Productivity Improvement for Lamp Assembly Process in Electronics Industry

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PRODUCTIVITY IMPROVEMENT FOR LAMP ASSEMBLY PROCESS IN ELECTRONICS INDUSTRY.

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ABSTRACT

The electronic part manufacturing company in the author's research encountered loss problem from waiting in the part assembly process, which caused idling, non-continuous working process and productivity falling short of the customer demand of 30,720 parts per month. Currently the factory was able to produce 23,040 parts per month. The factory worked 6 days per week, 22 hours per day (in 2 shifts), and overtime work was needed to make up the shortfall. The Company therefore aimed to improve productivity to be able to deliver parts at the number in demand by the customer while only working 16 hours per day without overtime. The author therefore came with Takt Time calculation that would manufacture to the customer's demand. The author collected information time each working cycle of each subprocess of taillight assembly. The data collection revealed delay in Wire assembly and PCBA & Carrier assembly process, thus all the other subsequent processes had to wait. The author analyzed the problem using Why-Why Analysis and Tree diagram to improve the process. This case, process improvement was done with the ECRS technique. After improvement, it was found that the working cycle was reduced by 92.14 seconds, from overall cycle time at 542.17 seconds to 450.03 seconds (16.99% reduction), which did not exceed the Takt Time and could reduce one process while still able to meet the customer's demand within the 16-hour daily work period without the need for overtime work (6 hours per day). This also generated morale for the employees.

Keywords: *Productivity, Lean Manufacturing, ECRS*

INTRODUCTION

The study company was a contract manufacturing company for microelectronics, the company has a total of 26 working days per month, 1 working day, 16 hours, divided into 2 shifts of 8 hours each. But there is a large part of the work being forwarded from the subsidiary company. Which is an electronic part that is component of a car's taillight. Which is large and there is a new process that has never been done causing the production process to not be smooth as shown in Figure 3.

The work schedule, starting from preparing the parts for assembly, insert the Fixture (Package Board), then assemble the wires to the parts (Manual Soldering) and forward to the lead welding machine to fix the wires to the parts (Wave Soldering), then label the workpiece (Labeling), check the adhesion of lead to the parts and check the label (Visual Inspection). Assembling a pre-assembled lead-based assembly to a plastic carrier (PCBA & Carrier Assembly), and then forward to melt the pin's carrier to firmly attach to the set again (1st & 2nd Heat Staking). Pass the fire test, then take the work to check the details outside and submit the quality work before packing the box. from checking the customer's order information. It was found that there were more orders coming in every 3 months (from the historical data of the year 2021 orders).

The customer has a demand for orders that increase to 30,720 parts per month, which the company is unable to produce according to this order. Currently, production capacity is not enough to meet the additional 33.33% increase in customer demand during normal working hours. From the aforementioned problems the researcher needs to take corrective action by suggesting ways to increase production capacity to meet customers in a timely manner. without overtime to make customers satisfied and the company does not increase production costs.

LITERATURE REVIEW

Productivity improvement could be applied to both the manufacturing and service sectors, so the company supported continuous improvement for both the organization and personnel with emphasis on application of various tools for improvement. In this studied case, the improvement by using Lean Six Sigma, ECRS, Line Balancing, Work Study to solve problems in transportation, delays, losses and mistakes that affected the company's cost.

Productivity is a ratio between output and input at a given time. The goal of productivity improvement is increasing output or reduce cost to enlarge profit [1-2]

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

The study in leather goods industry examined and improved the product using Work Study and Method Study. The efficiency in leather product assembly was improved through line balancing, by reducing working time and adjusting the process [8].

