DEVELOPMENT OF COMPUTER SIMULATION FOR FACTORY LAYOUT OF MANUFACTURING SYSTEM

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ABSTRACT
Factory simulation applications have been widely utilized especially in industries nowadays. Factory simulation helps manufacturer to visualize and predict the current state of the factory operations as well as the final outcome. Factory simulation also can be utilized to model and analyze the factory layout of manufacturing system. Factory layout comprises of integration of several suppliers which will cooperate to transform raw materials until final products have been produced. In this project, the layout is focusing on the internal layout within the factory. Actual data of manufacturing system has been acquired from Nichicon (M) Sdn. Bhd., a capacitor manufacturer company located in Bangi. Data given which includes the Block Capacitor Department layout, machine processing rate and daily target output are used to model the existing layout and simulation by using Rockwell Arena software. Apart from the existing layout and simulation, four proposed layouts and simulations have also been modelled as a comparison with the actual data.

Keywords: Computer simulation; Factory Layout; Manufacturing system

1. INTRODUCTION

The factory simulation concept offers an integrated approach to enhance the product and production engineering processes and simulation are the key technology within this concept. Different types of simulation, such as discrete event or 3D motion simulation can be applied in virtual models on various planning levels and stages to improve the product and process planning on all levels. The focus and key factor is the integration of the various planning and simulation processes. In an advanced stage, simulation technology can be applied in the digital factory concept to enhance the operative production planning and control as an integrated process from the top level to the factory floor control [Kuhn, 2006].

2. BACKGROUND

Factory simulation is defined as extendable and interactive discrete simulation system constructed to interpret the factory model directly. It allows the user to dynamically query the simulation for state information (e.g., state of a machine, process, etc.), where objects are located (e.g., what operation is being carried out on an order), and regular statistical analyses. It also allows the user to alter the factory model before and during simulation. The factory can be simulated and displayed at variable levels of detail [Fox, 1981].

The factory simulation concept focuses on the integration of methods and tools available on different levels for planning and testing the product and the related production and operative control of the factory [Schloegl, 2005]. Factory simulation serves the following purposes:

- Product development, test and optimization
- Production process development and optimization
- Plant design and improvement
- Operative production planning and control

The view of a factory simulation as an integrated model of various sub-systems in a factory is also similar to that taken in some of the enterprise modelling architectures. The enterprise models view the organization as an integration of the major sub-systems [Jain et al., 2001].

The purpose of factory simulation that will be developed in this project is to analyze the factory layout of manufacturing system. There are CAD tools factory layout planning available that provide predefined modules for creating detailed, factory models. These layout tools allow working with predefined objects that represent virtually the resources used in a factory, from floor and overhead conveyors, mezzanines and cranes to material handling containers and operators. With these predefined objects, a layout model can be implemented in 3D quickly and efficiently without drawing the equipment in details.

Every layout has four fundamental elements: Space Planning Units (SPUs), Affinities, Space and Constraints. These fundamental elements apply to any size facility and at any level. Just as a few chemical elements give rise to an infinite number of compounds, the four layout elements and their variations can produce an almost infinite number of factory layouts [Blatt, 2006].

- SPUs combine with Affinities to form an Affinity Diagram. The Affinity Diagram is an idealized spatial arrangement that eventually becomes a layout.
- Each SPU requires some finite space whether great or small. Space, added to the Affinity Diagram, distorts it into the Layout Primitive.
- Constraints are conditions, assumptions, policies or edicts that restrict the design in some way. For example, "The layout must fit into the existing building." Constraints further modify the spatial arrangement and a Macro- layout results.

