Chapter III

LAYOUT DESIGN

3.1 Introduction

To improve the process layout, the traditional schematic technique of Muther and Apple (1) is implemented. The result of this technique is the problem summary of the current layout including their priorities. Additionally, the alternative solutions should be suggested to correct them. There are 5 main steps in this technique as shown in Figure 3-1:

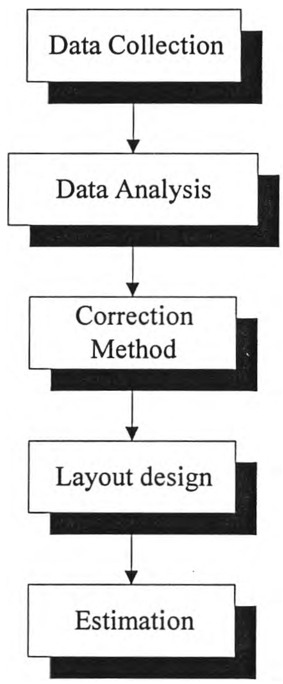

Figure 3-1: Traditional Schematic Technique of Muther and Apple

3.2 Data Collection

3.2.1 Introduction of Factory

Rianthai Interplas Company has 4 production factories. In this study, one of all factories will be the case of our study. This factory will be called as factory A.

The main product of this company is plastic packaging. This company also provides wide range of products with different types of materials to suit each client's requirements. The main products consist of:

ξ Bottle, jar, and extrusion blow molded tube: materials used include PE, PVC, PET, PETG and PC.

ξ Cap and plug: PP and SAN are materials used for caps. LDPE is used for plugs.

This company shares the production among the affiliated plants, based on their facilities and capacities. The factory A consists of the Extrusion Blow Molding machine, Injection Stretch Blow Molding machine, Injection Molding machine, Printing machine and Labeling machine. It is assigned to fulfill the products by considering its production process. The following products are produced in factory A:

(1) Bottle produced by the Extrusion Blow Molding machine, Printing machine and labeling machine. It's called as product A.
(2) Bottle produced by the Extrusion Blow Molding machine and Labeling machine. It's called as product B.
(3) Bottle produced by the Injection Stretch Blow Molding machine, Printing machine and labeling machine. It's called as product C.
(4) Bottle produced by the Injection Stretch Blow Molding machine and Labeling machine. It's called as product D.
(5) Cap produced by the Injection Molding machine. It's called as product E.

Most of the bottle sizes are 100, 200, and 300 ml.

3.2.2 Factory under Study

Factory A has 7 stations and one warehouse. The machine tools are grouped in each station by considering its function. To be convenience for further analysis, the number will be used instead of the name of stations as follows:

(1) Station 1: It consists of 2 injection stretch blow molding machines. Its function is to produce the bottle with injection stretch method.
(2) Station 2: It consists of 2-extrusion blow molding machines. Its function is to produce the bottle with extrusion method.
(3) Station 3: It consists of 2 injection-molding machines. Its function is to produce cap with injection method.
(4) Station 4: It consists of 2 printing machines. Its function is to print information on the bottle.
(5) Station 5: It consists of 2 labeling machines. Its function is to label the sticker on the bottle.
(6) Station 6 and 7: Normally, it consists of 6 staffs being responsible for checking the product quality and packaging the product into the box respectively.

Moreover, there is the additional function in each station except the station 6. This function is to check the quality of its output.

3.2.3 Current Layout of Factory A

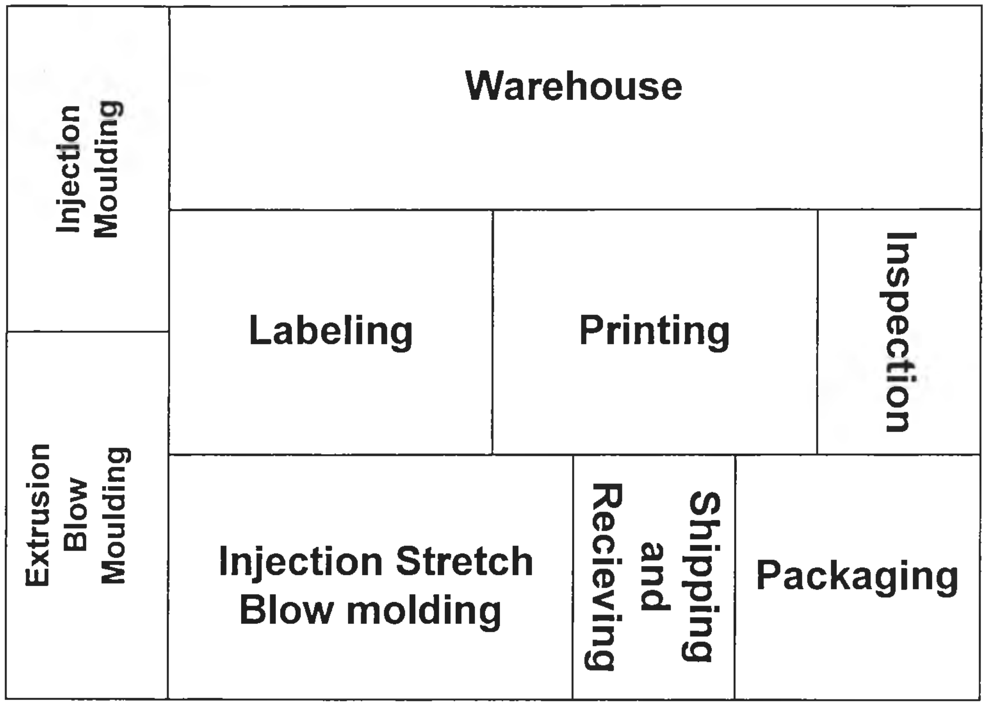

Figure 3-2: Outline of Plant A Layout

The next table shows the actual area of each station and the space used for machines and operation in each station.

