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Original Article

Using ProModel as a simulation tools to assist plant layout design and planning: Case study plastic packaging factory

Pochamarn Tearwattanarattikal*, Suwadee Namphacharoen and Chonthicha Chamrasporn

Department of Production Engineering , Faculty of Engineering,
King Mongkut's University of Technology Thonburi
Bangmod, Thung Khru, Bangkok, 10140 Thailand.

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Abstract

This study is about the application of a Simulation Model to assist decision making on expanding capacity and plant layout design and planning. The plant layout design concept is performed first to create the physical layouts then the simulation model used to test the capability of plant to meet various demand forecast scena. The study employed ProModel package as a tool, using the model to compare the performances in term of % utilization, characteristics of WIP and ability to meet due date. The verification and validation stages were perform before running the scenarios. The model runs daily production and then the capacity constraint resources defined by % utilization. The expanding capacity policy can be extra shift-working hours or increasing the number of machines. After expanding capacity solutions are found, the physical layout is selected based on the criterion of space available for WIP and easy flow of material.

Keywords: Simulation, utilization, capacity constraints

1. Introduction

Simulation technique is a tool for analyzing and testing solutions before implementing in the real system. As computer, because more powerful, so the use of simulation techniques as a tool for research and solving problems became more popular.

Concept of simulation technique is to imitate the real system as a model and after that use the model to work in many conditions and study the effects to evaluate the solution strategies for the real system. Since the simulated model will show the results and the side effect of different conditions as assumption in testing stage of the simulation model. These outcomes help the analyzer better understand the transient stage of the system and predict the effects that showed occurr during changing the system.

*Corresponding author.
Email address: ipocasdi@kmutt.ac.th

This study concernes the case of Plastic Packaging Company which plans to move to a new plant area. They have a fixed area to set up, and they also have forecast demand for next ten years to run a business in this factory. The owner knows that the expanding production capacity is necessary to run the future business also the new plant will run the new type of packaging product. They would like to lay out the plant in the best way far to handle the future changes. They also need to have a nice layout in term of good flow of material and production methods. Since the size of factory area is the constraint for designing the new plant, the simulation model will use to run various scenarios to see what the effects are and which layouts are affected in which conditions and parameters. In this way, the optimum layout for new plant can be identified.

Starting with plant layout designing stage, the physical alternative layouts were created and compared to investigate the optimum layout in material flow and space requirement in each stage of capacity expansion using ProModel simulation running scenarios. Other objectives of the study can be summarized as follows:

- To determine the capacity constraints of the production and the relevant effect of moving capacity constraints in each expanding capacity stage
- To maximize the space utilization in advance considering with the space requirement in the future stage
- To provide the guideline of capacity expansion between using the alternatives of extra working hours or increasing machines

The existing manufacturing system, for plastic packaging, in the current factory has much transportation waste since the layout of the process is limited by the area and the layout was not designed according to minimize internal process transportation.

The new plant is designed using the systematic layout planning approach (Francis and White, 1974); in addition some area is previously fixed because of the size of machines and government rules. Each alternative layout was designed under the following properties:

- Blown Film Extrusion Machine must be placed at the right side of the area which is the starting point of the process. This area is constrained by the height of the machine which need the higher roof construction.
- Because of the hygiene production rule the factory must be a closed environment, therefore the gate for worker will be placed at one point which was previously located at the lower-right corner of the area.
- The printing and laminate steps will be placed in the closed environment because of the hygiene and the safety requirements. This section is closed by a fire-resistant wall then the size of this area need to be considered for future expansion, which will require space to place the extra Automatic Printing Machine and Laminating Machine.
- The rest of production area accommodates all the rest of machines, which are Seal and Gusset Machine, Slitting Machine, Cutting Machine, Roll Rewinding Machine (for inspection), and the inspection section. The last section will be the packing and finished product warehouse and loading area.
- The testing labs and offices will be placed on the mezzanine floor, which will be excluded from the model study.

2. Design of the study

To achieve the objectives of the study, the requirement of the following three steps were sequentially satisfied:

1. Physical alternative layouts of machines and working sections were designed under the current manufacturing system by considering the activities associated with production (Dileep, 1994). From these data, the physical layouts can be designed by using plant layout concept to determine the process areas and locations (Tompkins *et al.*, 1996)
2. Using simulation model to study and analyze to determine the plant performance according to the predetermined performance measures.
3. Alternative layouts were compared in terms of capability of plant to satisfy the forecast demand in next ten-years.