Factory layout is the focal point of facility design. It dominates the thinking of most managers. But factory layout is only one of several detail levels. Factory planning can be classified into five levels [Iqbal and Hashimi, 2001]:

I. Global (Site Location)
II. Supra (Site Planning)
III. Macro (Building Layout)
IV. Micro (Work cell / Department Layout)
V. Sub-Micro (Workstation Design)

At the Global level, site location is selected. This involves factors such as freight cost, labor cost, skill availability and site focus.At the Supra-Layout level, the site is being planned. This includes number, size, and location of buildings. It includes infrastructure such as roads, water, gas and rail. This plan should look ahead to plant expansions and eventual site saturationThe Macro-Layout plans each building, structure or other sub-unit of the site. Operating departments are defined and located at this level. Frequently, this is the most important level of planning. A Macro-Layout institutionalizes the fundamental organizational structure in steel and concrete.The Micro Level IV determines the location of specific equipment and furniture. The emphasis shifts from gross material flow to personal space and communication. Socio-Technical considerations dominate.The sub micro level focuses on individual workers. Workstations are designed for efficiency, effectiveness and safety. Ergonomics is a key.

Ideally, the design progresses from Global to Sub-Micro in distinct, sequential phases. At the end of each phase, the design is "frozen" by consensus.

Plant design and optimization focuses on the optimization of material flow, resource utilization and logistics for all levels of plant planning from global production networks, through local plants down to specific lines with the objectives:

- Shorten new product introduction, time-to-market, and time-to-volume
- Improve production layout and minimize investments
- Machines and equipment are in the right place
- Sufficient material handling equipment available
- Optimized buffer dimensions
- Product handling is kept to a minimum

Modeling and simulation techniques enable dynamic analysis to ensure that plant design problems and waste are discovered before the company ramps up for production. Further simulation technology ensures in advance of the start of production, that the factory hits the demands for efficient operations.

Factory layouts can be analyzed in a first step by using part routing information, material storage requirements, material handling equipment specifications, and part packaging information. The shortest distance between any two points the closest incoming dock and storage area to a part's point of use have to be identified.

Material flow studies have to be performed on alternate layout configurations and layout options are compared in order to find the best layout to improve production efficiency. Enhancing the factory layout based on material flow distances, frequency and cost is a first step towards more efficient factory layouts, which directly result in reduced material handling and improved production outputs [Askin and Strandridge, 1993].

3. METHODOLOGY

The project is done by analyzing the factory layout of Block Capacitor department of Nichicon (M) Sdn. Bhd. Using appropriate software, the manufacturing lead time from current layout is acquired. Four proposed layouts are then being proposed to improve the current layout.

After reviewing all possible software that can be used to complete this project, Rockwell Arena software has been chosen. Arena software enables user to bring the power of modelling and simulation to the business. It is designed for analyzing the impact of changes involving significant and complex redesigns associated with supply chain, manufacturing, processes, logistics, distribution and warehousing, and service systems. Arena software provides the maximum flexibility and breadth of application coverage to model any desired level of detail and complexity.

Nichicon (M) Sdn. Bhd. is a capacitor manufacturer company originated from Japan. The company branch in Malaysia is situated in Bangi Industrial Area. Nichicon produced different sizes of aluminium electrolytic capacitors to meet different customer demand. Capacitors produced by Nichicon (M) are exported to Singapore, Hong Kong and United States. Nichicon (M) production capacity today has reached 247.6 million units per month.

Compared to other departments, Block Capacitor department of Nichicon (M) is a standalone department, which means that the department can run its own production and manufacturing activities without any help or interference with other department. The components of factory layout that will be taken into account for factory simulation modelling are as follows:

i. Complete department layout, including the distance between raw material storage with production area, distance between machines and distance between manufacturing areas with the warehouse.
ii. Machines production rates and capability.
iii. Raw materials and work part transfer.
iv. Daily production target.

4. RESULTS AND DISCUSSION

Factory layout comprises of the flow of product, from raw materials through the processes involved until the final product has been stored in the warehouse for shipment. Therefore, suitable factory layout is necessary to ensure that the raw materials will flow smoothly until they become the final products.