Work study was method study and work measurement to examine the work process and improve it, improve working standard, and apply tools to promote productivity in the employees. The work study thus was directly related with productivity and process improvement. There were two methods: Method study – a study to find the easiest, most convenient, best-saving and more efficient method to replace the old. Work measurement – a technique to measure working time as a time or labor unit, and get useful time value for production planning or line balancing. Work measurement is a continuous process. Work study aims to eliminate unnecessary steps, while work measurement is a study to reduce losses by reducing wasted time. Occasionally, time study could be applied directly to get the working time. The result is working process improvement, and productivity improvement (standard time) [3], [10].

Lean Manufacturing reduce the operation time of process, increase maneuverability, and improve the corresponding attributes. It optimizes customer significance, minimizes wastes. Leaning focuses on constant customer valuing, application of continuous learning and improvement, use of instability and loss reduction techniques, long-term vision, value improvement throughout the value chain, meeting the customer's demand at the first time, and creation of long-term relationship with stakeholders, including the employees, managers, owners, suppliers, distributors, customers, communities, societies, and the environment. This would promote flowing to increase value [9].

ECRS is an effective method to examine movement to improve the production line, proposed by Mogensen 1932, consisting of four principles. Eliminate waste found in the production line such as waiting time, unnecessary movement and step. Combine unnecessary steps, streamline the process and time. Rearrange the process to reduce movement time. Simplify the process with new approach or equipment such as clamps, jigs, supporting tools or machinery modification. ECRS improvement leads to reduction of system and energy cost, along with processing time. The material cost and waste from inappropriate working process will also decrease [5-7].

Work Study and ECRS that the two when well combined and used, will be the universal solution for any type of industry having any sort of problem recording the productivity. If implemented in proper order, 100% positive results are assured.[9]

Waste

Maximization of production requires waste reduction. Waste could be divided into seven types: Overproduction, Processing, Inventory, Motion, Delay, Defect, Transportation.

Takt Time

Takt time is fundamental for standardizing work to the expected time to make one unit product [4]. Tells to how many products need to be produced in a given time period to meet customer demand.

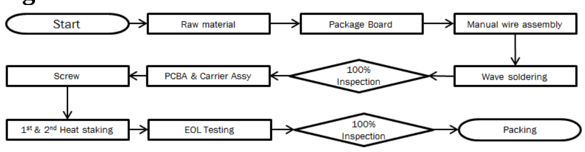
As it defines with what frequency there should be a product output on the line. According to Wang et al. (2014), takt time is a function that determines how fast a process has to be in order to meet the customer demand. In terms of calculation, it is the time available to produce parts in a specific time interval divided by the number of parts demanded in that interval. For Sabet-Rasekh (2014), takt time is commonly associated to the cycle time. While the first is based on the customer's need, the second represents the production capacity of that process.

Generally, an operation balance chart is used to show how cycle times compare to Takt times. It can be utilized to clarify doubts about process capacity [13-14].

OBJECTIVES AND METHODOLOGY

The author studied a taillight assembly process had the process flow as shown in Figure 1.

Figure 1: Process Flow Chart



Currently, the company worked 26 days per month, and 16 hours per day (in two eight-hour shifts). The customer demand increased from 23,040 parts per month to 30,720 parts per month, or 1,181.54 per day. Takt time could be calculated as follows.

$$\text{Takt Time} = \frac{\text{PT Available per day}}{\text{Customer demand per day}}$$

PT = Production Time [14]

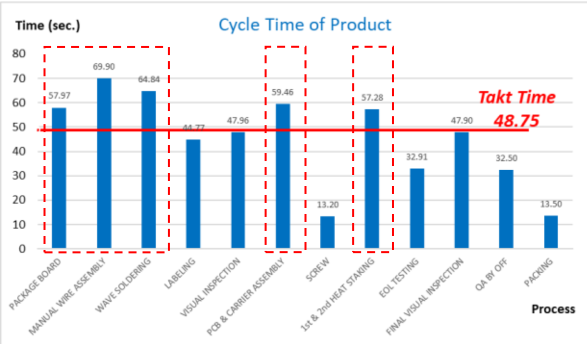
$$\text{Takt Time} = \frac{(16 \times 3600)}{1{,}181.54}$$

= 48.75 seconds per part

As seen in Figure 2 that the current production capability was short of the 33.33% increase in demand, requiring an overtime work of 3 hours per shift or 6 hours every day to meet the demand. The author thus proposed cycle time reduction of any process that exceeding the Takt time, by balancing the taillight production process and increasing productivity to meet customer demand, using existing resources without adding more manpower into the process.