3. Physical Layouts

Assumptions and constraints for designing the physical alternative layouts are as follows:

- The supporting units' space requirement are predetermined based on the current system and were assumed constant in time horizon
- As mentioned earlier Blown Machines and enter-exit gate are pre-located and have fixed the locations
- Using the relation between the processes to determine their locations as displayed in Figure 1 and Figure 2

The differences between these two layouts are;

	Layout alternative 1	Layout alternative 2
Raw material space	Estimated area = 864 m^2	Estimated area = 288 m^2
Post cast area	Estimated area = 3,240 m^2	Estimated area = 3,960 m^2
Pre cast area	Estimated area = 2,880 m^2	Estimated area = 2,160 m^2

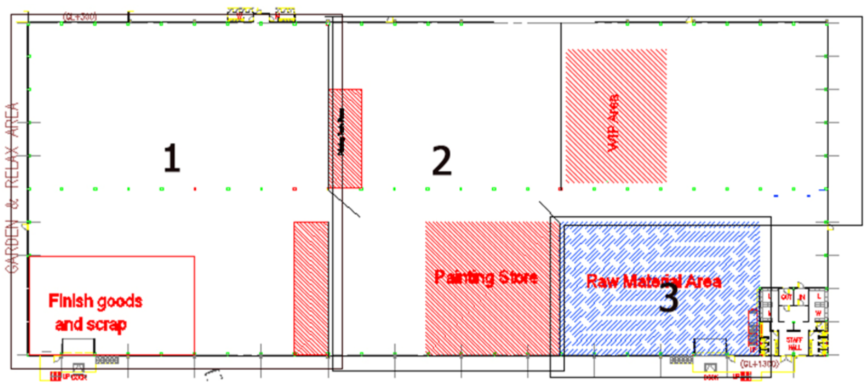

Figure 1. Physical layout alternative 1

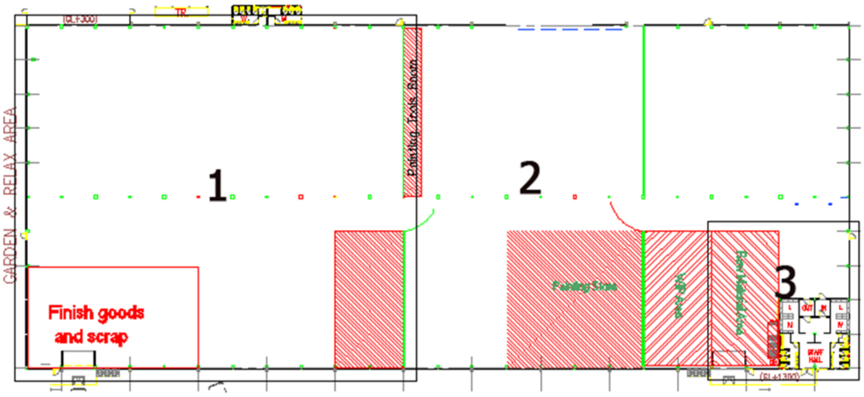

Figure 2. Physical layout alternative 2

The raw material store space in alternative plant 2 may acquire the company to set up a second warehouse for raw material outside the plant.

4. Model and Simulation

4.1 Assumptions of the model:

- Setup time, load or unload time, and processing time are average and constant for all processes
- 10-year demand forecast converted to equal monthly demand of each product type and plotted into a production plan for model testing
- Scheduling for production of all products is random and planned to meet lead time for one month
- Hours of working conditions are as follows
  - 8 hours: working 8 hours per shift
  - 10 hours: working 8 hours for regular plus 2 hours as overtime per shift
  - 16 hours : working 8 hours per shift and working 2 shifts per day
  - 20 hours : working 8 hours for regular plus 2 hours as overtime per shift and working 2 shifts per day
  - 6 days : working for 6 days and off for one day
  - 7 days : working every day using alternate workers to continue tasks

4.2 Performance measures

- Completion period : The due date of overall demand used as a limitation for production during the test of capacity feasibility.
- Resources utilization : The utilization of each machine can foresee the situation of the manufacturing requirement to increase capacity. When the utilization of resources reachs 80% assuming the expansion capacity is needed, the criteria are the company predetermined policy.
- WIP's characteristics: Behavior of WIP can determine the capacity constrained machines and guide line for space requirement for necessary WIP.