4.1 Existing Layout

Figure 1 shows the existing layout of Nichicon's Block Capacitor department.

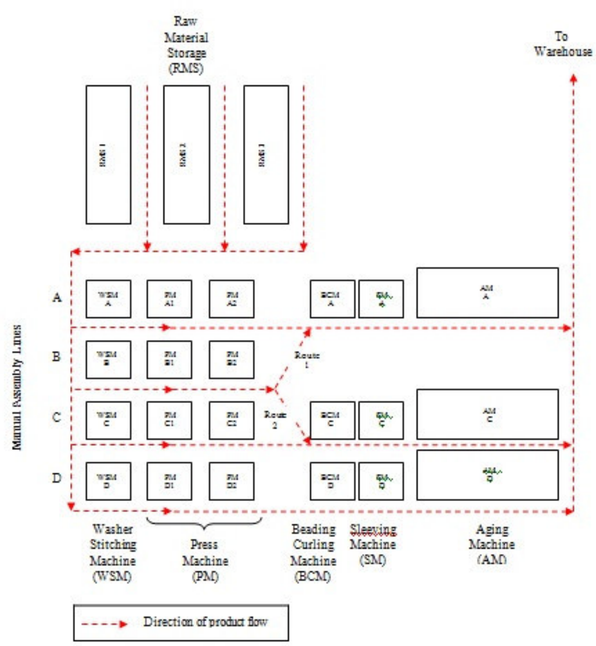

Figure 1: Existing Layout

From verbal communication with the Block Capacitor department manager, Mr. Haszaki Mohd and the technicians, two major weaknesses associated with the Existing Layout have been identified. The weaknesses of Existing Layout are:

i. The distance from the last manufacturing process which is the aging process is too far from the warehouse. This has resulted in a longer material handling time to transport the finished products to the warehouse.
ii. The products from Manual Assembly Line B are distributed to the next production processes in Line A and C since there are only three available production line for beading curling process, sleeving process and aging process. This has caused high level of delay at production

line A and C since both lines have to process the products from their subsequent line and also from line B. The products from Manual Assembly Line B are usually not being transferred to production line D due to its distance which is far compared to other lines.

Summary of Existing Layout calculations and values that will be used in factory layout simulation modelling is shown in Table 1.

Table 1: Summary of Existing Layout calculations

Description	Line A	Line B	Line C	Line D
Distance from Material Handling Raw Material Storage – Manual Assembly Line (s)	59.0924	60.77	64.4478	64.1255
Manual Assembly Process Setup Time (s)	600	600	600	600
Washer Stitching process (s)	3	3	3	3
Pressing process (s)	2	2	2	2
Pressing process (s)	2	2	2	2
Manual Assembly process Inspection (s)	300	300	300	300
Material Handling Manual Assembly Line – Beading Curling Machine (s)	1.4913	2.2447	1.4913	1.4913
Beading Curling process Setup time (s)	60		60	60
Beading Curling process (s)	1		1	1
Sleeving process (s)	1		1	1
Material Handling Beading Curling Machine – Aging Machine (s)	2.2369		2.2369	2.2369
Aging Process Setup time (s)	60		60	60
Aging process (s)	1		1	1
Material Handling Aging Machine – Warehouse (s)	44.1790		47.5349	49.2126

The simulation result for Existing Layout is as shown in Figure 3. From the figure shown, the total time required by Existing Layout to run into completion is 4.1762 hours.

4.2 Proposed Layout 1

After reviewing the Existing Layout, it is noted that the layout has some weaknesses as has been discussed earlier. Therefore, four alternative layouts have been introduced and modelled to improve the current Existing Layout. Proposed Layout 1 is as shown in Figure 2.