The author collected data from the production process and timed the process. The result is shown in Figure 2.

Figure 2: Cycle Time of Product, Before



According to the graph, the time-intensive process was wire assembly. The author therefore investigated the process using Micro Motion Study, one method for work measurement. In the study, the author video-recorded the work for analysis and detail study. Examination of work led to division of the process into sub-processes. It was found that there was underlying waste in 6 steps as shown in Figure 3.

Figure 3: Element Flow Process

Flow Process Chart

Job : Package board + Manual Wire Assembly + Wave Soldering

No.	Details of the Method	Time (Sec/2 PCs)	Operation	Inspection	Movement	Delay	Storage	Wastes
1	Insert 20 PCBA into 1 fixture	51	○					Unnecessary motion
2	Lock fixture with PCBA	15	○					Unnecessary motion
3	Insert 2 connector and 24 wire into hole PCBA	139	○					
4	Unlock fixture with PCBA and keep work set in tray	31	○					Unnecessary motion, Defect
5	Insert work set into fixture lock PCBA and lock cover with fixture and check wire	115		□				Inappropriate processing
6	Load fixture into Selective soldering machine	2	○					
7	Load out fixture out off Selective soldering machine	2	○					Waiting
8	Take off cover out off fixture and unlock fixture with PCBA and keep work set in tray	30	○					Unnecessary motion
	Total Time per 2 work set	385	270	115				5 wastes

The analysis showed waste in 6 steps, came from motion, defect, and processing. After analyzing the process and waste, the author made a Why-Why analysis as show in Figure 4, Tree diagram as shown in Figure 5.

Figure 4: Why-Why analysis of take long time to Wave soldering process

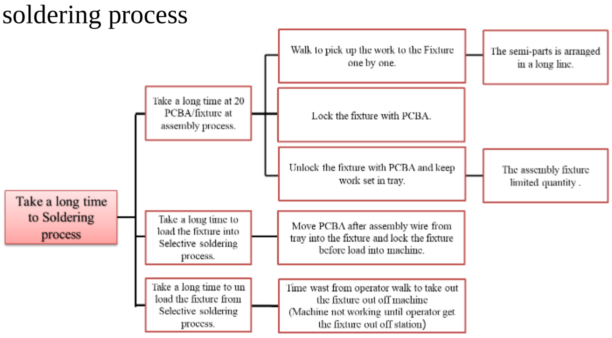
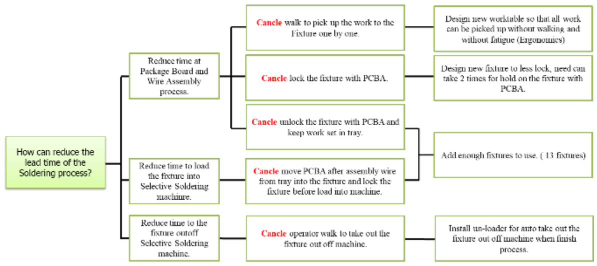


Figure 5: Tree Diagram of How can reduce lead time of the Soldering process



1.Cycle time reduction at Package Board – Manual Wire Assembly – Wave Soldering process,

1.1 E-Eliminate: Originally the material was placed on a long table as shown in Figure 6, requiring the operator to use carts for fixture placement. In this case, PCBA had to be loaded into the fixture (20 for one fixture), thus more time was wasted in pushing the cart back and forth, and the operator incurred more fatigue. The author thus designed a new work table as a U-shaped as shown in Figure 7, one with the operator standing in the center. The fixture will be in front of the operator, and the 10 PBCAs will be placed on both sides so the operator can reach without leaning the body.