Table 3-1: Area Requirement of Each Station

Station	Area	Availability
Injection	14* 7	70 %
Stretch	18 * 7	60 %
Extrusion	14 * 7	70 %
Labeling	7 * 14	70%
Printing	21 *14	70 %
Packaging	7 * 10	70 %
Inspection	14 * 7	60 %
Warehouse	35*7	40 %
Shipping	7 * 7	80 %

3.2.4 Description of Operation

1. Production Command Issuing

When an order is coming to the company, it will be transferred to the department concerned and technical department. In technical department, the paper slip of processing technique will be dispatched to warehouse and the station management. Paper slip of technique briefly contains the followings:

- Technique to process the product in details
- Type or code number of raw material
- Quantity of raw material
- Quantity of WIP per transporter
- Other necessary information

The production schedule almost follow FIFO rule. However, occasionally some orders will be treated as the special order.

2. Processing Routes of Each Product

In this section, the table of the processing routes of each product and the material flows are shown. The route to process the products are as follows:

Table 3-2: Processing Routes of Product A, B, C, D and E

Products	**Station**					
	1	2	3	4	5	6
A		a		c	b	d
B		a		b		c
C	a			c	b	d
D	a			b		c
E	a					

Note:
Processing sequence is according to alphabetical order

Legend:
Station 1: (Stretch blow molding machines)
Station 2: (Extrusion blow molding machines)
Station 3: (Injection molding machines)
Station 4: (Printing machines)
Station 5: (Labeling machines)
Station 6: (Inspection)
Station 7: (Packaging)
Mat: Material Warehouse
W: Warehouse
F: Finished Product Warehouse
S: Shipping and Receiving area

Material Flow of each product is shown in the figure below.

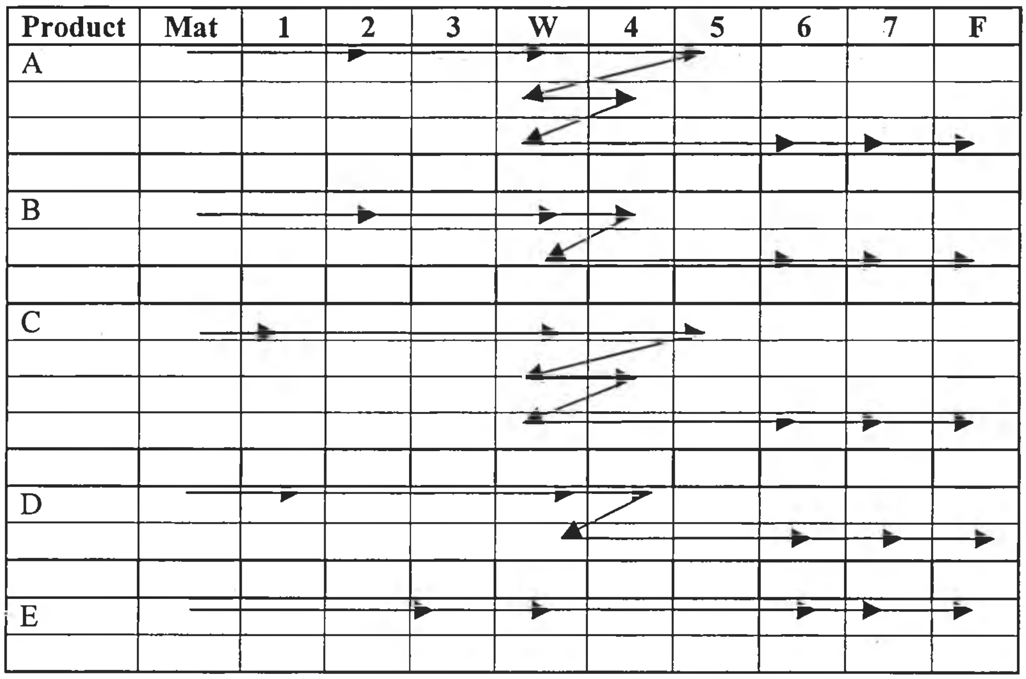

Figure 3-3: MPC of Product A, B, C, D and E

3. Material Handling

- Raw material, work-in-process and finished products will be transported between warehouse and station by a wheelbarrow.
- The inter-station moving is worked out by hand.
- The finished product is transported to the store where locates outside the plant A by a motor truck.

4. Quality Checking

As we said in the section 3.2.2, the quality checking is implemented in every station. Thus, it may mean that technical personnel always observe the products during processing in terms of quality. If there is anyone making mistake, they will be sent to the warehouse for the failure product immediately. The further process for the failure product is to melt them and to use the chemical process to extract the material, which can be used to produce the plastic product again.

5. Processing time

The time required for each machine to process a product might be constant or deterministic or random variable. For the automated machines, it's reasonable to assume a deterministic or constant processing time because the coefficient of variation of distribution would be quite small. In our factory, there are 4 stations using the automated machines. These stations are station 1, 2, 3 and 4. The table below shows the processing time in each station.

