CALCULATION AND LAYOUT DESIGN OF ASSEMBLY SYSTEM AND DETECTION OF PRODUCT ERRORS IN ELECTRONIC CIRCUIT BOARD MANUFACTURING

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ABSTRACT

The research team investiged and analyzed data related to the assembly process and detected errors in electronic circuit board manufacturing, work stations, movement flow, number of workers and real operating time of the machines during the production process. From that, calculate and determine the location of work stations, distance, area, space and build the overall plan of the system. The results of calculating the coordinates of the work stations using Lingo software are D (X_1, Y_1) = (10, 4); E (X_2, Y_2) = (10, 3.99); F (X_3, Y_3) = (9.99, 3.99) respectively. Based on the found coordinates, design and simulate the system using Tecnomatix Plant Simulation software. Simulation results using factory simulation show that the production rate on the assembly line increased by more than 11%. Comparing before and after the change, the added value is quite high at 71.6%. The initial input products of 400 products/day has increased to 440 products/day, including errors during the production process.

Keywords: *Bottlenecks; Lean; Output; Productivity; Simulation modeling; Quantity; Congestion; Error Detection.*

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NOMENCLATURE

No.	Name	Description
1	SA-1	Material
2	SA-2	Base circuit
3	SMD	electronic components
4	A-1	Printed circuit
5	A-2	conductive layer
6	A-3	Circuit board border
7	A-4	Apply component mounting cream
8	A-5	Weld the connections in the circuit board
9	A-6	Dry the circuit board
10	P_i	Input productivity at activity i (product/period)
11	s_i	Input loss rate Pi
12	O_i	Output productivity at activity i
13	T_i	Processing time per unit at activity i (time/product)
14	E_i	Operational equipment efficiency
15	R_i	Reliability of the equipment
16	M_i	The number of machines of type j required
17	X_i	Set of activities to be processed on the machine j
18	D	Distance between 2 points
19	x_i,x_j,y_i,y_j	Coordinates of the points
20	f_{ij}	Frequency of movement from part i to j
21	C_{ij}	Cost per unit movement from part i to j
22	d_{ij}	Distance of movement from part i to j

1. INTRODUCTION

The electronic circuit will be made from discrete components linked together by wire segments or electrical patchs. Nowadays, the most commonly used is to create connections using optical printing techniques on the surface of a thin film layer (a printed circuit board or PCB) and electronic components are connected through welded joints on the surface. circuit board to create a complete circuit board. In an integrated circuit or IC, electronic components will be connected at the same surface. A example is semiconductors such as silicon, some of which are gallium arsenide.

Currently, the system for assembling and detecting errors in electronic circuit board manufacturing and the steps in performing tasks still has many defects, directly affecting product quality as well as the productivity of the assembly line ... Therefore, calculating and designing the assembly line system layout and detecting errors in electronic circuit board manufacturing using Technomatic plan simulation software can improve the system layout and lean the production process, profit maximization.

2. METHODS

- Investigating of necessary data of the assembly system and detect product errors in electronic circuit board manufacturing such as movement flow, number of machines, work stations, number of necessary workers, product processing time [4]. The purpose of data investigating is to understand the current conditions of the overall system .

- Determining the type of layout is important design decision because it affects many aspects of the production system. There are four basic forms of layout: product-based layout, group layout, process-based layout, and combined layout [1, 2]. After layout selected , determine the work stations in the system, the types of machines and the corresponding quantity of each type. The typical I- Flow has a movement flow from receiving input materials to producing finished products and vice versa [1, 2].

- Use the front-to-back order algorithm to determine the assembly steps that need to be performed in a certain order, describing the order of the product's front-to-back assembly process divided into different levels. each other in order from left to right [3-6].

- Build a relationship diagram between work stations: analysis and calculation process, we build a relationship diagram to implement the relationships between work stations. The goal of the relationship diagram is describe the spatial relationship between work stations [2, 4, 5, 6].

- Simulate the system using Tecnomaxtic Plan Simulation software, set up time cycle, failure rate of machines in the system. Test run of the model to evalant the performance of the machines and the production of each lines [7-9].

