Optimization Of Assembly Line Of Printed Circuit Board Using Simulation

Kamal Alzameli, Daw R. Alwerfalli, Ahad Ali, Ahmed Alsamarai

ABSTRACT: The development of an assembly line would not stop at a specific research even if that research contains very detailed sectors of one assembly line, or starting from customer order to product delivery. Therefore, continuous improvement needs to be vigorous for continuous productivity improvement and innovation. The optimization process of printed circuit board assembly line includes hard and soft optimization. The hard optimization includes hardware changes via design, and the soft optimization is figured via simulation of the current assembly line and analysis. The aim of the research is to determine the bottlenecks, find a solution, and develop improvement method via changing the configuration of the setup on the assembly line until the feasible optimal configuration is definite. The software that will be used for this simulation is Arena software. The data of the research is collected from real assembly line. The best engineering assumption for the area is used for no permanent data that could be available such as the data that might be collected from the manual stations. In addition to the aim of the research is to get a better yield via improving the time of the PCB assembly process. Hence, the outcome to all of these attempts of optimizing the assembly line of PCB for continuous improvement is to deliver good quality products, reduce cost, and minimize the time to delivery and meet the customer expectations.

Key words: printed circuit board, simulation, PCB, Optimization, enhance assembly line

1 INTRODUCTION

Electronic components are found in various devices of people's lives such as laptop, auto sensor light, phone, television, radio, cars, robots, laser, GPS, Aero planes , vehicle, school, street, office…etc. The concerns with PCB manufacturing start from customer order where sometimes no particular order is placed (no requirements). Another PCB company's problem is customer order conflict which leads to a delay of the deliverable date; thus, production planning is required. In addition, the assembly line and production process time are also considered part of the PCB Company's problems. One of the problems that causes delay is when there are several stations; each station has the same worker placing different components on the PCB. For an electronic company to maintain in the market with other competitive companies, the company must persist in enhancing their manufacturing process to obtain high quality products with less budget. In addition, in order to have an accurate optimization plan, the time of the process on the real assembly line of the manufacturing needs to be known for each machine on the line.

- *Kamal Alzameli DEMS student-Doctor of Engineering in Manufacturing Systems, Design and Release multimedia system engineer, Research and vehicle technology, Ford Motor Company*
- *Dr. Daw R. Alwerfalli Professor, Lawrence Technological University, A. Leon Linton Department of Mechanical Engineering. 21000 West Ten Mile Road, Engineering Building, Southfield, MI 48075*
- *Dr. Ahad Ali Associate Professor, Lawrence Technological University, A. Leon Linton Department of Mechanical Engineering. 21000 West Ten Mile Road, Engineering Building, Southfield, MI 48075*
- *Dr. Ahmed Alsamarai Senior Electrical Engineering, Product devolvement center, Ford Motor Company.*

In this paper, we will present a study of the assembly line of printed circuit board for one of the PCB manufacturing companies and determine the bottleneck of which machine takes more time and then obtain a solution that could be applied for any other PCB assembly line.

2 LITERATURE RVIEW

Mohamad and Chang [1, 2] have similar objectives of increasing the production line but have used different techniques to determine and solve the problems. Mohamad conducted a simulation study towards productivity improvement for assembly line. His study proposed assembly line improvement focused on a Material Handling Operator (MHO) solution as a process simulation method. Mohamad described the productivity of the ABC Company as an unsatisfactory and fails to achieve its target output because each workstation is managed by one workstation operator. Chang used simulation for PCB assembly plant to improve the production line, his objective was reducing the manufacturing cycle time and reducing work-In-process to increase the total output. Chang focused on simulation with data collection and building in addition to validation model then improve it on the factory floor. In the manufacturing process of hard disk drive, the final assembly process is an important section of the process. It is the last stage of the HDD production process. Ali and Souza [3] study the hard disk drive final assembly process using an HDD template. Yilmaz [4] studied the simulation of mixed-model PCB assembly lines with group setup and bypass conveyors. The main objective is balancing the workload in the first stage where component and placement operations for every PCB given to the machines in the assembly line. Kallio, Martin, and Gebus [5, 6, 7] studied discrete-event simulation from different perspectives and with different objectives. Kallio studied the process time of flexible surface mount placement machines and discrete-event simulation which are used to predict components placement time. Kallio used observation technique (camera or laser) to check each component position to make sure each one of them is placed on the right location then adjust placement machine if necessary. On the other hand, Martin studied how the discrete event simulation can be used to optimize the electronics assembly line and tried to avoid the worker experience and rely on the facts of the study. Of course he needs to match whatever results obtained and what workers are saying and compare these two. Martin used the simulation on other research because the simulation is cheaper and validation can be done without interrupting the real assembly line system. Arena software was selected for this study. Discrete-event simulation was also used by Greasley [8]. He accomplished a case study by using discrete event simulation for facility design, the reason for that was to estimate the storage area for the manufacturing facility and determine the work-in-process WIP. Johnson [9] and his teamwork studied a modeling decomposition method that is time saving scheme for the modeling process. Model decomposition is time saving because each subsystem can be established by different teams thus, expediting the modeling process. Nevertheless, Jadhav [10] studied analyzing printed circuit board assembly lines using a custom established PCB assembly template. Jadhav used Arena software to develop the simulation model. Also, Ilgin [11] and Gupta proposed a simulation optimization method. In contrast to Ilgin and Gupta use of the simulation model, Joseph [12] and Wigglesworth model and analyze new product development in electronic sub-assembly manufacturing.