Simulation runs were conducted based on the design plans shown in Table 1

Plans are designed under the circumstances of the factory which forecasts and determines the future machine requirements focusing on feasible capacity and space requirements of the new plant.

Since the number of items affects capability of the printing process, the printing machine has to use at least 5 hours for setup even the improvement to reduce setup time is in progress but in this simulation we will assume a pessimistic view to study the capability of printing process, which will fix the setup time as 5 hours during the time horizon. In case the improvement is successful the capacity of the

Table 1. Plans are designed based on monthly demand of each product items in each time horizon

Plan	Number of Product Items	Quantity of each product items (m)			
		A	B	C	D
1	58	4,567,989	1,281,599	39,886	49,858
2	58	5,600,051	1,562,100	49,858	69,801
3	58	6,838,523	1,876,455	79,772	179,488
4	58	7,655,197	2,328,642	119,659	239,318
5	82	4,603,887	1,271,926	39,886	49,858
6	82	5,626,973	1,588,700	49,858	69,801
7	82	6,838,523	1,951,416	79,772	179,488
8	82	7,700,069	2,364,913	119,659	239,318

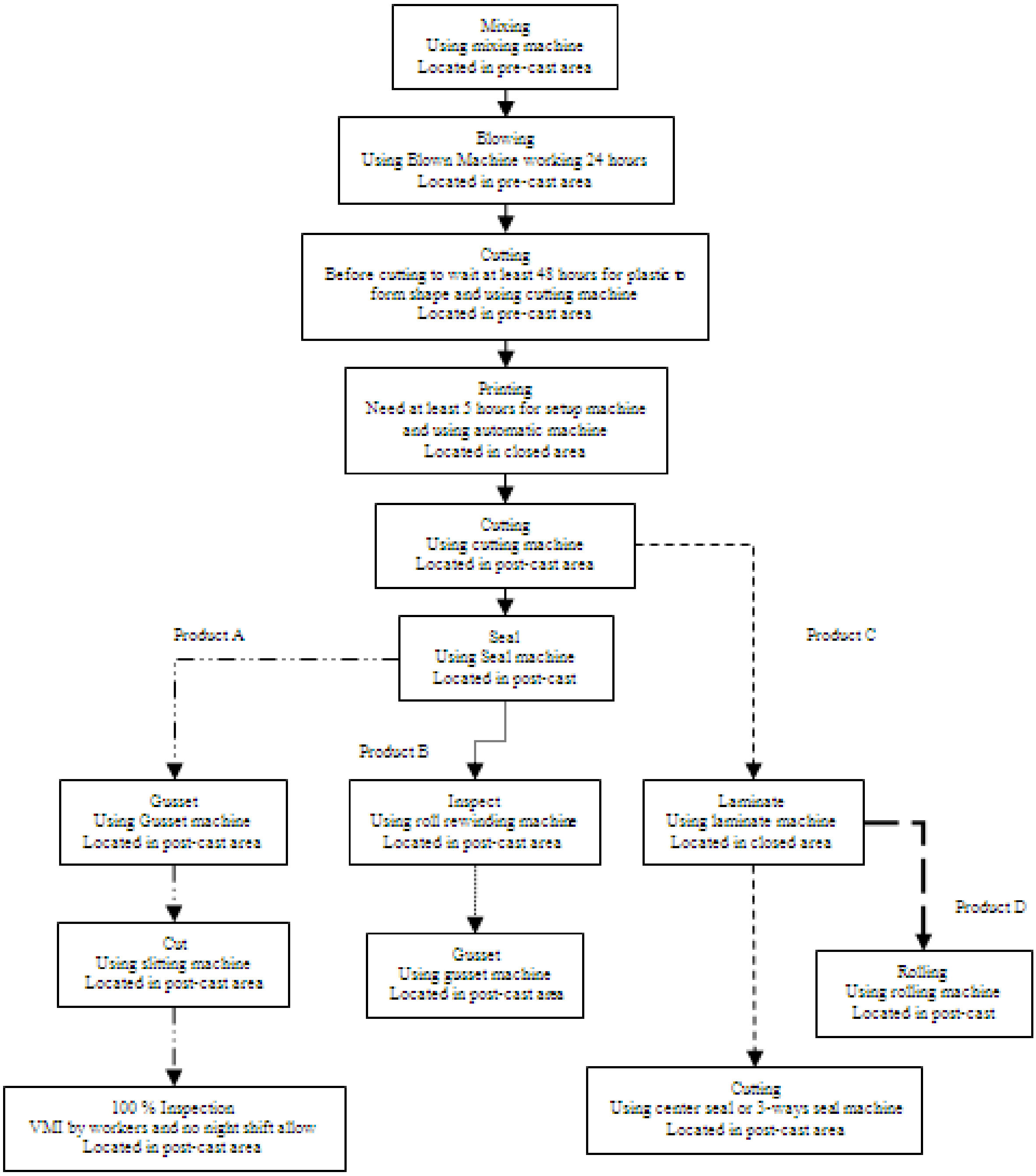

Figure 3. Process Flow of Product A - Product D

printing process will automatically increase.

The possible numbers of items are 58 and 82, derived from the past data, and are the average items and the maximum items produced in the existing plant.

Plans 1-4 are the demand forecast in year 1, year 3, year 5 and year 7, respectively, also plan 5-8 have the same meaning. The difference among eight plans is that the first four plans are created under situation producing 58 items and the last four plans under that producing 82 items in one month.

4.3 Simulation Model

The model places the machine location according to the physical layout and creates the process flows of each product as follows the flow chart in Figure 3.

The model requires four modules to supply all the input data required to perform the simulation experiment (Figure 4):

Capacity Inputs: The information provided in this module indicates the number of machines in each process

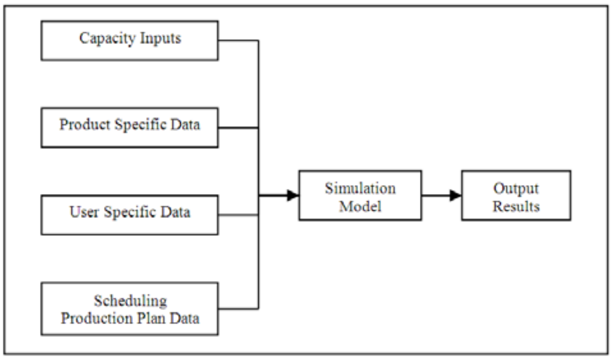

Figure 4. Simulation Model Data Flow

and the schedule cycles of workers to operate. These aids in determining the amount of "capacity" should be in each time horizon.

