

Chapter IV

SIMULATION MODELING



4.1 Introduction

As a result of test in last chapter, we can know which layout can generate the lowest moving distance but it doesn't mean that layout will have the better productivity. Thus, the difference of their productivity should be compared. The method chosen is the simulation method. There are 3 reasons for choosing this method:

1. High cost to test this experiment in the real system
2. The mathematical method is complicated and need longer time
3. Simulation can help understand the problem in depth and be useful for the planning step.

Therefore, the simulation method is the appropriate method for this experiment. However, the simulation methods have some disadvantages. In this case, we would like to show 3 main disadvantages:

1. To make the high model quality, the cost for data collection will be high
2. Model can't be the representation of the real system completely
3. The precision of result from simulation can't be defined.

The process of simulation is shown in Figure 4-1 on the next page.

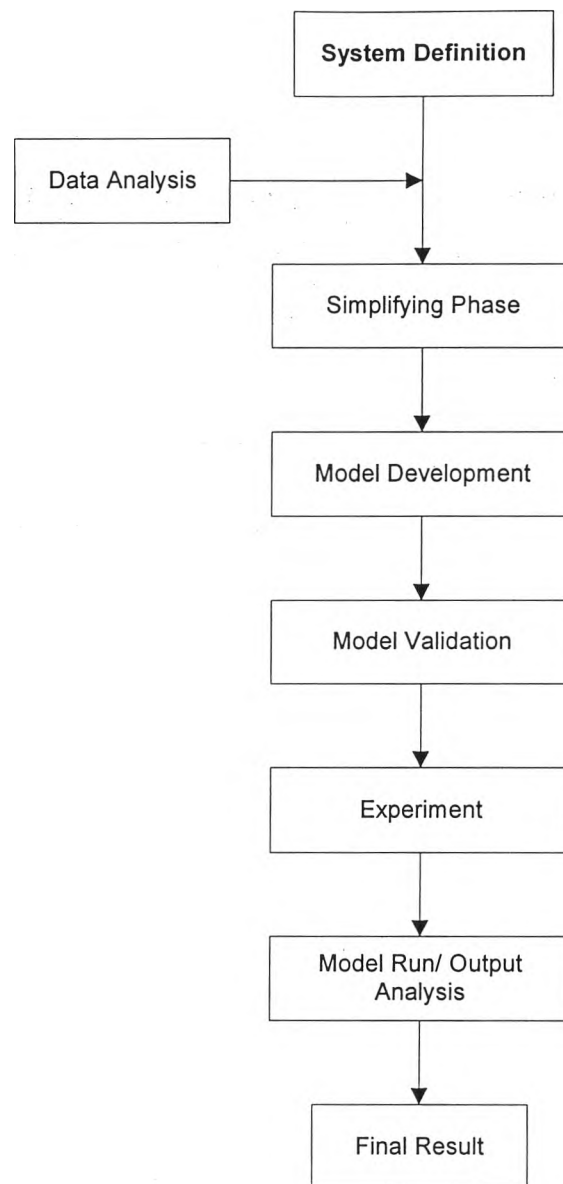


Figure 4-1: Simulation Process of Study

4.2 Definition for Simulation Modeling

4.2.1 **Modeling Objective:** To check the new chosen layout whether they can help to improve the productivity.

According to the last chapter, we can select which layout should be the suitable layout when considering the moving distance and frequency. However, we can't state the new layout can help reduce the material handling cost or production time. One way to prove this question is to test the productivity of new layout because the better productivity means that the material handling cost, the production time or

the levels of inventory are improved. Thus, the simulation method is implemented to compare the productivity between the current layout and the chosen layouts.

4.2.2 Scope of Model

- Consider the order for plant A only (4 types and 3 sizes of bottles + cap)
- Implement statistic in every stations (can't use only the first station, i.e. statistic for order of bottle A, amount of bottle A, we can't use the same amount to calculate the moving time but it instead of the statistic)
- In case of model for cap production, we may say that it's not necessary to make it because cap will be packed with its bottle that its production time is too short when comparing it with the bottle production time. So, most of orders depend on the bottle production time.

4.3 Simplifying phase

4.3.1 Analysis Method

The analysis tool used to simulation is Promodel software.

The tests used for the data analysis are Chi-square test and t-test. Chi-square test is the powerful test because it can be applied for both discrete and continuous distribution. T-test can be used as test for the model validation.