Figure 6: Before

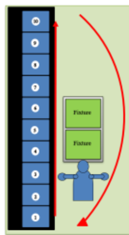
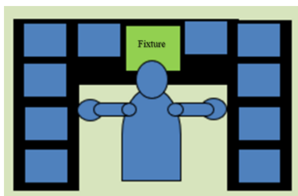


Figure 7: After



1.2 R-Rearrange: After using the U-shaped table, the author created a PCBA picking sequence to be systematic and simple. The PCBAs will be picked from left to right in a loop, as shown in Figure 8. The operator will start with the first tray to the left, then work up to the fixture, then switch to the tray on the right, and work up to the fixture again as shown in Figure 9. This systematic approach will be easier to memorize and prevent PCBA skipping or forgetting.

Figure 8: Step of picking up PCBAs at Fix

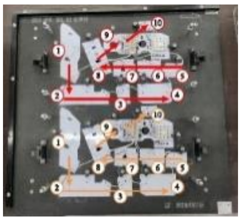
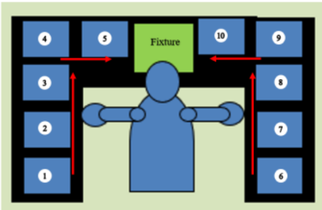


Figure 9: Step of picking up PCBAs at Tray to Fixture



1.3 S-Simplify & C-Combine: In the manual wire assembly step, after the wire is affixed to the PCBA, the operator has to secure the PCBA to the fixture, and put on the cover, thus showing redundancy in the step of securing the PCBA, and putting on the cover and pressing the PCBA on the fixture again. It was found that 18 securing spots were per fixture as shown in Figure 11, thus the operator was unable to pass the part to the next step. The author therefore designed a new fixture that could reduce unnecessary steps as shown in Figure 10, using concept of securing by compression. In the new design, magnets were used to secure the cover to the fixture. Therefore, only the cover could be placed on the fixture (that already had the workpiece). So, one fixture would only need covers twice from 18 times per Fixture, without redundancy as shown in Figure 12.

Figure 10: New Fixture Design

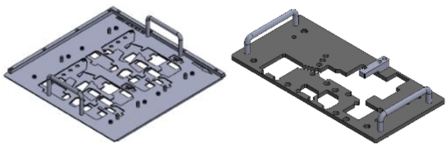


Figure 11: Before **Figure12:** After

1.4 C-Combine: In the manual wire assembly step, after the wire was affixed to the PCBA, the assembled workpiece would be removed to the tray for passing on to the wave soldering step. The wave soldering operator would secure the workpiece to the fixture, and close with a cover again before soldering the PCBA and wire, using the selective soldering machine as shown in Figure 13. The author saw these steps as similar, using the same tools and deemed the steps redundant, in addition to being risky of wires coming loose which would require wire repositioning, wasting time. The author therefore combined the steps. After the wire was affixed to the PCBA, the whole workpiece would simply be passed to the wave soldering process, to be directly loaded into the machine without further securing. This improvement reduced redundancy and waste, and eliminated the need to reinsert the wire before putting the workpiece into the Selective Soldering Machine as shown in Figure 14. 13 fixtures were also ordered from the original five.

Figure 13: Before

Figure 14: After

1.5 S-Simplify: The step in using the Selective Soldering Machine started from loading the fixture into the machine, and then the soldering spot is flux sprayed with water. Then, the spot is pre-heated and the whole fixture is passed to the soldering point. After soldering, the fixture is moved to the exit point to be unloaded from the machine (by hand) as shown in Figure 15, and then the machine will accept the next fixture. If unloading is too slow, the machine will stop, and waste time, while the operator would feel rushed and anxious. Therefore, the author installed the auto load out device in the back of the Selective Soldering Machine so the fixture could be automatically unloaded to the rest area for manual pickup as shown in Figure 16, while the machine could still take in work. As the machine did not have to stop, the operator could go do other things without having to wait for the machine. This also helped cooling the fixture, because the fixture would still have some residue heat from soldering.