The modifications to Existing Layout that have been applied to the Proposed Layout 1 are:

i. For each batch of production, the workers need to collect raw materials from the Raw Material Storage since each production batch specifications are different with others. The arrangement is made to reduce the distance from Raw Material Storage to the Manual Assembly Lines.

ii. The beading curling and sleeving machine are organized so that their positions are in between two manual assembly lines. This is done so that the distance from manual assembly line to the beading curling machine is the same for all lines.

iii. The position of aging machines which is the last manufacturing process is located closer to the warehouse. This is done to reduce the material handling time to transport finished product from aging machine to the warehouse.

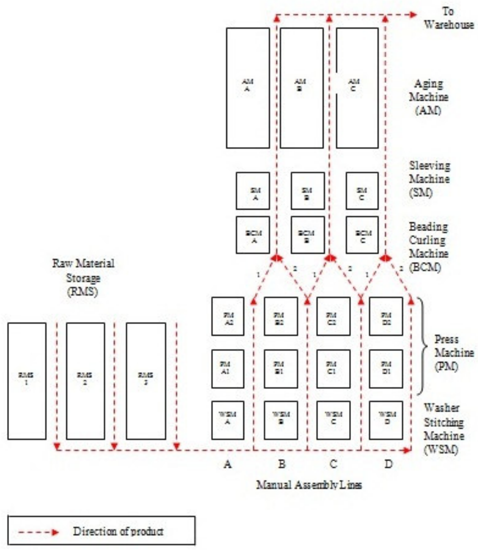

Figure 2: Proposed Layout 1

The summary of calculations and values that will be used for simulation modelling is as shown in Table 2.

Table 2: Summary of Proposed Layout 1 calculations

Description	Line A	Line B	Line C	Line D
Material Handling Raw Material Storage – Manual Assembly Line	39.3328	41.0105	42.6882	44.3659
Manual Assembly Process Setup Time	600	600	600	600
Washer Stitching process	3	3	3	3
Pressing process	2	2	2	2
Pressing process	2	2	2	2
Manual Assembly process Inspection	300	300	300	300
Material Handling Manual Assembly Line – Beading Curling Machine	1.5927	1.5927	1.5927	1.5927
Beading Curling process Setup time	60	60	60	
Beading Curling process	1	1	1	
Sleeving process	1	1	1	
Material Handling Beading Curling Machine – Aging Machine	1.4913	1.4913	1.4913	
Aging Process Setup time	60	60	60	
Aging process	1	1	1	
Material Handling Aging Machine - Warehouse	41.7561	40.0784	38.4007	

The simulation result for Proposed Layout 1 is as shown in Figure 5. From the figure shown, the total time required by Proposed Layout 1 to run into completion is 4.1697 hours.

4.3 Proposed Layout 2

Proposed Layout 2 is almost similar to Proposed Layout 1 except that the position of beading curling machine, sleeving machine and aging machine is slightly different. The Proposed Layout 2 is as shown in Figure 6.

Modifications made to Proposed Layout 2 is the same with that of Proposed Layout 1 except that the flow of products from manual assembly lines to beading curling machines is made slightly different as can be seen in Figure 3. The modification to the product flow is made to reduce the distance from aging machine to the warehouse.

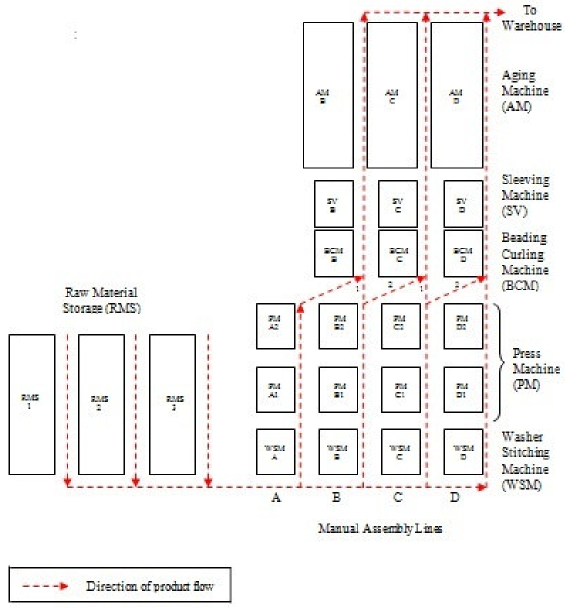

Figure 3: Proposed Layout 2

Summary of Proposed Layout 2 calculations and values are shown in Table 3.