Table 3-3: Processing time of each station for product A, B, C, D and E

Product	pcs / hour / 1 machine						
	Station 1, 2 or 3			Station 5	Station 4	Station 6	Station 7
	100	200	300				
C	600	450	350	2950	2700	3500+/-50	3600+/-50
D	600	450	350	2950	2700	3500+/-50	3600+/-50
A	1160	1020	850	2950	2700	3500+/-50	3600+/-50
B	1160	1020	850	2950	2700	3500+/-50	3600+/-50
E	1800	1500	1200	2950	2700	4000+/-60	4000+/-60

6. Transportation

Raw material, work-in-process and finished products will be transported between warehouse and station by a wheelbarrow. The amount of them moved in 1 round depends on the size of product and its type.

Table 3-4: Number of WIP and Material moved in 1 round of Product A, B, C, D and E

WIP		Material	
	X100 pcs/1 move		X100 pcs/1 move
A-1	2.4	A-1	10
A-2	1.4	A-2	10
A-3	3	A-3	10
B-1	2.4	B-1	10
B-2	1.4	B-2	10
B-3	3	B-3	10
C-1	2.4	C-1	10
C-2	1.4	C-2	10
C-3	3	C-3	10
D-1	2.4	D-1	10
D-2	1.4	D-2	10
D-3	3	D-3	10
E-1	16	E-1	10
E-2	14	E-2	10
E-3	11	E-3	10

Legend:
A-1: Product A with size 100 ml.
A-2: Product A with size 200 ml.
A-3: Product A with size 300 ml.

B-1: Product B with size 100 ml.

B-2: Product B with size 200 ml.
B-3: Product B with size 300 ml.
C-1: Product C with size 100 ml.
C-2: Product C with size 200 ml.
C-3: Product C with size 300 ml.
D-1: Product D with size 100 ml.
D-2: Product D with size 200 ml.
D-3: Product D with size 300 ml.

7. Amount of product of each type

In this case, the amount of product of each type in 1 week is used. As a test with Chi-square test, the result obtained is that all of distribution of product amount in 1 week is the normal distribution. More details can be found in Appendix A-1.

Table 3-5: the Mean and S.D. of the Number of Products in 1 week

Product Type	Means (x1000 pcs)	S.D. (x 1000 pcs)
A-1	29.25	6.25
A-2	20.79	4.45
A-3	12.9	2.88
B-1	19.56	4.3
B-2	16.46	3.41
B-3	8.9	1.93
C-1	107.62	8.43
C-2	65.1	5.2
C-3	42.87	3.38
D-1	38.9	3.15
D-2	34.91	2.75
D-3	18.52	1.36
E-1	193.2	22.15
E-2	135.2	16
E-3	91.3	10.16

3.3 Data Analysis

3.3.1 Problem of Current Layout

As a result of analysis, we found the following problems:

1. High moving distance: Most of WIP can't be moved to next station suddenly but they are moved to warehouse and then moved to the next station because of high difference of the processing time of the stations. Thus, the total moving distance of production is high.
2. Number of Moving Rounds: Because of the same reason in item 1 and the size of orders, the number of Moving rounds is also high.

3. Continuation of Material Flow: Most of WIP can't be continued because the processing time of each station is high difference and the limitations of plastic production. One of the limitations of plastic production is long set-up time so that it's not convenience to swap the WIP of different products. Therefore, WIP must be stored in warehouse until the next station is idle.
4. Bottleneck: Sometimes, the big order can make the bottleneck in the system.
5. Cleanness and Perfect Order: We had ever found that the remains of insects affect the quality of the plastic product.

The figure below shows the priorities of these problems.

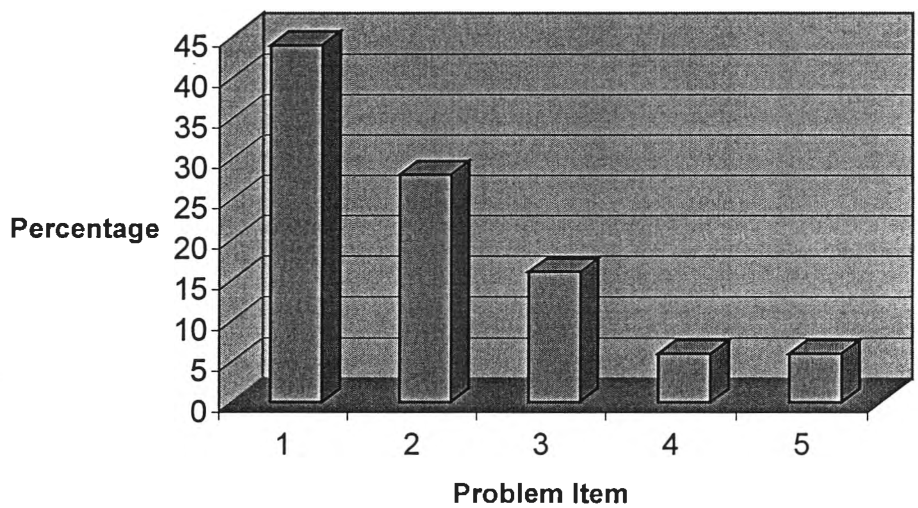

Figure 3-4: Problem of Current Layout in terms of Percentage

3.3.2 Alternative Solutions

According to Figure 3-4, the important problems of the current layout are item 1. To correct this problem, three solutions are provided to choose which one is appropriate in this situation.