3 PROBLEM STATEMENT AND STUDY OBJECTIVE

Local electronic manufacture company in Michigan as a small business of Printed Circuit Boards (PCB) assembly house is facing challenges such as waste, quality issues, long set-up times, and late delivery. These challenges represent the loss of over a million dollar per year. As a small business competing in a fierce global market, the company decided to investigate the sources of these challenges by conducting a thorough study using simulation techniques to identify these sources and eliminate them. The issues mentioned above could be in any stage of the manufacturing process such as job pre-setup, pick and place machine programming and scheduling, reflow oven profile, and manual workstations (through- hole assembly). In addition to that, the inspection process using the AOI (Automated Optical Inspection) and manual visual inspection has a major role regarding the quality of the products. The main objective of this research is to conduct a process mapping of the production floor in addition to identifying the current state of production of PCB assembly. To start assessing the effectiveness of the PCB assembly production process at the assembly line of the company, a thorough study of the assembly bottlenecks are to be investigated, Wastes such as Wasting Time, Over-Processing, Inventory (WIP), Excessive Motion, Scrap and Rework, Simulation techniques using ARENA utilized to optimize the assembly line by eliminating the non-value added activities and minimizing waste; ultimately increasing system output leads to reduced cycle time, and set-up time improving productivity, enhancing quality, delivery, customer satisfaction and profit margin. Also, develop Hypotheses tests that will show acceptance and rejection as validation. The PCB assembly line manufacturing process is shown on figure1 for this study.

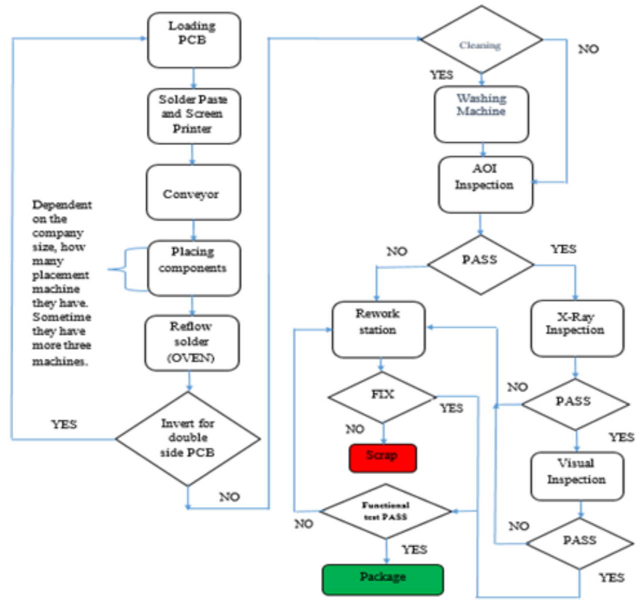

Fig 1: PCB assembly line manufacturing process

4 DATA COLLECTION

Data collection is one of the most challenges in this research or might be on a lot of other research due to the resistance of change from workers; workers like to remain doing what they use to do every day. Data collection has the most period in this research; it took about 13 months. The data collection starts from monitoring the PCB assembly first, then gathering data of each machine on the assembly line. Data collection included the following machines on the assembly line and workstation: SMT-Loading PCB, Solder paste and screen printer, Place components, De-penalization, potting, Reflow solder, washer machine, manual workstation 1-5. Data collection gathered from the Machine itself and by collecting data from each station manually by the employee.