Table 3: Summary of Proposed Layout 2 calculations

Description	Line A	Line B	Line C	Line D
Material Handling Raw Material Storage – Manual Assembly Line	39.3328	41.0105	42.6882	44.3659
Manual Assembly Process Setup Time	600	600	600	600
Washer Stitching process	3	3	3	3
Pressing process	2	2	2	2
Pressing process	2	2	2	2
Manual Assembly process Inspection	300	300	300	300
Material Handling Manual Assembly Line – Beading Curling Machine	2.2447	Route 1: 1.4913 Route 2: 2.2447	Route 1: 1.4913 Route 2: 2.2447	1.4913
Beading Curling process Setup time		60	60	60
Beading Curling process		1	1	1
Sleeving process		1	1	1
Material Handling Beading Curling Machine – Aging Machine		1.4913	1.4913	1.4913
Aging Process Setup time		60	60	60
Aging process		1	1	1
Material Handling Aging Machine - Warehouse		40.6377	38.96	37.2823

The simulation result for Proposed Layout 2 is shown in Figure 7. From the figure shown, the total time required by Proposed Layout 2 to run into completion is 4.1693 hours.

4.4 Proposed Layout 3

Proposed Layout 3 is designed with an arrangement similar to Proposed Layout 1, except that the position from Raw Material Storage, Manual Assembly Lines, Beading Curling Machine, Sleeving Machine and Aging Machine is different. Figure 4 shows the Proposed Layout 3 and from the figure, it is highly noticeable that the layout is similar to Proposed Layout 1 in term of its arrangement but different in its orientation.

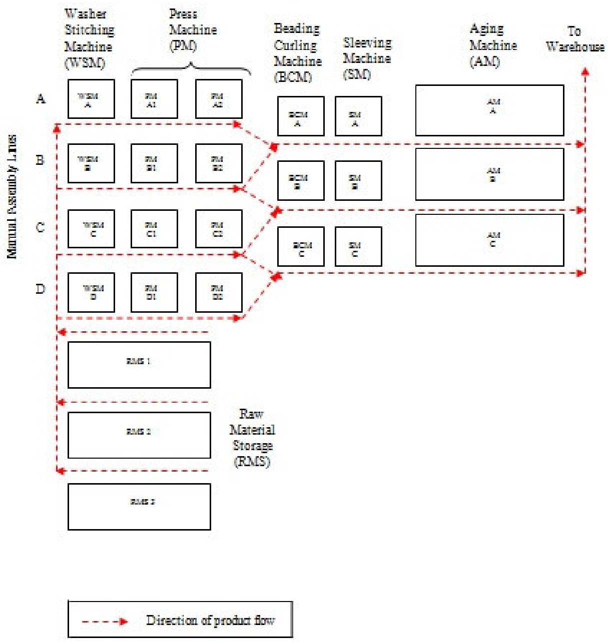

Figure 4: Proposed Layout 3

Summary of Proposed Layout 3 calculations and values are shown in Table 4.