3. RESULTS AND DISCUSSION

3.1. Data and input operations

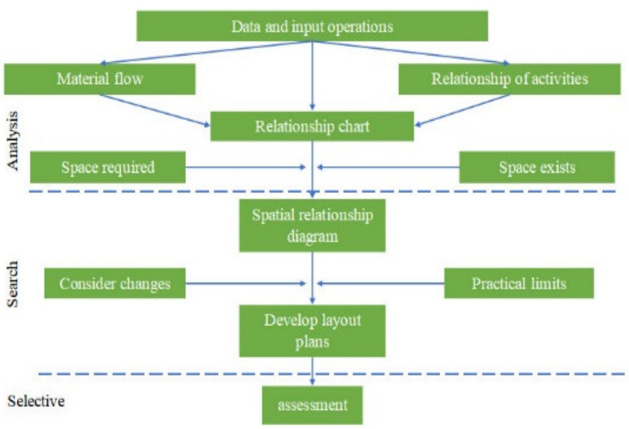

Fig. 1. Layout planning process

Input data is divided into 3 main groups: product design, process design, and scheduling design.

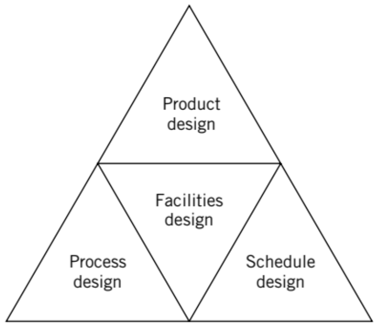

Fig. 2. Data groups impact layout design

3.2. Before-after sequence diagram and Assembly process

The electronic circuit board assembly process is the process of building and linking electronic components to the circuit board

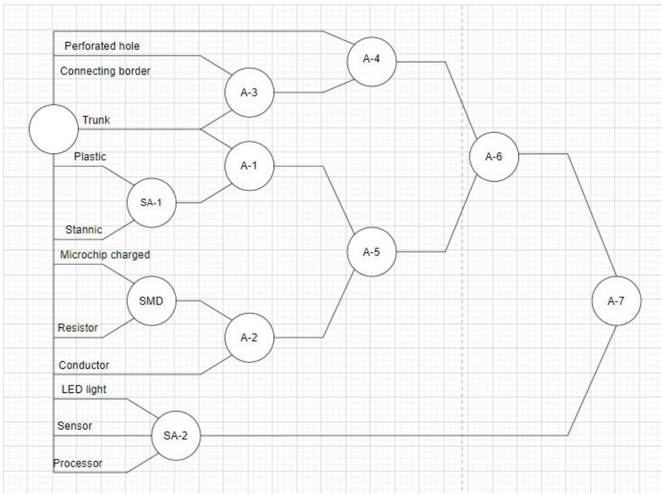

Fig. 3. Before - After diagram

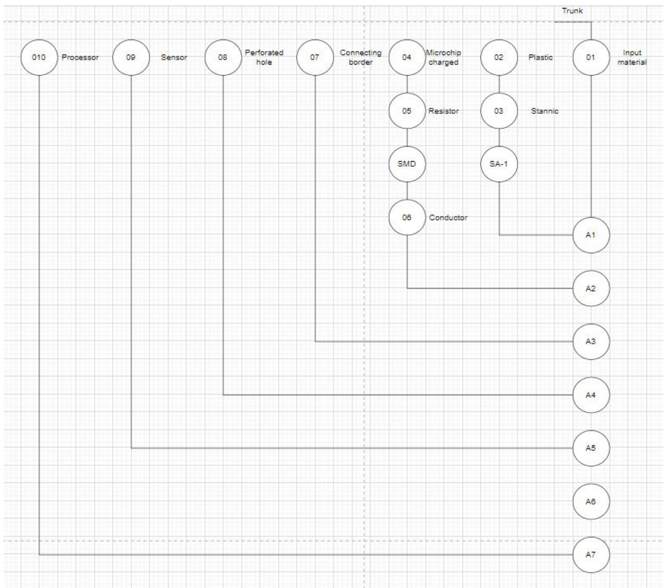

Fig. 4. Assembly process and error detection

After completing the assembly and inspection steps, the finished product will be moved and the semi-finished product will be classified for recycling.