5 MODELING AND SIMULATION

5.1 INITIAL RESULT AND DECISION

As result of the initial simulation there are serval stations that showed the number of waiting on the queue or instantaneous utilization as “correlated,” and after investigation we found out that the stations are manual which is why the average of wait are high. Noted that correlated means that there are sufficient data to trial for “uncorrelated” but the trial is unsuccessful. The cause of delay on manual stations is the same worker placing different components on the PCB for several stations. The second issue observed is the programing, it takes a lot of time; the most station that has this issue is the Oven and this is found because the thermal profile process is to control the period time and the temperature, in other words, the solder joints has to reach the time of the soldering temperature. Therefore, it is challenging to control the temperatures in different zones with specific time in each zone. The solder paste and components should be well-matched in the heating slope for each zone; the solder paste has different types and different manufacturer. Also, these variables (temperature in each zone and time in each zone) are interconnected and thus, a result in good quality in solder joint; this is by itself is separate approach and it will be discussed in different paper. The third observed issue is the time needed to perform the rework PCBs once the AOI found missing part or reverse polarity. The simulation for the entire PCB assembly line includes automated and manual stations are shown on figure 2.

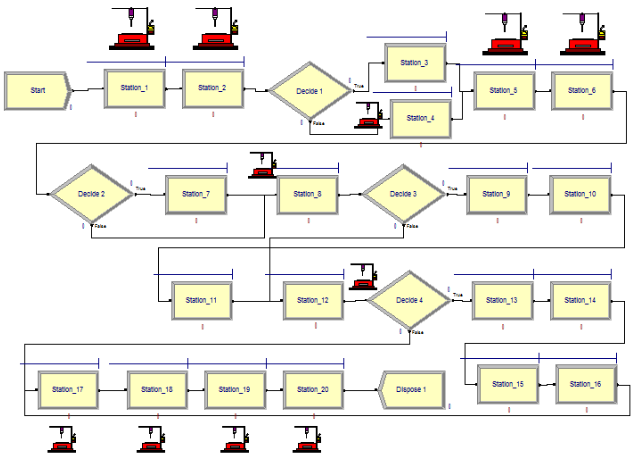

***Fig 2:** simulation PCB assembly line include automated and manual stations*

5.2 PROPOSE MODIFICATION

After getting the results from the simulation and determined several issues and discussed them with the expert local PCB Company, we have decided to propose the following items for process enhancement.

1- Organize the Cell operator to minimize the time on the manual work stations, the company needs to have the one employee doing the same thing and not placing several components on one station (with option of rotating the employee on different stations)
2- For the programing issues, there are main issues (as discussed in the initial results section) and general programing issues for the most of the assembly line stations; the propose solution for general programing issues, is perform offline training for the responsible employees on each station on the assembly line.
3- Perform separate research for oven where the thermal profile is the main programing issue and repeated serval times until the temperatures in different zones are controlled with specific time in each zone, so, the solder paste and components should be well-matched in the heating slope for each zone.
4- Another suggestion for rework PCBs after finding the issue on AOI is to split the AOI to two different stage as shown on figure 3 with circular around these two stations.
   A- One AOI after wash machine (which is usually most of PCB company do that)
   B- The second AOI set before the OVN. This is very important idea, especially for the prototype stage, why is important? It is important to check the following two possible occurring issues:
      - Missing parts.
      - Reverse polarity.

The advantage of checking these two items is quick AOI test and saves a lot of time if issue found on this stage, so machines need to stop and check the missing parts and or inverse polarity and rerun the machine. This method will prevent rework PCB if PCB already went through the OVN and wash machines then missing part or inverse polarity found on the AOI after the wash machine. In addition, after PCB go through the wash machine this means a lot of production was built which leads to a massive time to rework station. Moreover, preventing PCB to go through the rework station provide the company good quality; that is why it is important to perform quick check for these two items before the PCB go to OVN.