1. Increase Machines: This solution can help reduce the moving distance because the processing time of each order will be reduced so the opportunity of idle station will increase. However, it's not appropriate when considering the machine cost. The price of the plastic production machine is expensive so that the management isn't interested in this solution.
2. Increase Transporter Capacity: At the moment, the capacity of transporter can is 240 pieces per round. There are two limitations to do this solution. First, the size of route is smaller. Second, the more manpower is required.
3. Layout Redesign: This solution seems to be the proper solution in this case because the moving character involves in the warehouse with some stations. Thus, we can move these stations to close to the warehouse.

3.4 Correction Methods

To develop new layouts based on the short moving distance, the Flow and Relationship analysis are suggested.

3.4.1 Flow Analysis

In this method, the data about the round between stations in 1 week is required. This data will be used to identify which activity between stations has high density. The numbers of move rounds of material and WIP is shown in table 3-6 and 3-7 respectively.

Table 3-6: the Number of Move Rounds for Material in 1 week (Mean)

Material				
	Means (x1000 pcs)	X100 pcs/1 move	Rounds	%
A-1	29.25	10	29.25	**3.50**
A-2	20.79	10	20.79	**2.49**
A-3	12.9	10	12.90	**1.54**
B-1	19.56	10	19.56	**2.34**
B-2	16.46	10	16.46	**1.97**
B-3	8.9	10	8.90	**1.07**
C-1	107.62	10	107.62	**12.88**
C-2	65.1	10	65.10	**7.79**
C-3	42.87	10	42.87	**5.13**
D-1	38.9	10	38.90	**4.66**
D-2	34.91	10	34.91	**4.18**
D-3	18.52	10	18.52	**2.22**
E-1	193.2	10	193.20	**23.12**
E-2	135.2	10	135.20	**16.18**
E-3	91.3	10	91.30	**10.93**
Sum	835.48		835.48	100.00

Table 3-7: the Number of Move Rounds for WIP in 1 week (Mean)

WIP	Means (x1000 pcs)	X100 pcs/1 move	Rounds	%
A-1	29.25	2.4	121.88	**4.16**
A-2	20.79	1.4	148.50	**5.07**
A-3	12.9	1	129.00	**4.41**
B-1	19.56	2.4	81.50	**2.78**
B-2	16.46	1.4	117.57	**4.02**
B-3	8.9	1	89.00	**3.04**
C-1	107.62	2.4	448.42	**15.32**
C-2	65.1	1.4	465.00	**15.89**
C-3	42.87	1	428.70	**14.65**
D-1	38.9	2.4	162.08	**5.54**
D-2	34.91	1.4	249.36	**8.52**
D-3	18.52	1	185.20	**6.33**
E-1	193.2	16	120.75	**4.13**
E-2	135.2	14	96.57	**3.30**
E-3	91.3	11	83.00	**2.84**
Sum	835.48		2926.53	100.00

According to the data in table 3-6 and 3-7, we can know the move rounds between stations in 1 week. This data can be used in the table 3-8 in order to estimate the density of each activity.

Amount	**S**	**2**	**1**	**3**	**5**	**4**	**6**	**W**	**7**
S									100
2	3.69								
1	10.52								
3	14.34								
5								59.51	
4								89.74	
6								100	
W		23.49	66.25	10.26	59.51	30.23			
7							100		

Table 3-8: the number of WIP between stations in term of percentage

As a result of Table 3-8, the data is plotted into the chart in Figure 3-5 to prioritize the activities.

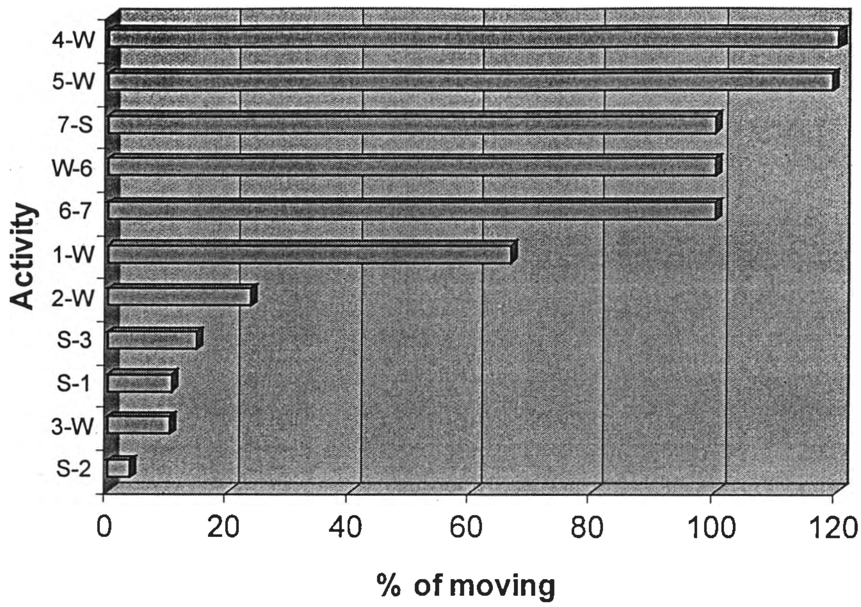

Figure 3-5: Chart of moving between stations in term of percentage

From Figure 3-5, it shows that we can categorize the level into 6 levels. The activities between station 4 and warehouse and station 5 and warehouse have highest density. Thus, they are set as the highest priority. We use the same method for the rest of activities.