3.3. Calculate and arrange parts in the layout

The premises are designed to satisfy future production needs. Starting from market demand forecasts, productivity requirements or production speed will be determined. On this basis, the required number of machines, equipment or human resources, the number of working hours per year, material handling equipment and warehouse requirements can be calculated to satisfy the proposed production speed.

- The formula to calculate the input productivity at activity i [1].

$$P_i = \frac{O_i}{1-S_i} \quad (1)$$

- The formula to calculate the requantity of machine type j [1].

$$M_j = \sum_{i \in X_j} \frac{P_i T_i}{C_i E_i R_i} \quad (2)$$

Besides, it is necessary to know the product types that will be produced on the layout and the time required to meet production needs. In this study, research team used the group layout technique - direct clustering algorithm .

Steps in the direct group algorithm:

Step 1. Order the rows and columns. Sum the 1s in each column and in each row of the machine-part matrix. Order the rows (top to bottom) in descending order of the number of 1s in the rows, and order the columns (left to right) in ascending order of the number of 1s in each. Where ties exist, break the ties in descending numerical sequence.

Step 2. Sort the columns. Beginning with the first row of the matrix, shift to the left of the matrix all columns having a 1 in the first row. Continue the process row by row until no further opportunity exists for shifting columns.

Step 3. Sort the rows. Column by column, beginning with the leftmost column, shift rows upward when opportunities exist to form blocks of 1s. Performing the column and row sortation is facilitated by using spreadsheets, such as MS Excel.

Step 4. Form cells. Look for opportunities to form cells such that all processing for each part occurs in a single cell.

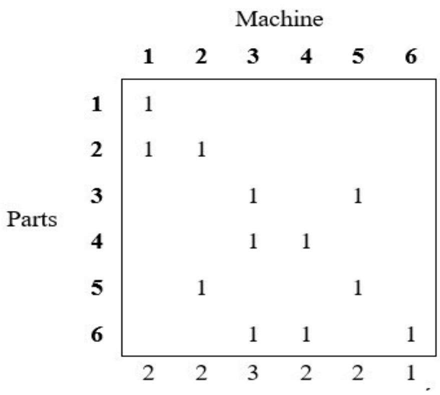

Fig. 5. Machine - Part matrix

Solving the matrix, we get the results of the ground solution by technology group as follows:

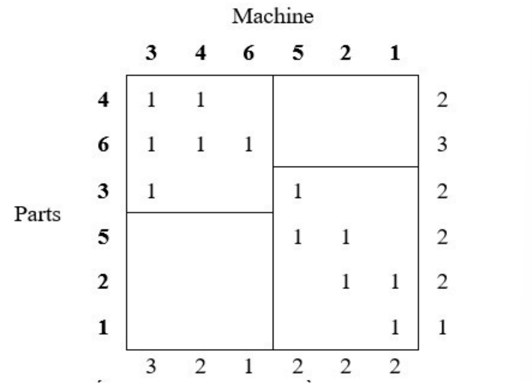

Fig. 6. Results of layout solutions by technology group

3.4. Build a relationship diagram between work stations ts in the process

The overall design of the layout is in an I-Type with a straight flow from receiving products to shipping and vice versa. This setup is purposed maximize optimization as it uses the overall length of the workshop, keeps similar products separated by assembly line format, and minimizes bottlenecks by avoiding move back and forth.