4.3.2 Flow chart for simulation model

To make the model, the working process should be defined clearly. Thus, the working process charts are presented. Because the size of chart is too big, it's necessary to separate the chart into 13 figures.

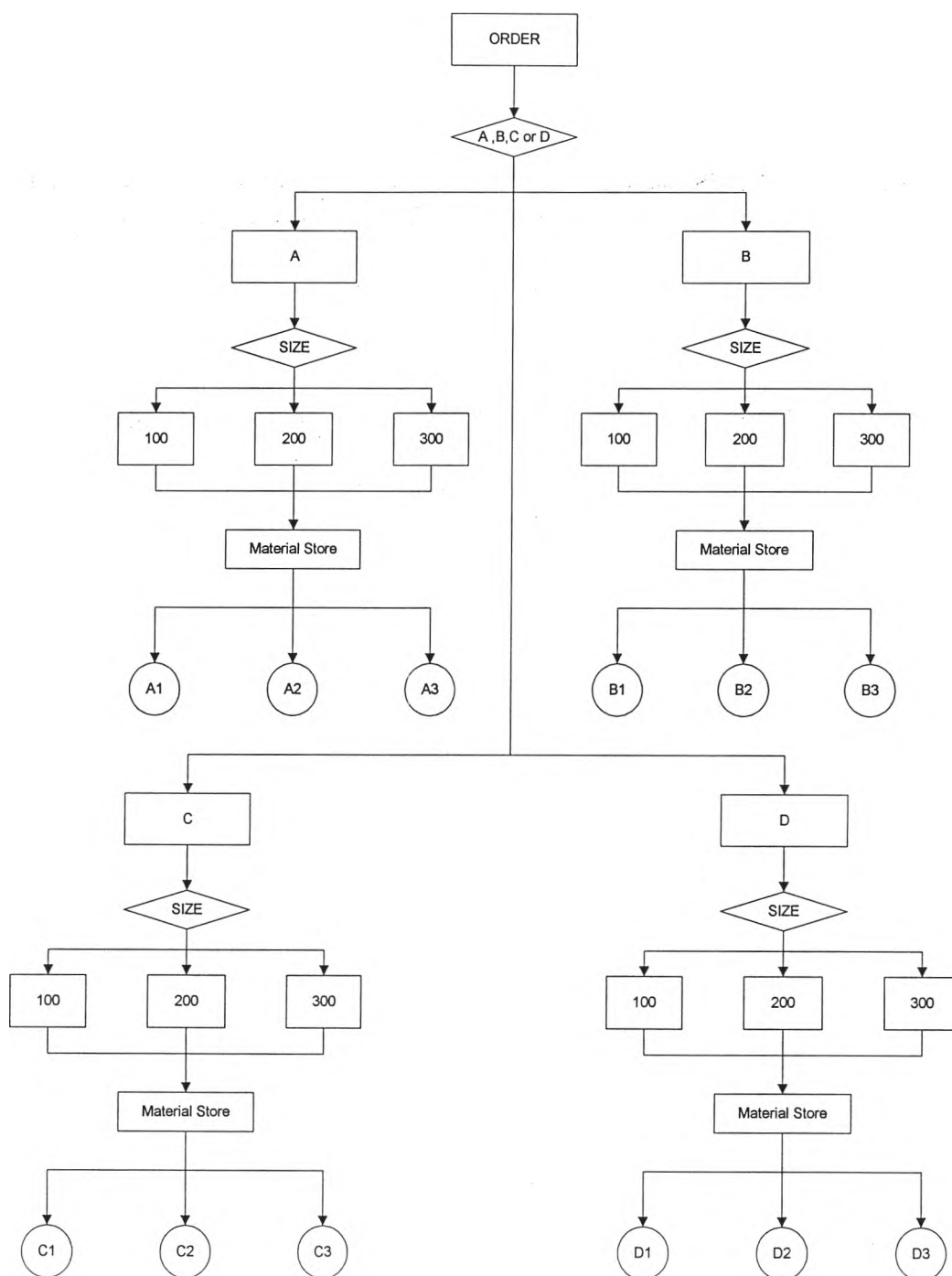


Figure 4-2a: Main model for Plastic production of factory A

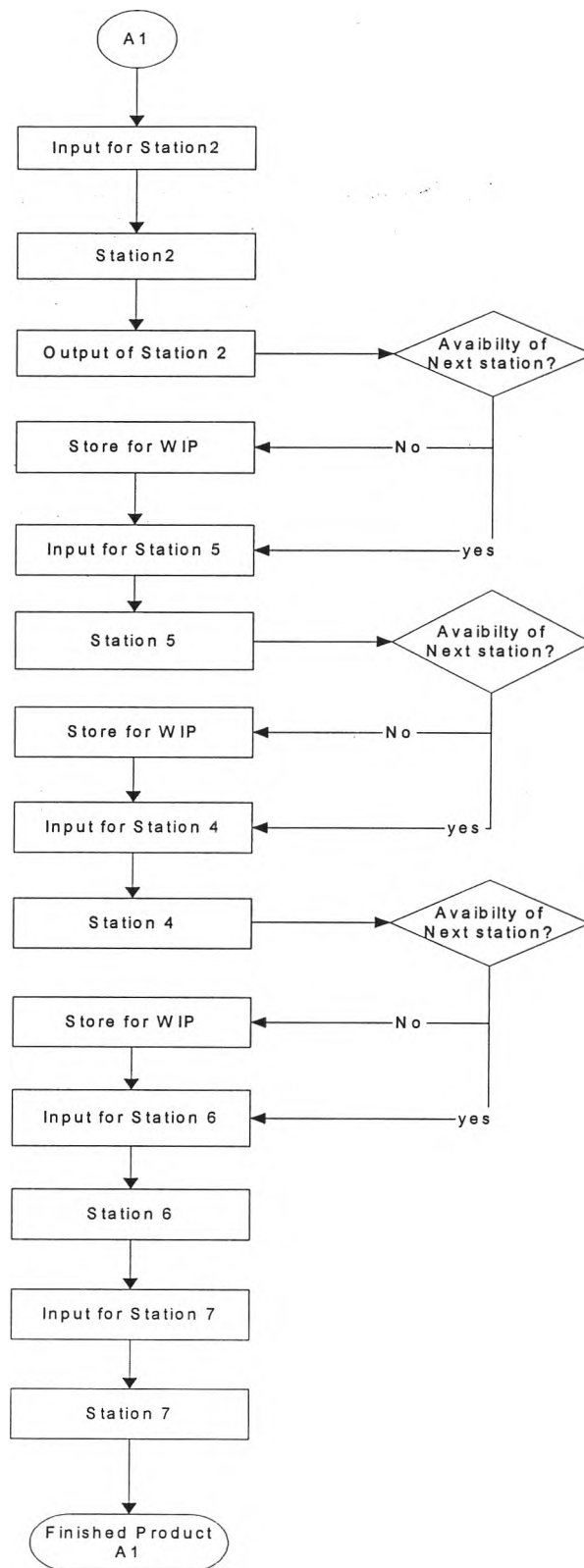


Figure 4-2b: Sub-model of production for bottle A 100 ml.