3.4.2 Relationship Analysis

The relationship analysis is used to give the constraints of design based on the relationship between stations. Otherwise, only only the density of material flow sets the constraints. The theory of this method is discussed in section 2.2.2.2. The result of this analysis is shown in Figure 3-6.

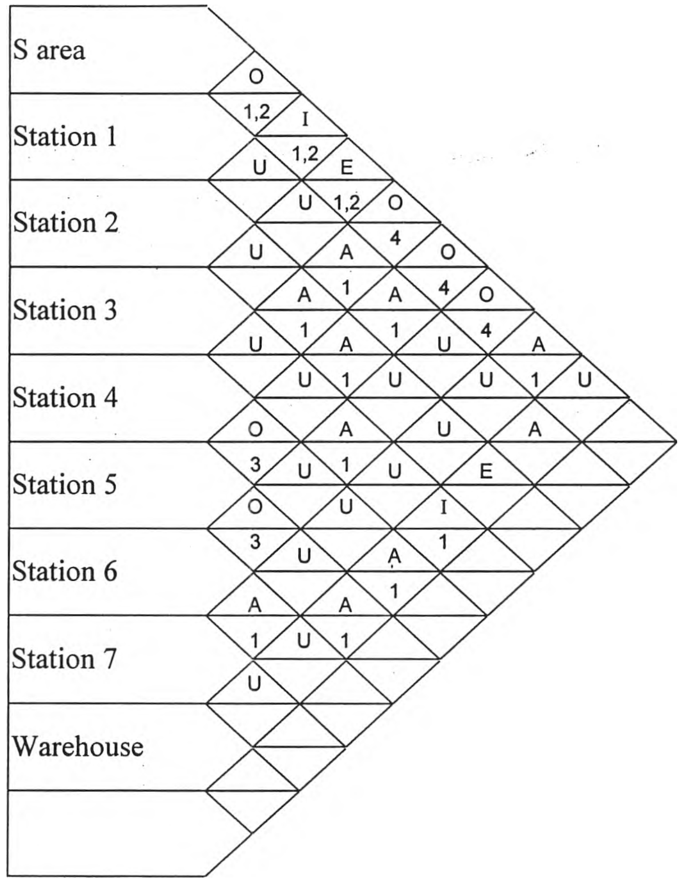

Figure 3-6: Relationship Chart of each station in factory A

Legend:

Value	Level of Relationship
A	Highest
E	Higher
I	High
O	Normal
U	Lower
X	Lowest

Code	Reason
1	Material Flow
2	Easy to control
3	Communication
4	Easy to move
5	Cleaning

3.4.3 Integration of Flow and Relationship Analysis

The results of flow and relationship analysis are summarized in this section. Its result can be used as the constraints for layout design.

1. Summary Table

According to Figure 2-2 of Chapter 2, the priority of flow analysis is higher than relationship analysis. That means the ratio of priority between flow and relationship analysis is 2:1.

Table 3-9: Summary Table for Relationship Chart and Travel Chart

Activity	**Flow**			**Relationship**		**Summation**	**Final level**
	From-to	Both way	Level	Level	Reason		
S-2			X	O	1,2	5	U
S-1			U	I	1,2	8	U
S-3			U	E	1,2	10	O
2-W			O	E	1,4	11	O
1-W			I	A	1,4	14	I
3-W			U	I	1,4	8	U
5-W			A	A	1,4	18	A
4-W			A	A	1,4	18	A
6-7			E	A	1,2	16	E
W-6			E	A	1,4	16	E
7-S			E	A	1,4	16	E

Legend:

See in last page (used the same legend of Figure 3-6)

2. Constraints for Layout Design

The result from the summary table 3-9 is used to make the constraints for new layout design. According to this result, we can separate the priority between process activities into 5 levels. The table 3-10 shows their priorities used to design new layout.

Table 3-10: Summary Constraints for Layout Generation

Activity	Priority
4-W	Highest
5-W	Highest
6-7	Higher
W-6	Higher
7-S	Higher
1-W	High
S-3	Normal
2-W	Normal
S-1	Low
3-W	Low
S-2	Low

3.5 Layout Design

With the criteria and the specific area discussed in this chapter, we can design 4 additional designs as follows.