Table 1. Movement distance between perpendicular machines

Cluster	PCB drilling and cutting machine	Solder paste scanner	Automatic component mounting machine	Welding furnace	X-ray machine checks PCB errors	Compressed air dryer
PCB drilling and cutting machine	-	3.75	-	-	-	-
Solder paste scanner	3.75	-	4.15	7.545	13.905	-
Automatic component mounting machine	-	4.15	-	3.395	8.765	-
Welding furnace	-	7.545	3.395	-	5.37	-
X-ray machine checks PCB errors	-	13.905	8.765	5.37	-	6.36
Compressed air dryer	-	-	-	-	6.36	-

Determine the relationship from which we can establish the FROM - TO matrix, using a common scale summarized as follows:

A - Absolutely necessary

E - Especially important

I - Important

O - Ordinary closeness

U - Unimportant

X - Undesirable

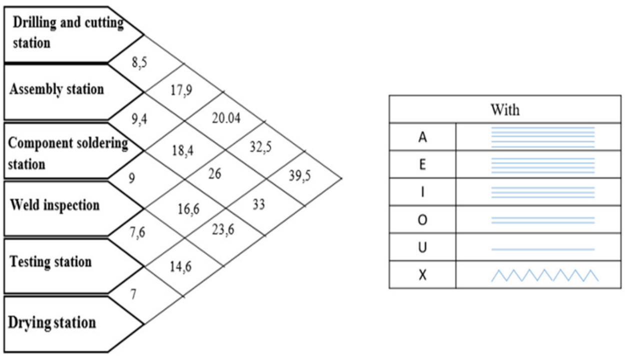

Fig. 7. From - To matrix

Therefore, we create a relationship diagram between the work stations:

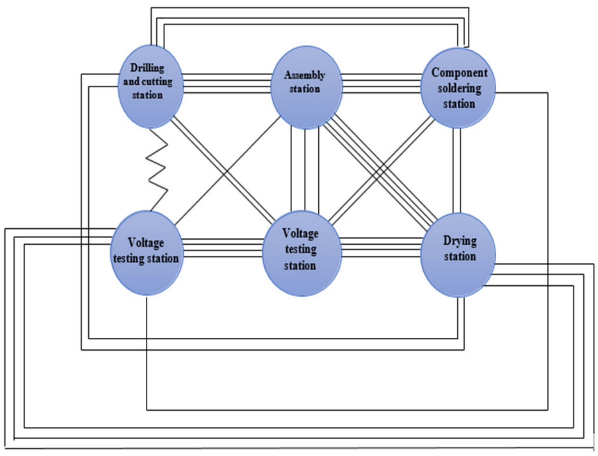

Fig. 8. Relationship diagram between the work stations

3.5. Layout planning

The layout of the assembly workshop must ensure that during the assembly process, parts and components move in the most appropriate, shortest path, do not intersect and do not go in opposite directions. So, we must base on the steps of the assembly process to arrange the works stations of the workshop in the following general order: A - circuit drilling machine; B - weld paste scanner; C - automatic component mounting machine; D - welding furnace; E - X-Ray machine checks PBC errors; F - compressed air dryer. To arrange a appropriate location for production and assembly, we must calculations. We have the coordinates and moving weights of related work stations shown in the following Table 2.

Table 2. Effective locations and movement relationships between new locations and current location

Current equipment				Relationship between divices						
Position	X	Y		New - New				New - Current		
A	18	2			D	E	F	A	B	C
B	1	5		D	0	150	160	250	280	240
C	10	4		E		0	240	170	100	230
				F			0	90	150	270

The direct distance between two points of work stations with coordinates (x_i, y_i) is determined according to the following formula [1]:

$$d = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (3)$$

Calculate the total travel distance between work stations taking into residual the weight or movement expense between parts using the objective function or coordinates of the department according to the following formula [1]:

$$z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} C_{ij} d_{ij} \quad (4)$$

Use the lingo model to determine the perpendicular distance:

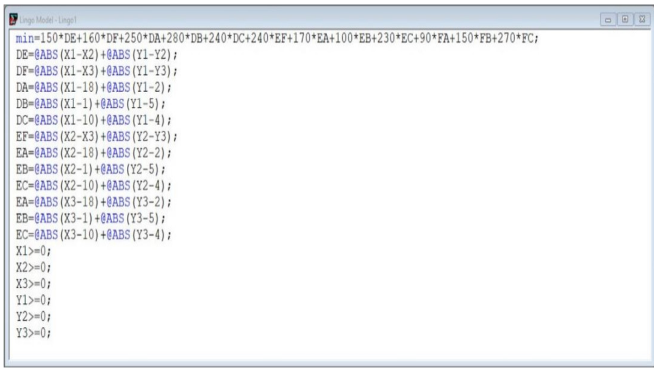

Fig. 9. Lingo model with perpendicular distance

Solving the problem results from the Lingo model to determine an optimal solution for 3 new locations with coordinates as follows: D (X_1, Y_1) = (10, 4).