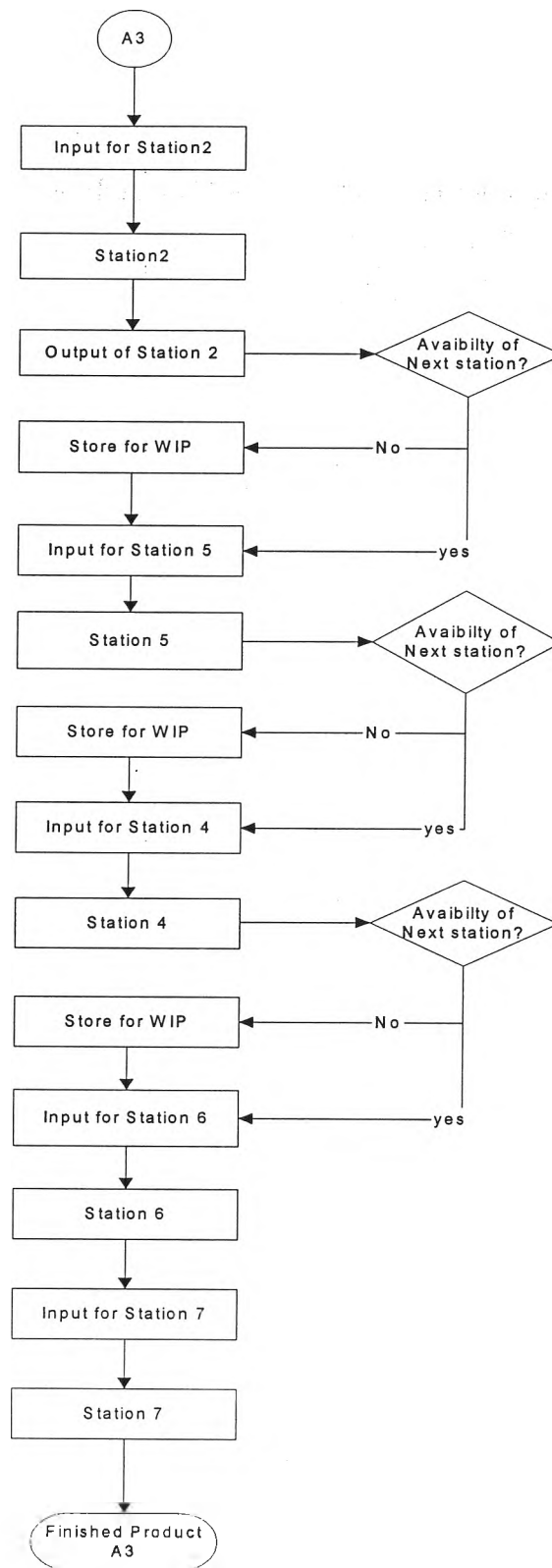


Figure 4-2c: Sub-model of production for bottle A 200 ml.

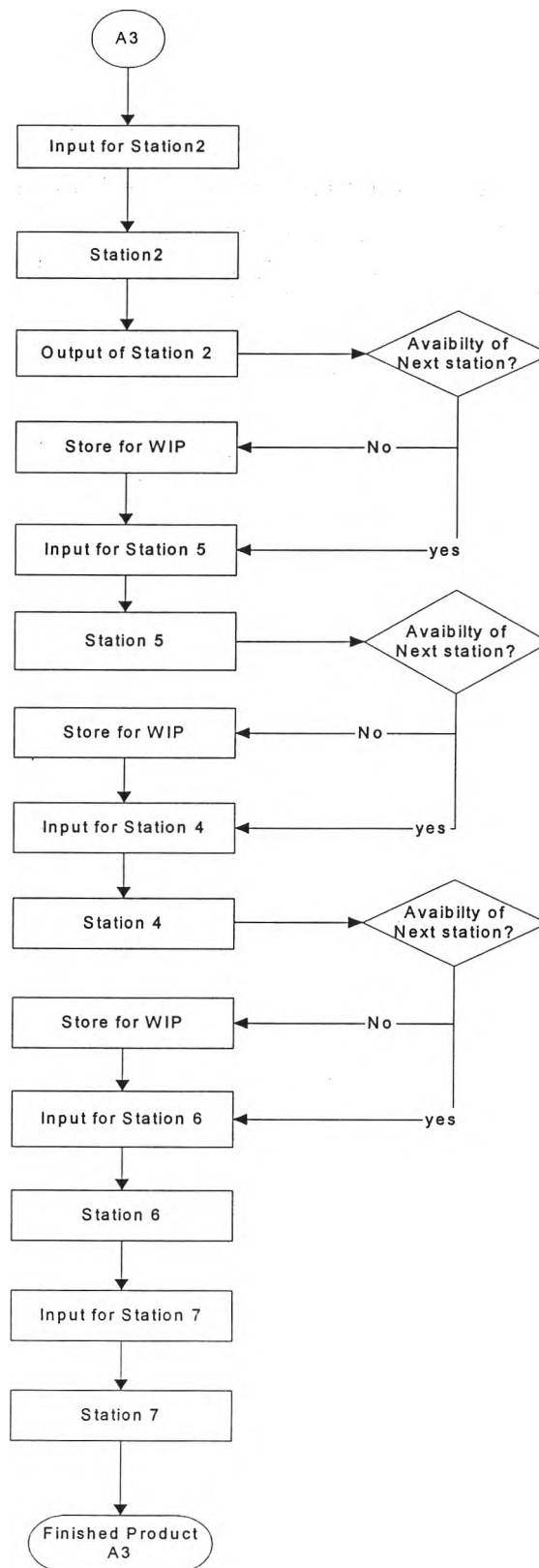


Figure 4-2d: Sub-model of production for bottle A 300 ml.