Figure 15: Before **Figure 16:** After

2.Cycle time reduction at PCBA & Carrier assembly – Screw – 1st & 2nd Heat Staking process.

2.1. As seen in Figure 2 Cycle Time of Product, Before, that in the PCBA & Carrier Assembly and Screw and 1st & 2nd Heat Staking had cycle difference of 46 seconds per cycle. Therefore, the screwing step had to wait for workpieces from the PCBA & Carrier Assembly step, which was done 100% manually assembly and relatively slow. Thus, the author desired process after made Why-Why analysis to combine the

PCBA & Carrier Assembly with Screwing steps and shared the workload equally among the three operators, reducing waste and fatigue as show in Figure 18.

Figure 17: Before

No.	PROCESS	Man-power
1	PACKAGE BOARD	1
2	MANUAL WIRE ASSEMBLY	2
3	WAVE SOLDERING	1
4	LABELING	1
5	VISUAL INSPECTION	2
6	PCB & CARRIER ASSEMBLY	2
7	SCREW	1
8	1st & 2nd HEAT STAKING	1
9	EOL TESTING	1
10	FINAL VISUAL INSPECTION	2
11	QA BY OFF	2
12	PACKING	1
	Total	17

Figure 18: After

No.	PROCESS	Man-power
1	PACKAGE BOARD	1
2	MANUAL WIRE ASSEMBLY	2
3	WAVE SOLDERING	1
4	LABELING	1
5	VISUAL INSPECTION	2
6	PCBA & CARRIER ASSEMBLY & SCREW	3
7	1st & 2nd HEAT STAKING	1
8	EOL TESTING	1
9	FINAL VISUAL INSPECTION	2
10	QA BY OFF	2
11	PACKING	1
	Total	17

2.2 Regarding the 1st & 2nd Heat Staking Process, the pin of plastic carrier is melted to affix the Carrier to the assembled and wired PCBA to get one finished good. This step requires 2 machines and one operator for both. The operator inspects and adjusts the wire before loading the workpiece to prevent wire damage (due to the machine clamping the wire because of incorrect position). The 1st heat-staked part is then unloaded and a new workpiece is loaded. After that the operator walks to the second machine to unload the 2nd heat-staked part. Then, the operator walks back to check the workpiece at the first machine, and load the workpiece into the second machine. Then, the operator checks the 2nd heat-staked part and put it in a tray. After that, the operator walks back to the first machine for the next part as shown in Figure 20. The machines are large (two meter per machine) and walking distance is considerable (walking distance has 4 meter or 17 steps per cycle). Thus, time is wasted without value. The author saw the waste and did not want to assign more manpower to reduce waste, thus proposing a new layout of the heat staking machines. Proposed rearrange layout under Why-Why analysis as shown in Figure 19, the 2nd machine would be placed perpendicular to the first (in an L-shaped layout) as shown in Figure 21. Thus, the operator would not incur fatigue and the machine could be constantly kept running without waiting.