Table 4: Summary of Proposed Layout 3 calculations

Description	Line A	Line B	Line C	Line D
Material Handling Raw Material Storage – Manual Assembly Line	42.3154	40.6377	38.9599	37.2823
Manual Assembly Process Setup Time	600	600	600	600
Washer Stitching process	3	3	3	3
Pressing process	2	2	2	2
Pressing process	2	2	2	2
Manual Assembly process Inspection	300	300	300	300
Material Handling Manual Assembly Line – Beading Curling Machine	1.5927	1.5927	1.5927	1.5927
Beading Curling process Setup time	60	60	60	
Beading Curling process	1	1	1	
Sleeving process	1	1	1	
Material Handling Beading Curling Machine – Aging Machine	1.4913	1.4913	1.4913	
Aging Process Setup time	60	60	60	
Aging process	1	1	1	
Material Handling Aging Machine - Warehouse	39.1464	41.3833	43.6203	

The simulation result for Proposed Layout 3 is shown in Figure 9. From the figure shown, the total time required by Proposed Layout 3 to run into completion is 4.1703 hours.

4.5 Proposed Layout 4

Another layout designed to improve the current factory layout is Proposed Layout 4 which is shown in Figure 5. Proposed Layout 4 is similar to Proposed Layout 3 except that the product flow from manual assembly lines to the beading curling machine is slightly different.

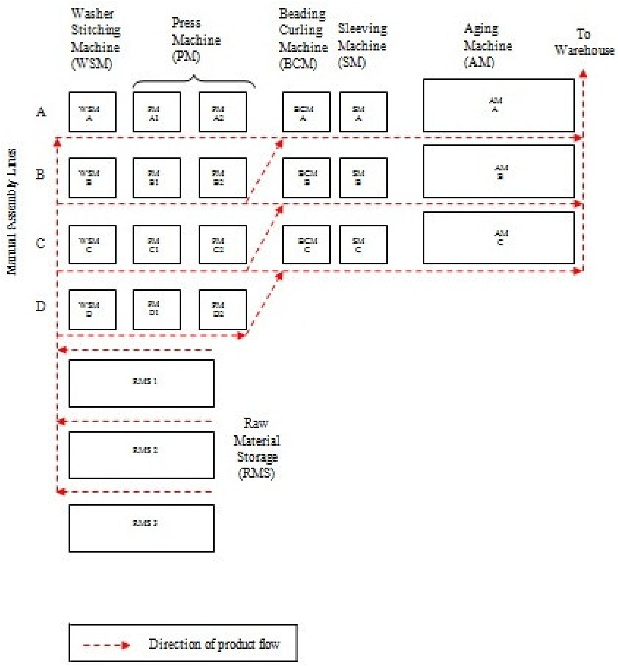

Figure 5: Proposed Layout 4

Summary of Proposed Layout 4 calculations and values are shown in Table 5.

Table 5: Summary of Proposed Layout 4 calculations

Description	Line A	Line B	Line C	Line D
Material Handling Raw Material Storage – Manual Assembly Line	42.3154	40.6377	38.9599	37.2823
Manual Assembly Process Setup Time	600	600	600	600
Washer Stitching process	3	3	3	3
Pressing process	2	2	2	2
Pressing process	2	2	2	2
Manual Assembly process Inspection	300	300	300	300
Material Handling Manual Assembly Line – Beading Curling Machine	1.4913	Route 1: 1.4913 Route 2: 2.2447	Route 1: 1.4913 Route 2: 2.2447	2.2447
Beading Curling process Setup time	60	60	60	
Beading Curling process	1	1	1	
Sleeving process	1	1	1	
Material Handling Beading Curling Machine – Aging Machine	1.4913	1.4913	1.4913	
Aging Process Setup time	60	60	60	
Aging process	1	1	1	
Material Handling Aging Machine - Warehouse	41.7561	40.0784	38.4007	

The simulation result for Proposed Layout 4 is shown in 11. From the figure shown, the total time required by Proposed Layout 4 to run into completion is 4.1703 hours.

4.6 Discussion

From the simulation results obtained, the total run time of all four layouts were compared. This comparison is shown in Table 6.