Similarly, we have the coordinates: E (X_2, Y_2) = (10, 3.99); F (X_3, Y_3) = (9.99, 3.99)

3.6. Simulation

The research team used Tecnomatix Plant Simulation software to simulate the system.

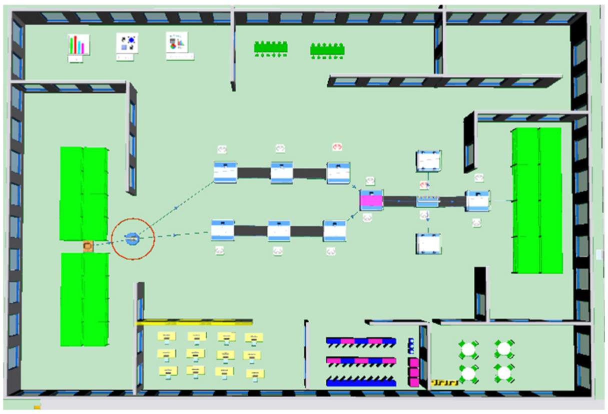

Fig. 10. 2D and 3D layout of the System before improvement

Because the workshop includes many working areas with different functions and tasks, many machines and equipment with their own working parameters that are not related or affect the welding line will be eliminated and only keep the main equipment and machinery that are in the line or directly impact the production process of the assembly system and detect electronic circuit board errors (Fig.10).

After checking the quality (shape and weld quality), the products are placed on shelves and carts at the inspection location and transferred to the finished product warehouse. Therefore, the output of the simulation system will be placed together with the product quality inspection area in the electronic components assembly system as shown in Fig. 11.

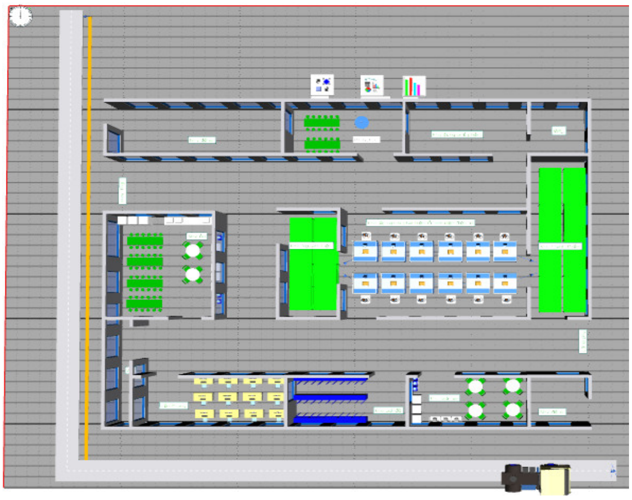

Fig. 11. 2D and 3D layout of the System after improvement

The input parameters of the simulation are performed when setting main parameters such as system execution time (including Setup time, Processing time, Recovery time, Cycle time) and number of products, productivity of the system. system. The system's execution time to 8 hours a day and is done in 2 shifts respectively.

Simulation analysis is performed in two options: Before improvement and after improvement

The results of simulation analysis using plant simulation before improvement are shown in Table 3 and Fig. 12 respectively.