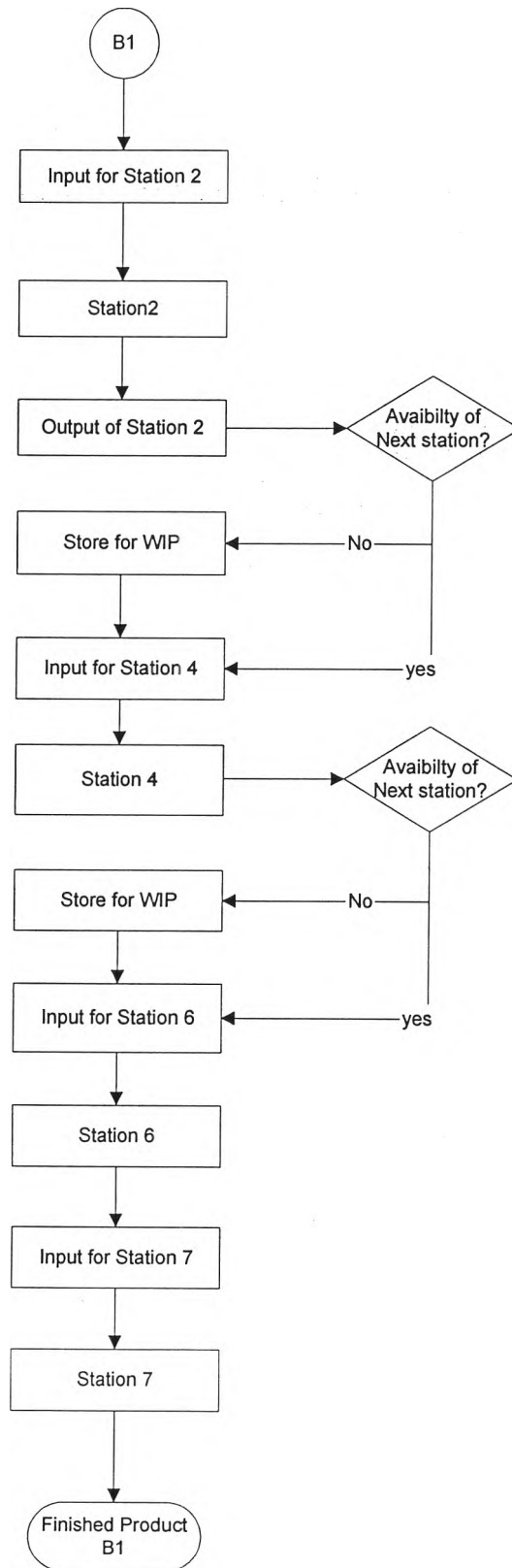


Figure 4-2e: Sub-model of production for bottle B 100 ml.