Product Specific Data: Data required processing each product type such as setup, load-unload time, production rates, processing batch size, and flow line.

User Specific Data: The user has ability to customize the simulation experiment by changing certain requirement in the model, such as shifts open of each process.

Scheduling Production Plan Data: The sequencing time table of product items for production to follow, this aims to find the ability of the plant to complete the demand within the limitation period, one month.

5. Simulation Experiment

5.1 Output Analysis

The simulation model was built using ProModel software package and the simulation output exported Microsoft Excel spreadsheets.

Since outputs of plans 5-8 have the same characteristics as plans 1-4, so the discussion will cove only outputs of plans 1-4.

The simulation output is used to determine if the capacity of production and the sequence of scheduled products are feasible or not in each time horizon. The WIP storage space requirement according to the WIP behaviors, shown in Table 3, was obtained by analyzing the number of WIP occurring in each plan. Table 2 shows the utilization of each process and is used for determining the expansion capacity.

From utilization results the projection of capacity expansion is focused on printing machines. The printing process has great effect in the overall production line and because of the policy limiting the number of printing machines which is fixed through the time horizon. The simulation results show that the printing machines can be used up to year 7 with a few capacities left for extra demand in the next year, but the improvement in the utilization of printing machines is in reducing setup time.

The second alternative of capacity expansion is using extra shifts, in which the number of machines and utilization results remain constant eventhough the demand is increased. Printing machine is an example of this case which test runs result shown that utilization decreased when demand increased without adding more machines.

As part of the planning process, the simulation outputs are also used to help design the space allocation for WIP storage. The ability to analyze the fluctuation of WIP inventories (Figure 5) is used to determine the size of space that needs to be allocated in plant layout.