Table 3. Data table results of system simulation analysis before improvement

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	Part	42:11.1480	200	25	55.96%	44.04%	0.00%	49.78%	
Drain1	Tractor	2:33:37.1086	10	1	49.99%	50.01%	0.00%	29.29%	

Cumulated Statistics of the Parts which the Drain Deleted

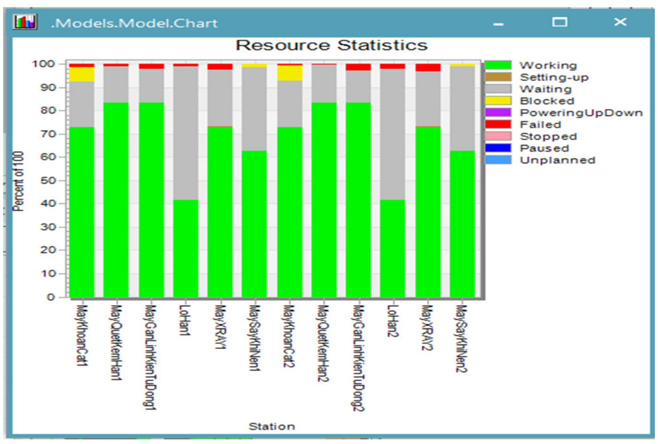

Fig. 12. Statistical chart of work performance of stations before improvement

Analysis results show: Total output (Throughput): 200/shift; There are 2 production shifts in a day; Output per hour (TPH): 25 (products); Added value: 49.78%.

The results of simulation analysis using plant simulation after improvement are shown in Table 4 and Fig. 13 respectively.

Table 4. Data table results of system simulation analysis after improvement

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Drain	Part	29:19.6702	220	28	80.05%	19.95%	0.00%	71.60%	
Drain1	Tractor	2:33:37.1086	10	1	49.99%	50.01%	0.00%	29.29%	

Cumulated Statistics of the Parts which the Drain Deleted

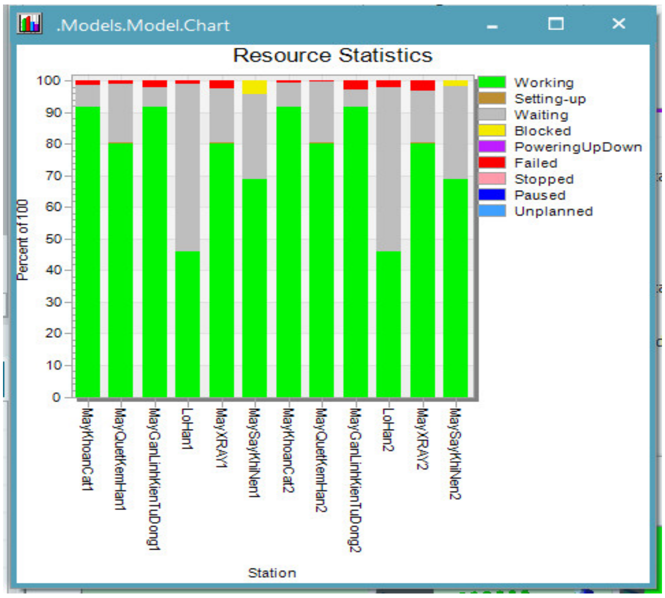

Fig. 13. Statistical chart of work performance of stations after improvement

Analysis results show: Total output (Throughput): 220/shift; Output per hour (TPH): 28 (products); Value added: 72.6%.

The parameters of each line are shown in the following Table 5.

Table 5. Mean operating parameters of each component after improvement

Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
MayKhoanCat1	91.67%	0.03%	6.95%	0.00%	0.00%	1.34%	0.00%	0.00%	0.00%	
MayKhoanCat2	91.67%	0.03%	7.73%	0.00%	0.00%	0.57%	0.00%	0.00%	0.00%	
MayQuetKemHan1	80.21%	0.02%	18.52%	0.00%	0.00%	1.26%	0.00%	0.00%	0.00%	
MayQuetKemHan2	80.21%	0.02%	19.47%	0.00%	0.00%	0.31%	0.00%	0.00%	0.00%	
MayGanLinhKienTuDong1	91.67%	0.05%	6.22%	0.00%	0.00%	2.06%	0.00%	0.00%	0.00%	
MayGanLinhKienTuDong2	91.67%	0.05%	5.42%	0.00%	0.00%	2.86%	0.00%	0.00%	0.00%	
LoHan1	45.83%	0.02%	53.09%	0.00%	0.00%	1.06%	0.00%	0.00%	0.00%	
LoHan2	45.83%	0.02%	52.09%	0.00%	0.00%	2.06%	0.00%	0.00%	0.00%	
MayXRAY1	80.21%	0.07%	17.14%	0.00%	0.00%	2.58%	0.00%	0.00%	0.00%	
MayXRAY2	80.21%	0.07%	16.28%	0.00%	0.00%	3.44%	0.00%	0.00%	0.00%	
MaySayKhiNen1	68.75%	0.00%	26.74%	4.51%	0.00%	0.00%	0.00%	0.00%	0.00%	
MaySayKhiNen2	68.75%	0.00%	29.37%	1.88%	0.00%	0.00%	0.00%	0.00%	0.00%	