Table 6: Comparison of simulation results

Layout	Total run time (in hours)	Time difference compared to Existing Layout (in hours)	Time difference compared to Existing Layout (in seconds) for 3000 units	Total time difference compared to Existing Layout for output target of 15000 (in seconds)	Percentage of time difference compared to Existing Layout (%)
Existing	4.1762				
Proposed 1	4.1697	0.0065	23.40	117.0	0.78
Proposed 2	4.1693	0.0069	24.84	124.2	0.83
Proposed 3	4.1703	0.0059	21.24	106.2	0.71
Proposed 4	4.1703	0.0059	21.24	106.2	0.71

From the results comparison above, Proposed Layout 2 showed total run time of 4.1693 which is the shortest time for the simulation to complete. This means that Proposed Layout 2 yield the most reduction in manufacturing lead time compared to Existing Layout as well as other proposed layouts. The time difference for Proposed Layout 2 is 24.84 seconds compared with the Existing Layout for one batch of 3000 pieces of capacitors. For full daily target output of 15000 pieces of capacitors, the time difference is 24.84 x 5 = 124.2 seconds. Dividing 124.2 seconds with the total run time for Existing Layout in seconds which is 4.1762 x 60 x 60 = 15034.32 seconds gives a percentage of time difference of 0.83 %.

Even though the percentage of time difference is low, it can still contribute to higher production compared to Existing Layout. As for the difference of production that can be achieved, the calculations are shown as follows:

Percentage of difference = 0.83%
Total daily output target = 15000 x 4 assembly lines
= 60000 units of capacitors

Assumption: The production time is the same with the amount of total run time taken by Existing Layout to complete the production of daily target output of 60000 = 4.1762 hours.

Difference in total unit of capacitors produced
= 0.0083 x 60000
= 498 units of capacitors

Nichicon working time consists of two shifts a day with 12 hours of working time for each shift. The calculations shown before are only for a single shift. Taking consider the total shift in a day which is two, the total difference in capacitors produced if modifications of layout is made according to Proposed Layout 2 is:

Total unit of capacitors produced for two shifts
= 498 x 2
= 996 units of capacitors

In term of difference in gross profit gained, taking the average capacitors price of RM 10.00 per unit, the total gross profit that can be increased by Proposed Layout 2 is:

Total gross profit made by Proposed Layout 2
= 996 x 10
= RM 9960.00

From the calculations above, it is proved that Proposed Layout 2 contributed not only reduction in manufacturing lead time, but also an increase of 996 units of capacitors produced and a gross profit of RM 9960.00.

5. CONCLUSION

After the project has been completed, initial objectives must be reviewed to ensure that the project was done correctly and stayed on track to achieve the objectives. Reviewing the first objective which is to model and analyze the layout of a factory using computer simulation, this objective has been satisfied by modelling of capacitor manufacturing processes in which the actual data was acquired from Nichicon (M) Sdn. Bhd. Actual data received from the company includes factory layout for Block Capacitor Department, processes involved in capacitor manufacturing, machine production rate and daily production target. This project is not only able to model and analyze layout of the factory, but also managed to come out with proposed layouts and configurations for the purpose of comparison and improvement. After the layout of Nichicon's actual data has been modelled using the Arena software, input from the actual data such as machine production rate, material handling time and machine setup will be used by the software to analyze the time for a batch of capacitors from raw materials going through all the production processes until they become the final product and being sent to the warehouse. At the end of the simulation, the user will be informed with the time taken for a selected layout to complete a batch of capacitor production.

For the second objective which is to utilize the factory simulation and verify that proposed modifications will result in reduction of manufacturing lead time, as had been mentioned earlier, besides modelling and simulating the actual data layout of Nichicon's Block Capacitor Department, four alternative layouts have also been developed to compare with the actual data layout. After going through the simulation and post-simulation analysis, it has been proved that all proposed alternative layouts achieve lower manufacturing lead time in which Proposed Layout 2 yield the lowest manufacturing lead time and improve the daily production capacity by 0.83%. Further analysis also showed that the improvement has contributed to addition of 996 units of capacitors produced and in term of gross profit, a total of RM 9960 is achieved.

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