Table 2. Utilization of each process step and adjusted capacity according to plan 1-4

Machine/process step	% Utilization							
	# M/C	Plan 1	# M/C	Plan 2	# M/C	Plan 3	# M/C	Plan 4
Blowing	3	61.38	3	68.80	3	56.06	3	66.95
Cutting (after blowing)	1	94.32	1	97.29	2	56.15	2	66.37
Printing	5	99.16	5	73.95	5	70.80	5	79.95
Cutting	2	89.49	2	99.24	3	81.65	3	94.84
Seal for product A	6	88.62	6	97.21	9	84.45	12	75.57
Seal for product B	3	55.98	3	60.71	3	63.41	4	51.28
Gusset type 1	4	87.39	4	98.28	4	93.82	4	94.80
Gusset type 2	9	90.52	11	98.49	14	93.74	16	95.33
Gusset for product B	1	84.66	1	97.99	1	94.10	1	93.99
Roll rewinding	7	86.34	8	98.65	12	73.37	12	88.11
Rolling	3	59.68	3	77.38	3	71.10	5	58.18
Laminate	2	7.81	2	10.73	2	23.36	2	32.60
3-ways seal	3	5.19	3	7.48	3	17.29	3	23.49
Center seal	2	3.50	2	5.05	2	15.74	2	21.93
Slitting type 1	2	38.24	2	50.55	2	71.40	2	66.04
Slitting type 2	5	56.54	5	69.74	5	86.76	5	87.25

Table 3. Maximum WIP in each area of each plan

Category	Maximum possible number (rolls)			
	Plan 1	**Plan 2**	**Plan 3**	**Plan 4**
Waiting for cutting (after blowing)	400	400	116	116
Waiting for printing	375	96	615	565
Waiting for cutting (after printing)	40	120	431	594
Waiting for laminate	8	22	56	72
Waiting for center seal or 3-ways seal	2	2	3	4
Waiting for seal (both product A and B)	83	96	405	89
Waiting for Roll rewinding	33	85	38	58
Waiting for gusset both type 1 and 2	60	201	499	259
Waiting for Slitting both type 1 and 2	45	67	309	249
Waiting for gusset for type B	115	155	205	181
Total WIP of Product A in post cast area	150	380	770	332
Total WIP of Product B in post cast area	162	211	409	298
Total WIP of Product C in post cast area	8	16	20	26

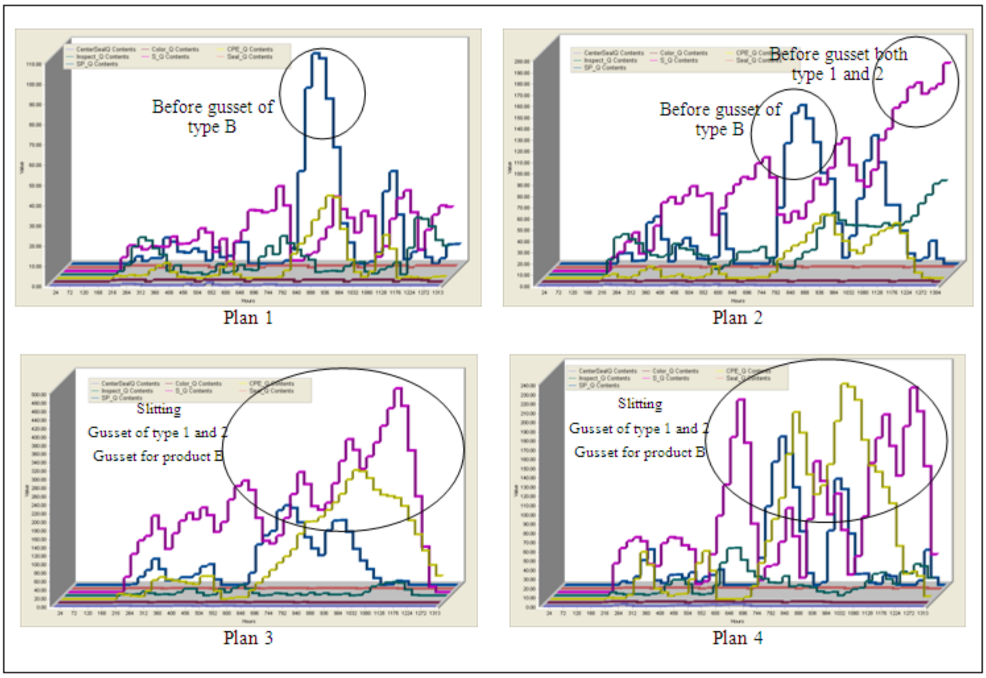

Figure 5. the WIP fluctuation in each process step of plan 1-4

5.2 Validation and Verification

Validation and verification evidence was gathered from the simulation results for the run simulating 30 days of activities. Since this was a closed queuing network there were no new entities entered or leaf the system except the entities indicated to ship-out from the plant as finished goods. The simulation output was verified by using a constant number to check with the summation of processing time of one flow line equal to simulation running result in order to make sure that model represented the real production system.