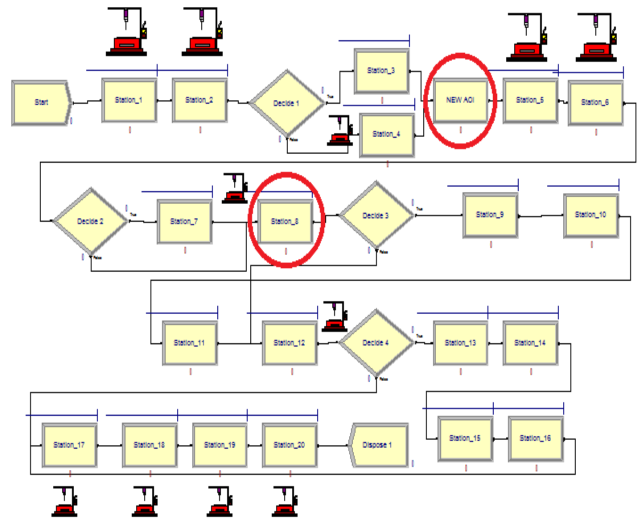

***Fig 3:** New AOI before the Oven machine*

6 STATISTICAL ANALYSES

Hypothesis test validation method involves results of the built model. Hypothesis test is the calculation of acceptability of specific declaration. The acceptability depends on the experimenter, so he/she might be concerned with certain fixed value of population mean. μ_0 is designated to fixed value and the statement will be called as null hypothesis. The simulation result expected to match the actual assembly line process, the difference between simulation and the actual process was 1.7% for the output. Comparison production included WIP, total output and Cycle time. (t_0: t-Test statistic, x: Mean that calculated was 3578.40; μ_0: the actual mean that assumed is 36000. S: standard deviation of the 10 values, which is 37.16 and n: 10. The consideration of the specified values of the Null Hypothesis with confidential interval CI 95% (α=0.05) for both side, and (α=0.025) for one side. The calculation for the hypothesis is done manually and verified by the Minitab software.

H_0: Null hypothesis
H_a: Alternative hypothesis

One side Hypothesis test

H_0: μ_0= 36000
H_a: μ_0 < 36000

First lets calculate the T value for one side; $t_{\frac{0.05}{2},10-1} = t_{0.025,9}$

= 2.262 (from T-table). Second, calculate the T- statistic $t_0 = \frac{3578.4 - 36000}{37.2/\sqrt{10}}$ = -18.69. (1)

Therefore if the $t_0 < -t$ value then H_0 will be rejected Is $-18.69 < -2.262$ (Yes). The Null (μ_0= 36000) will be rejected because the statistic value (-18.69) is outside accepted area (means the Alternative will be accepted μ_0 < 36000 as shown on Figure 4.

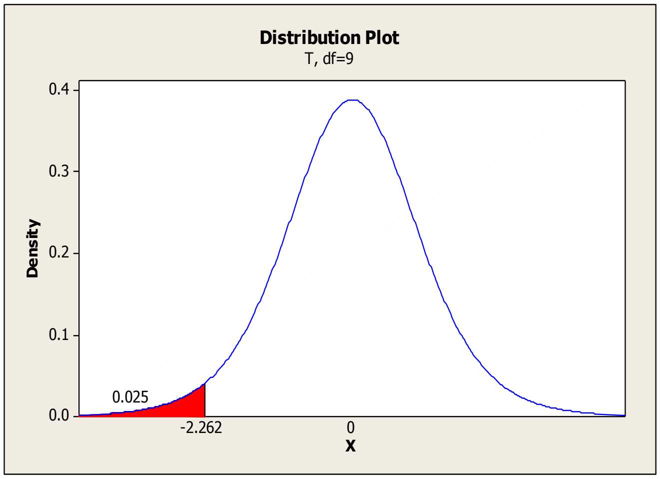

Fig 4: *Rejected region for the Hypothesis*

Two sided Hypothesis test
H_0: μ_0= 36000
H_a: $\mu_0 \neq$ 36000

First lets calculate the T value for both side; $t_{0.05,10-1} = t_{0.05,9}$ = 2.262 (from T-table). Second, calculate the T- statistic $t_0 = \frac{3578.4 - 36000}{37.2/\sqrt{10}}$ = -18.69. (2)

Therefore if the $|t_0| > t$ value then H_0 will be rejected $18.69 > 2.262$ (YES, The Null (μ_0= 36000) will be rejected because the statistic value (18.69) is in rejected area. Alternative HypothesisH_a: $\mu_0 \neq$ 36000 will be accepted as shown on Figure 5.