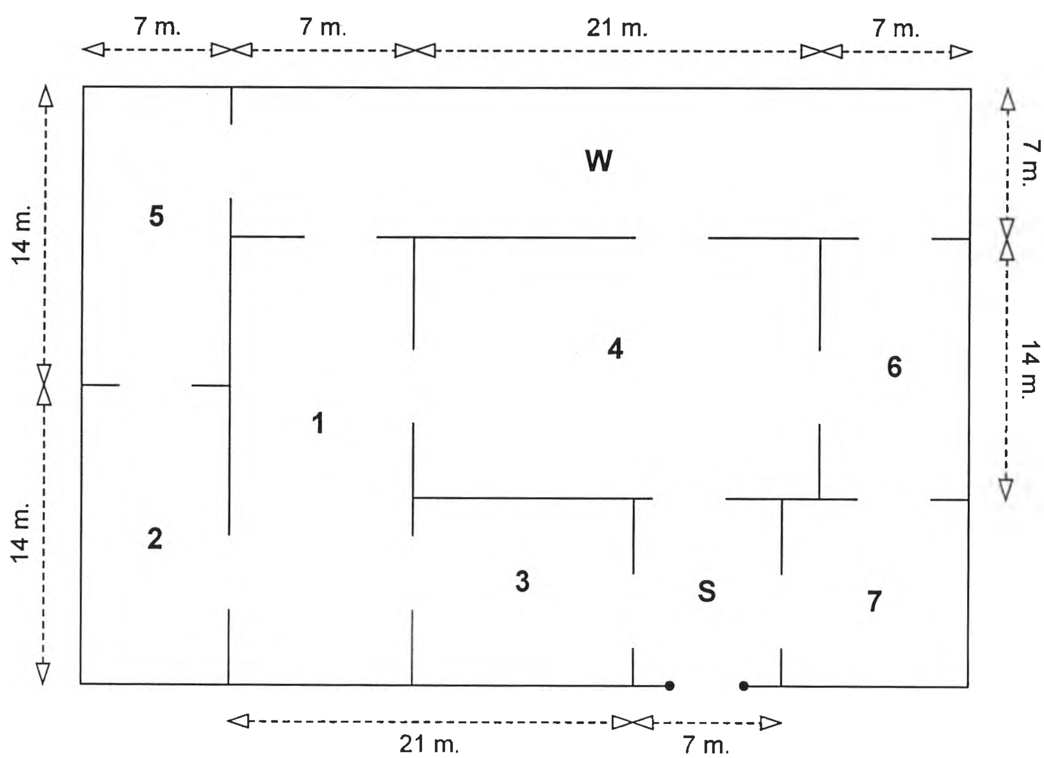

Figure 3-7: First new layout design

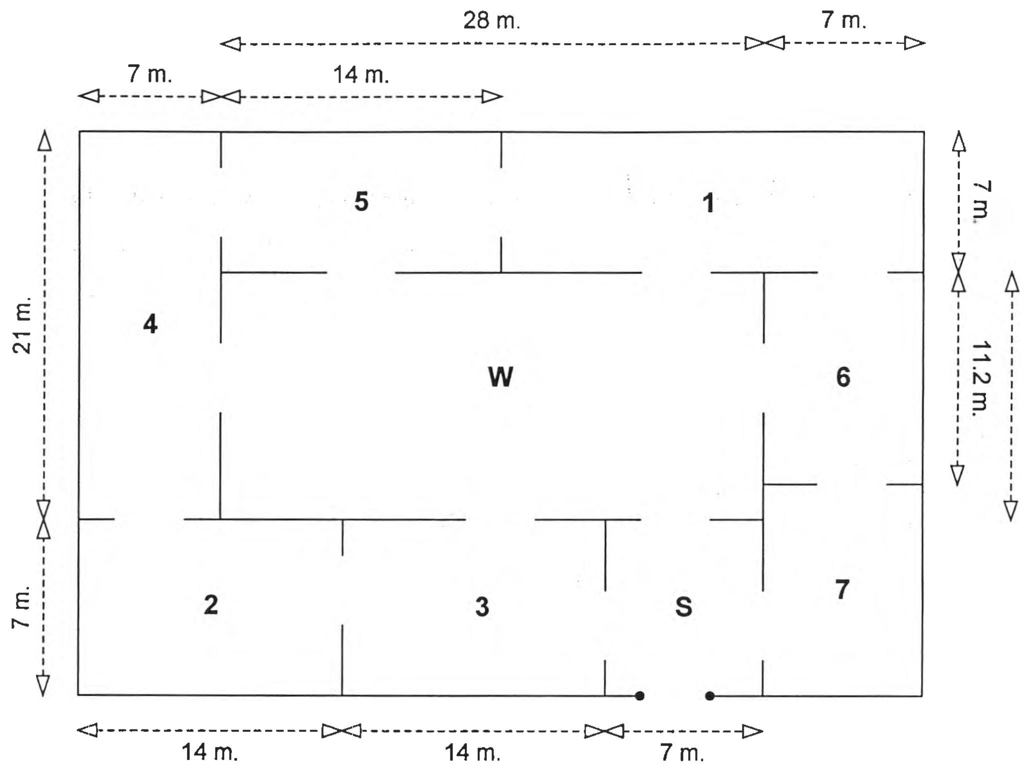

Figure 3-8: Second new layout design

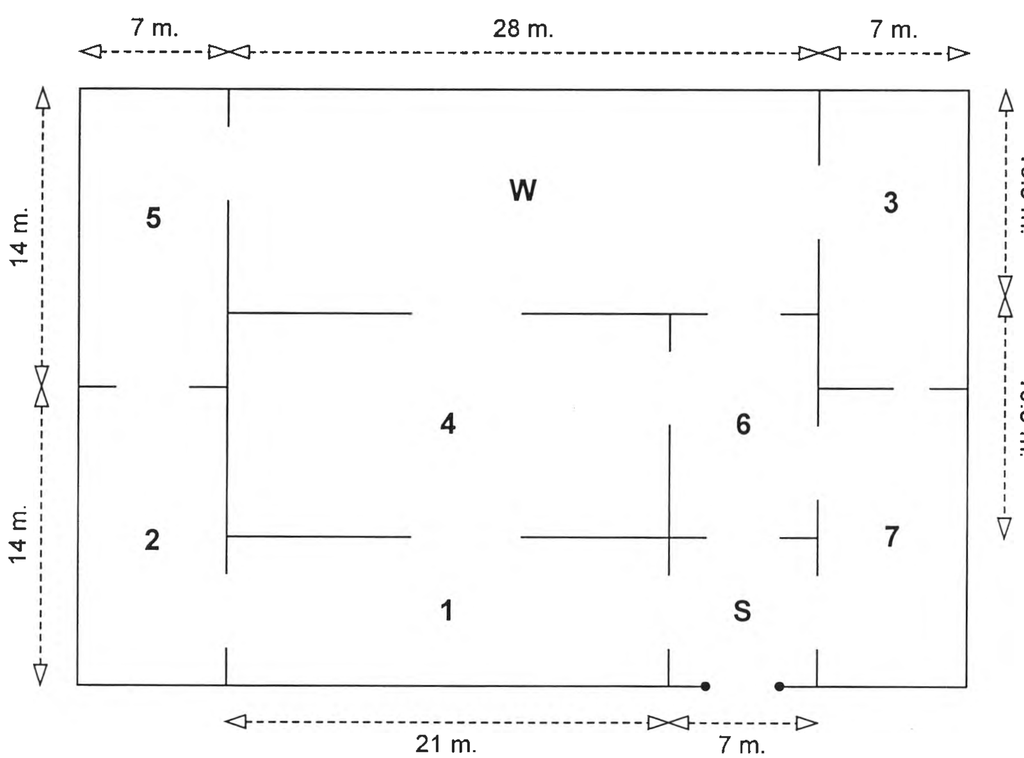

Figure 3-9: Third new layout design

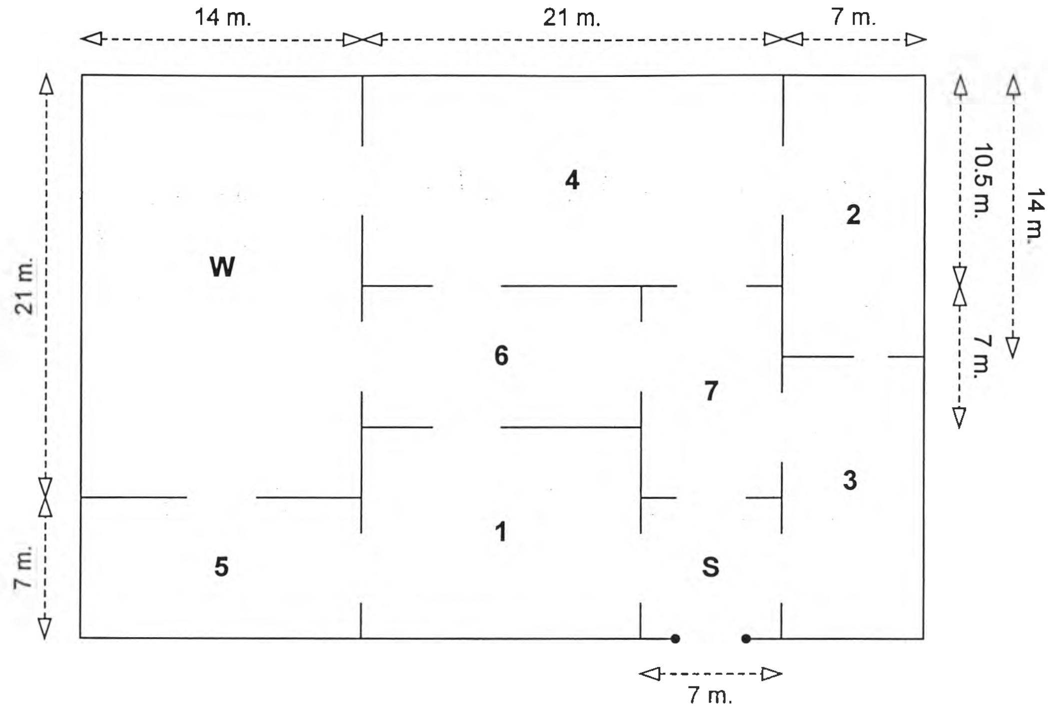

Figure 3-10: Fourth new layout design

The summary of stations moved will shown in table below to be useful for the estimation of the moving cost.

Table 3-11: Summary of Stations moved in each design

	Station								
Type of Design	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**W**	**S**
1	y		y	y	y				
2	y	y	y	y	y			y	
3			y	y	y	y		y	
4	y	y	y	y	y	y	y	y	

Legend:

y : the station is moved to another location

3.6 Layout Estimation

The amount-distance table is used to select the acceptable layout from all of layout designs. To make this table, the distance table and the data in table 3-4 are needed. The distance between stations is calculated from the distance between the central of each station.

- Current Layout Design

Distance Table from the existing layout:

Table 3-12a: Distance table of Current Layout

Distance of Current Layout

	S	2	1	3	5	4	6	W	7
S									8.4
2	28.7								
1	12.6								
3	31.5								
5								24.5	
4								10.5	
6								24.5	
W		38.5	40.6	24.5	24.5	10.5			
7							11.9		

Table 3-12b: Amount-Distance table of Current Layout

Amount -Distance of Current Layout

	S	2	1	3	5	4	6	W	7	Sum
S	0	0	0	0	0	0	0	0	840	840
2	105.9	0	0	0	0	0	0	0	0	105.903
1	132.6	0	0	0	0	0	0	0	0	132.552
3	451.7	0	0	0	0	0	0	0	0	451.71
5	0	0	0	0	0	0	0	1458	0	1457.995
4	0	0	0	0	0	0	0	942.3	0	942.27
6	0	0	0	0	0	0	0	2450	0	2450
W	0	904.4	2690	251.4	1458	317.4	0	0	0	5620.895
7	0	0	0	0	0	0	1190	0	0	1190
Sum	690.2	904.4	2690	251.4	1458	317.4	1190	4850	840	**13191.33**