Portions of the States

Thus, comparison with the two analysis options by simulation shows that: The number of products completed in 1 shift is 220 products, higher than the original 200 products (200 products/1 shift). This shows that the production rate in the assembly line increased by more than 11%. Compare before and after time change:

- The number of products produced per shift increased to fully satisfy the initial requirements.

- The added value is quite high at 71.6%.

- The initial number of input products was 400 products/day (working in 2 shifts) has increased to 440 products/day (to satisfy the necessary products for output), including error during production.

4. CONCLUSIONS

The research team analyzed the layout and equipment in the workshop, provided a work schedule and processing time for each machine and semi-finished product, using Tecnomatix Plant Simulation software to simulate the assembly line and Detect electronic circuit board errors, analyze and evaluate simulation results to calculate output, productivity and material flow of the line. To plan the layout for the electronic circuit board assembly system. Data groups that impact layout design include product design, process design and schedule design. The electronic circuit board assembly process needs to ensure product reliability. From there, we built a diagram of the before-after order relationship and a map of the circuit board is machining process. Based on the travel distance between work stations to the process and determine the relationship and relationship diagram. The relationship diagram between work stations shows the level of importance, close relationship or need to be placed close to each other. Set up an optimization proble using Lingo software to find the remaining positions of work stations in the electronic components assembly line as D (X_1, Y_1) = (10, 4); E (X_2, Y_2) = (10, 3.99); F (X_3, Y_3) = (9.99, 3.99).

During the design and analysis of component assembly systems and error detection of electronic circuit boards. The system is simulated with 6 stations, along with input and output output of finished and semi-finished products with a total of 12 machines divided into 2 production lines. Simulation results show that the production rate in the assembly line increased by more than 11%. Compare before and after time change, The added value is quite high at 71.6% The initial number of input products was 400 products/day has increased to 440 products/day, including error during production process.

REFERENCES

[1]. Sunderesh S. Heragu, *Facilities Design*. PWS Pub. Co; har/Dsk edition, 2008.

[2]. Tompkins A. T., White J. A., Bozer Y. A., Tanchoco J. M. A., *Facilities planning*, 3rd Edition. John Wiley & Sons, New York, 2010.

[3]. Erik Flores Garcia, et al., "Simulation-based Optimization for Facility Layout Design in Conditions of High Uncertainty," in *51st CIRP Conference on Manufacturing Systems*, Elsevier, 334-339, 2018.

[4]. Esfandyar Ataei, "Application of TOPSIS and Fuzzy TOPSIS Methods for Plant Layout Design," *World Applied Sciences Journal 23*, IDOSI Publications, 48-53, 2013.

[5]. D. Suhardini, et al., "Design and Simulation Plant Layout Using Systematic Layout Planning," in *10th ISIEM*, IOP Publishing, 2017.

[6]. K. Balamurugan, et al., "Design and optimization of manufacturing facilities layouts," *JEM382 IMechE 2006, Sage Journals*, 1249 – 1257, 2006.

[7]. Martijn K.R. Mes., *Simulation Modelling using Practical Examples: A Plant Simulation Tutorial*. University of Twente, 131-165.

[8]. Benjamin N., Anderis F., *Method standards & Work design*. Macgraw- Hill, 1999.

[9]. Rohan Ashork shintrel, Girish R. Naik, Mayur Bhujbal, "Facility and Plan Layout Using Tecnomatrix Plant Simulation," *International Research Journal of Engineering and Tachnology* (IRJET), 07, 12, 580-586, 2020.