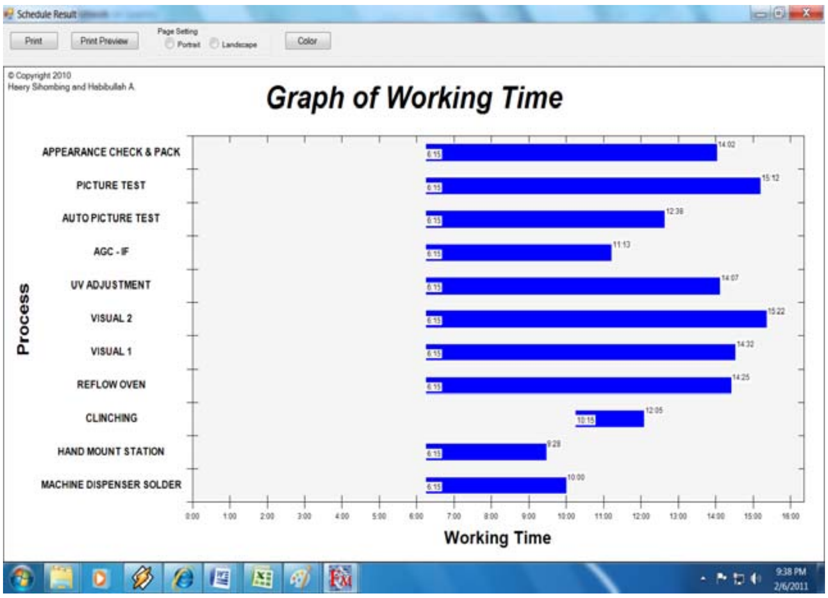
Working Hours with resources allocation
[1 operator in UV and Clinching workstation respectively][duration for 2000 pcs]



Working Hours with resources allocation
[3 operator in UV & 1 operator in Clinching workstation] [duration for 2000 pcs]



Working Hours with resources allocation
[4 operator in UV] [duration for 2000 pcs]



Working Hours with resources allocation [Final Improvement]