- First Layout Design

Distance Table from the first layout design:

Table 3-13a: Distance table of First Design

Distance of Current Layout

	S	2	1	3	5	4	6	W	7
S									7
2	28								
1	21								
3	10.5								
5								21	
4								7	
6								24.5	
W		42	28	31.5	21	10.5			
7							10.5		

Table 3-13b: Amount-Distance table of First Design

Amount -Distance of Current Layout

	S	2	1	3	5	4	6	W	7	Sum
S	0	0	0	0	0	0	0	0	700	700
2	103.3	0	0	0	0	0	0	0	0	103.32
1	220.9	0	0	0	0	0	0	0	0	220.92
3	150.6	0	0	0	0	0	0	0	0	150.57
5	0	0	0	0	0	0	0	1250	0	1249.71
4	0	0	0	0	0	0	0	628.2	0	628.18
6	0	0	0	0	0	0	0	2450	0	2450
W	0	986.6	1855	323.2	1250	317.4	0	0	0	4731.895
7	0	0	0	0	0	0	1050	0	0	1050
Sum	474.8	986.6	1855	323.2	1250	317.4	1050	4328	700	**11284.6**

- Second Layout Design

Distance Table from the second layout design:

Table 3-14a: Distance table of Second Design

Distance of Current Layout

	S	2	1	3	5	4	6	W	7
S									7
2	24.5								
1	24.5								
3	10.5								
5								17.5	
4								21	
6								18.9	
W		24.5	21	10.5	17.5	21			
7							10.5		

Table 3-14b: Amount-Distance table of Second Design

Amount -Distance of Current Layout

	S	2	1	3	5	4	6	W	7	Sum
S	0	0	0	0	0	0	0	0	700	700
2	90.41	0	0	0	0	0	0	0	0	90.405
1	257.7	0	0	0	0	0	0	0	0	257.74
3	150.6	0	0	0	0	0	0	0	0	150.57
5	0	0	0	0	0	0	0	1041	0	1041.425
4	0	0	0	0	0	0	0	1885	0	1884.54
6	0	0	0	0	0	0	0	1890	0	1890
W	0	575.5	1391	107.7	1041	634.8	0	0	0	3750.74
7	0	0	0	0	0	0	1050	0	0	1050
Sum	498.7	575.5	1391	107.7	1041	634.8	1050	4816	700	**10815.42**

- Third Layout Design

Distance Table from the second layout design:

Table 3-15a: Distance table of Third Design

Distance of Current Layout

	S	2	1	3	5	4	6	W	7
S									10.5
2	31.5								
1	14								
3	17.5								
5								19.25	
4								14	
6								21	
W		33.25	22.75	19.25	19.25	14			
7							12.25		

Table 3-15b: Amount-Distance table of Third Design

Amount -Distance of Current Layout

	S	2	1	3	5	4	6	W	7	Sum
S	0	0	0	0	0	0	0	0	1050	1050
2	116.2	0	0	0	0	0	0	0	0	116.235
1	147.3	0	0	0	0	0	0	0	0	147.28
3	251	0	0	0	0	0	0	0	0	250.95
5	0	0	0	0	0	0	0	1146	0	1145.568
4	0	0	0	0	0	0	0	1256	0	1256.36
6	0	0	0	0	0	0	0	2100	0	2100
W	0	781	1507	197.5	1146	423.2	0	0	0	4054.523
7	0	0	0	0	0	0	1225	0	0	1225
Sum	514.5	781	1507	197.5	1146	423.2	1225	4502	1050	**11345.92**

- Last Layout Design

Distance Table from the last layout design:

Table 3-16a: Distance table of Last Design

Distance of Current Layout

	S	2	1	3	5	4	6	W	7
S									8.75
2	26.25								
1	12.25								
3	10.5								
5								14	
4								22.75	
6								17.5	
W		36.75	17.5	42	14	22.75			
7							12.25		

Table 3-16b: Amount-Distance table of Last Design

Amount -Distance of Current Layout

	S	2	1	3	5	4	6	W	7	Sum
S	0	0	0	0	0	0	0	0	875	875
2	96.86	0	0	0	0	0	0	0	0	96.8625
1	128.9	0	0	0	0	0	0	0	0	128.87
3	150.6	0	0	0	0	0	0	0	0	150.57
5	0	0	0	0	0	0	0	833.1	0	833.14
4	0	0	0	0	0	0	0	2042	0	2041.585
6	0	0	0	0	0	0	0	1750	0	1750
W	0	863.3	1159	430.9	833.1	687.7	0	0	0	3974.425
7	0	0	0	0	0	0	1225	0	0	1225
Sum	376.3	863.3	1159	430.9	833.1	687.7	1225	4625	875	**11075.45**

3.7 Conclusion

The results from Tables 3-13a to 3-16b are summarized in Table 3-17 to consider which layout has the lowest moving distance.

Table 3-17: Summary of Total Distance of each Layout

Type of Design	Sum of amount-distance
Current Design	13191.33
1st Design	11284.6
2nd Design	10815.42
3rd Design	11345.92
4th Design	11075.45

According to the summary table, the second design has the lowest total of distance. However, the productivity should be considered when considering the cost and profit of rearrangement. With this method, it can't prove their productivity improvement. Thus, the simulation method is used to compare the productivity between the current and suggested layout in next chapter.