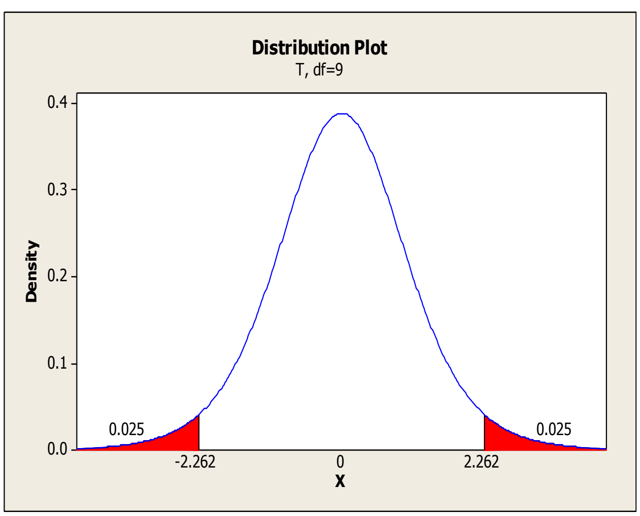

Fig 5: *Two sided Hypothesis test*

7 CONCLUSION

Studying productivity assembly line of PCB and analyzing via simulation saves cost, time, and provide better quality to meet customer expectation. Using the Arena simulation provides us system behavior and observation for what can be changed for productivity improvement and validate the model without distributing the PCB assembly line. Validation determines whether the current PCB yield is acceptable. In addition to the separate research that will be done for the Oven thermal profile, there was a current time improvement of 11.36% from adding additional AOI prior to the oven and other proposed ideas listed above (the first production run 1635 PCBs that needs rework). Also, product will efficacy quality since the PCBs will be delivering to the customer from the production line and annual cost save at the minimum level (assuming the missing part or reverse polarity happened only once week) is $145,352 included the employee's salary and machine down cost. Also, assuming that we capture the failure from the first PCB on AOI, but if the failure caught after a while and the stock has a lot of PCBs need to be fix then cost save could be go over $200k a year.

ACKNOWLEDGMENT

I would like to express my sincere appreciation to my committee members and special thanks for Dr. Daw R. Alwerfalli and Dr. Ahad Ali on their valuable encouragement, timely guidance and patience. In addition, I would like to express my sincere gratitude to Dr. Ahmed Alsamarai who helped a lot during the investigation of the topic.

REFERENNCES

[1] Mohamad, E., Ito, T., Salleh, M. R., & Nordin, N. A. (2012). Simulation Study Towards Productivity Improvement for Assembly Line. Journal of Human Capital Development, 5(2), PP 59-69.

[2] Chang Kian Chuan, Kum Wai Mun , Philip Er , George Sun. (1993). Simulation Application in Printed Circuit Board Assembly Industry. Singapore.

[3] Ali, A., & de Souza, R. (2007, December). Modeling and simulation of hard disk dive final assembly using a HDD template. In Proceedings of the 39th confer. on winter simulation: 40 years! The best is yet to come (pp. 1641-1650). IEEE Press.

[4] Yilmaz, I. O., Günther, H. O., & Jain, S. (2009). Simulation of mixed-model PCB assembly lines with group setup and bypass conveyors. The International-Journal of Advanced Manufacturing Tech, 42(3-4), PP 335-347.

[5] Kallio, K., Johnsson, M., & Nevalainen, O. S. (2012). Estimating the operation time of flexible surface mount placement machines. Production Engineering, 6(3), 319-328.

[6] Martin, O., Soulas, A., & Juuso, E. (2004). Production Optimization on PCB assembly lines using discrete-event simulation. Oulu University.

[7] Gebus, S., Soulas, A., & Juuso, E. Short Term Scheduling in Electronics Manufacturing using Discrete-Event Simulation.

[8] Greasley, A. (2008). Using simulation for facility design: A case study. Simulation Modelling Practice and Theory, 16(6), PP 670-677.

[9] Johnson, M. E., & Kalvenes, J. (1993, December). Subsystem decomposition in simulation of a PCB assembly line. In Proceedings of the 25th conference on Winter simulation (pp. 790-795). ACM.

[10] Jadhav, P. D., & Smith, J. S. (2005, December). Analyzing PCB assembly lines using a PCB assembly template. In Simulation Conference, 2005 Proceedings of the Winter (pp. 8-pp). IEEE.

[11] Ilgin, M. A., & Gupta, S. M. (2008, January). Joint optimization of transportation and spare parts inventory policies in a reverse logistics network using optquest. In ASME 2008 International Mechanical Engineering Congress and Exposition (pp. 877-885). American Society of Mechanical Engineers.

[12] Joseph, L. A., Watt, J. T., & Wigglesworth, N. (1990, December). Modeling & analysis of a new product development in electronic sub-assembly manufacturing. In Proceedings of the 22nd conference on Winter simulation (pp. 899-903). IEEE Press.