Figure 19: Why-Why analysis of machine waiting time

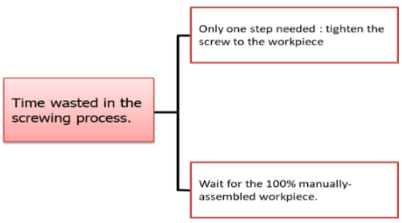


Figure 20: Before

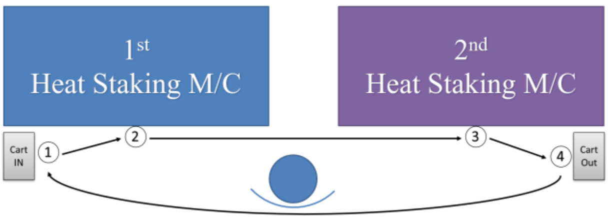
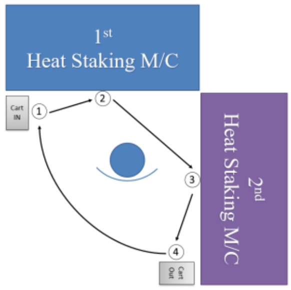


Figure 21: After



RESULTS AND DISCUSSION

This study allows cycle time reduction in each process to meet the Takt time of 48.75 seconds.

1. Cycle Time of the Package Board Process was reduced from 57.97 seconds to 44.46 seconds/Fixture (23.31%) which was close to the Takt Time of 48.25 seconds

2. Cycle Time of the Manual Wire Assembly Process was reduced from 69.90 seconds to 47.59 seconds/Fixture (31.92%) which was close to the Takt Time of 48.75 seconds

3.Cycle Time of the Wave Soldering Process was reduced from 64.84 seconds to 41.51 seconds/Fixture (35.98%) which was close to the Takt Time of 48.75 seconds

4. Process balancing allowed combination of PCBAs & Carrier assembly and Screw Process, increasing efficiency and reducing Cycle Time of the PCBA & Carrier Assembly Process from 72.66 seconds to 48.65 seconds/Fixture (33.04%) which was close to the Takt Time of 48.75 seconds

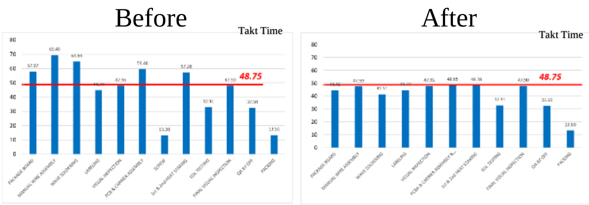
5. Cycle Time of the 1st & 2nd Heat Staking Process was reduced from 57.28 seconds to 48.88 seconds/ Fixture (14.66%), close to the Takt Time of 48.75 seconds.

6. The 4-hour overtime was reduced. Originally 20 hours were needed to perform, but after improvement, 16 hours were enough to meet the goal (20% reduction in working hours)

Figure 22: Compare results Before and After

Compare result Before & After					
No.	**Detail Improve**	**Before**	**After**	**Dff.**	**% Improve**
1	Cycle Time of the Package Board	57.97 sec.	44.46 sec.	13.51 sec.	23.31%
2	Cycle Time of the Manual Wire Assembly	69.9 sec.	47.59 sec.	22.31 sec.	31.92%
3	Cycle Time of the Wave Soldering	64.84 sec.	41.51 sec.	23.33 sec.	35.98%
5	Combination of PCBAs & Carrier assembly and Screw	72.66 sec.	48.65 sec.	24.01 sec.	33.04%
4	Cycle Time of the 1st & 2nd Heat Staking	57.28 sec.	48.28 sec.	9.0 sec.	15.71%
6	Work time	20 hr.	16 hr.	4 hr.	20.00%
7	Material transfer	8 meter	4 meter	4 meter	50.00%
8	Process	12	11	1	8.33%
9	Capacity	824	1181	357	43.33%

Figure 23: Cycle Time of Product, Before vs After



CONCLUSIONS

Process improvement by improvement of motion, equipment design and working space rearrangement was able to reduce work cycle by 92.14 seconds from 542.17 seconds to 450.63 or 16.82% reduction. Each process had cycle time similar to the Takt Time at 48.25 seconds. Therefore, 16 hours per day were adequate to meet the customer demand of 30,720 parts per month without the overtime.

ACKNOWLEDGMENT

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PHOTOS AND INFORMATION

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