6. Conclusion

The detailed layouts of this company are displayed in Figures 6 and 7, the difference between the two layouts is free space to place WIP and the effects are internal transportation for the worker, for which Layout 2 (Figure 7) are more competencies in these points.

This simulation application provided a projection layout design and planning solutions for the plastic packaging company. In conjunction with the capacity planning process, the simulation model was able to validate the production sequencing and scheduling plans of all 4 products to

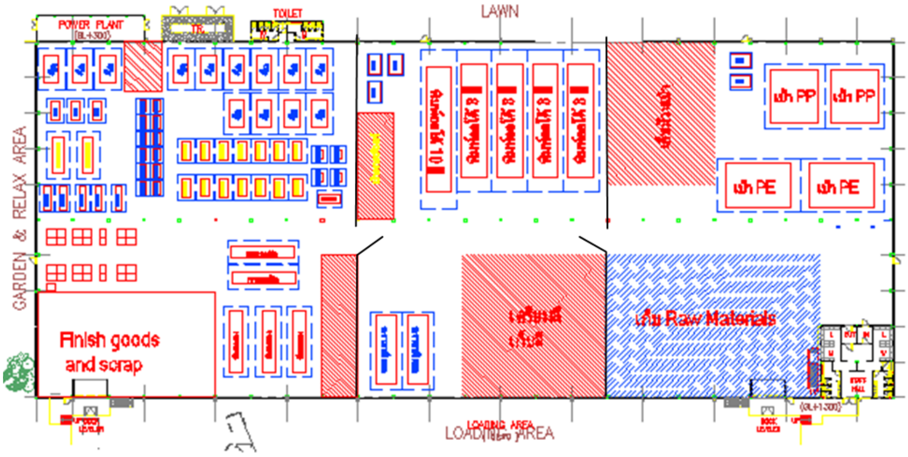

Figure 6. Plant Layout 1, based on physical layout alternative 1

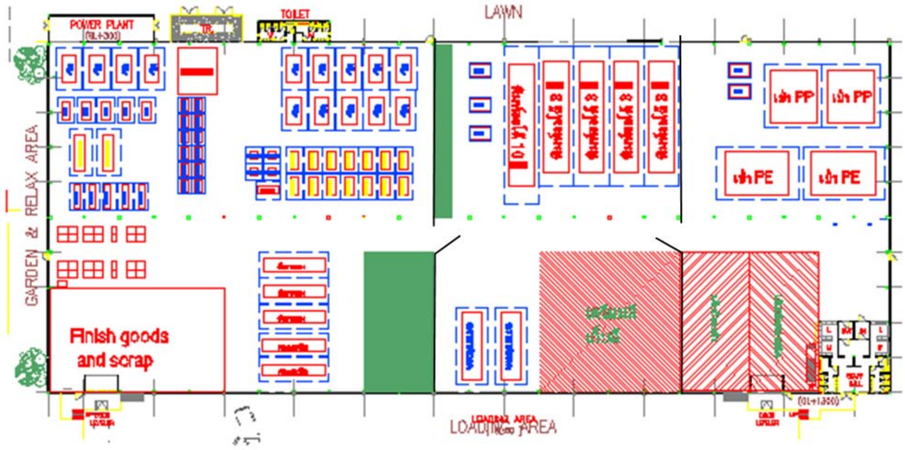

Figure 7. Plant Layout 2, based on physical layout alternative 2

meet the one-month due date. The production planners are also able to use the model to perform "what-if" scenarios to determine where to focus in the expansion capacity planning. The development of the simulation model is meant to provide a planning tool that provides not only the ability to determine if the capacity planning process is valid but also the ability to project the situations and constraints which effects the demand expansion (Joseph, 2001); to identify problems that may cause strategic decision making issues, and to evaluate the impact of continuous improvement efforts.

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