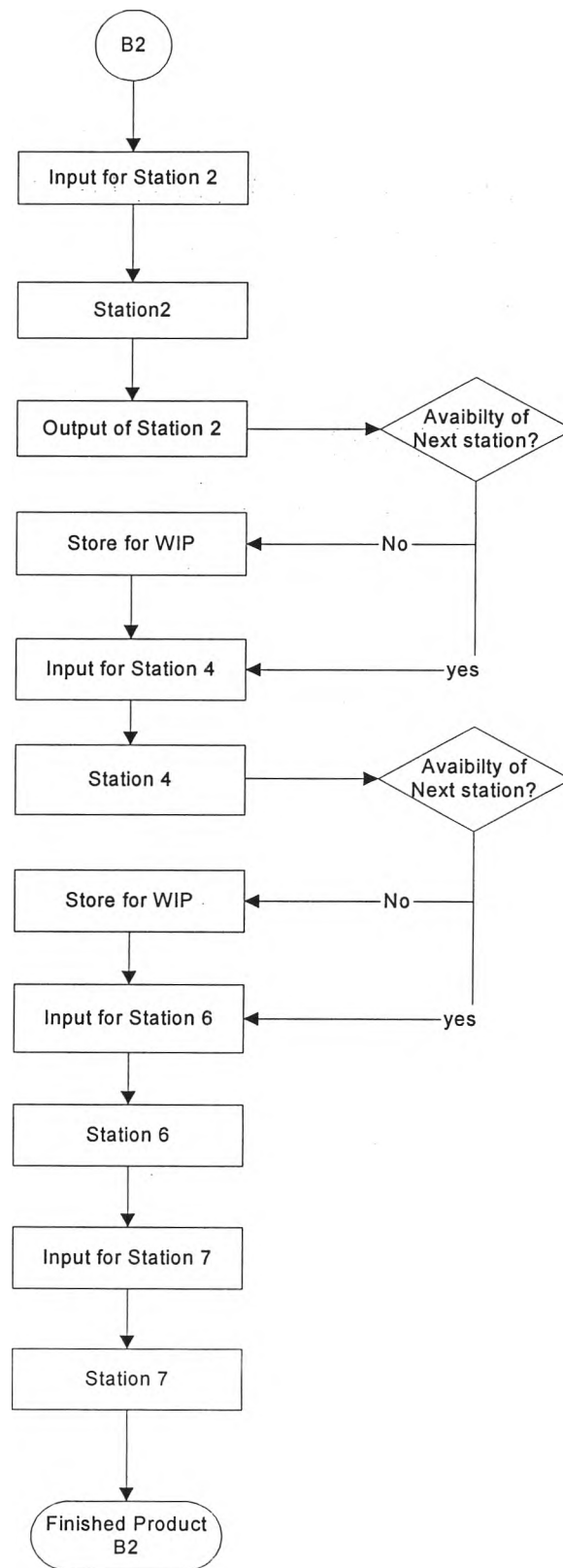


Figure 4-2f: Sub-model of production for bottle B 200 ml.

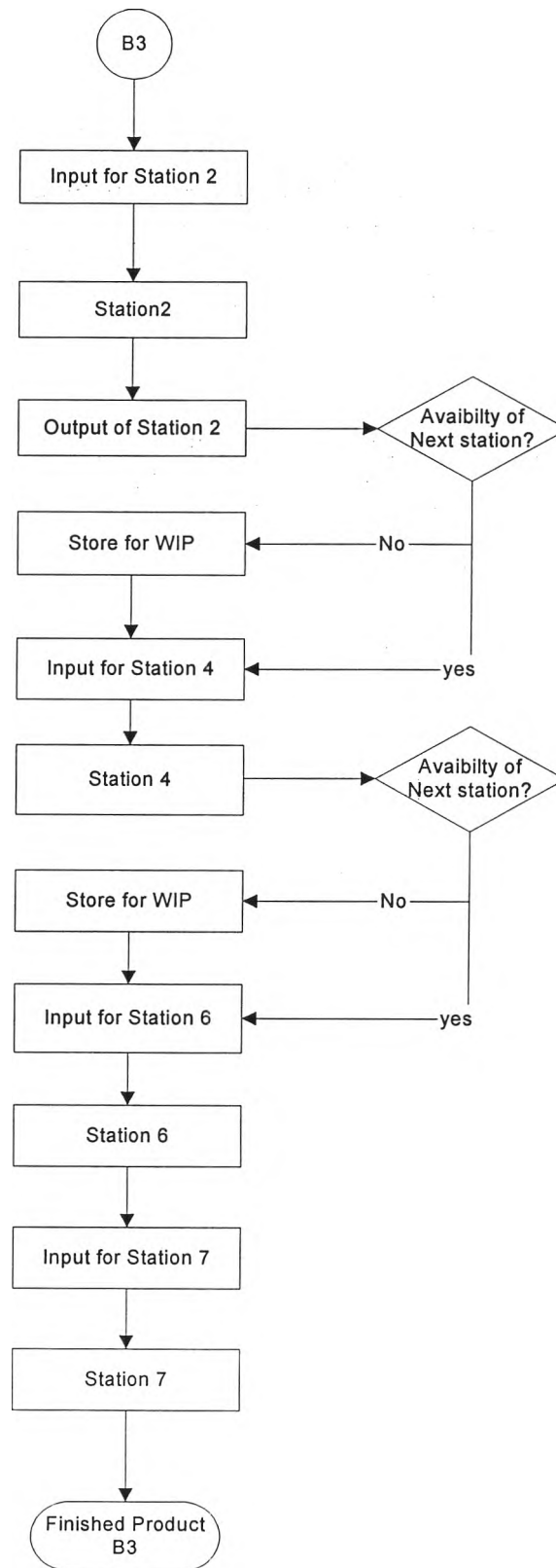


Figure 4-2g: Sub-model of production for bottle B 300 ml.

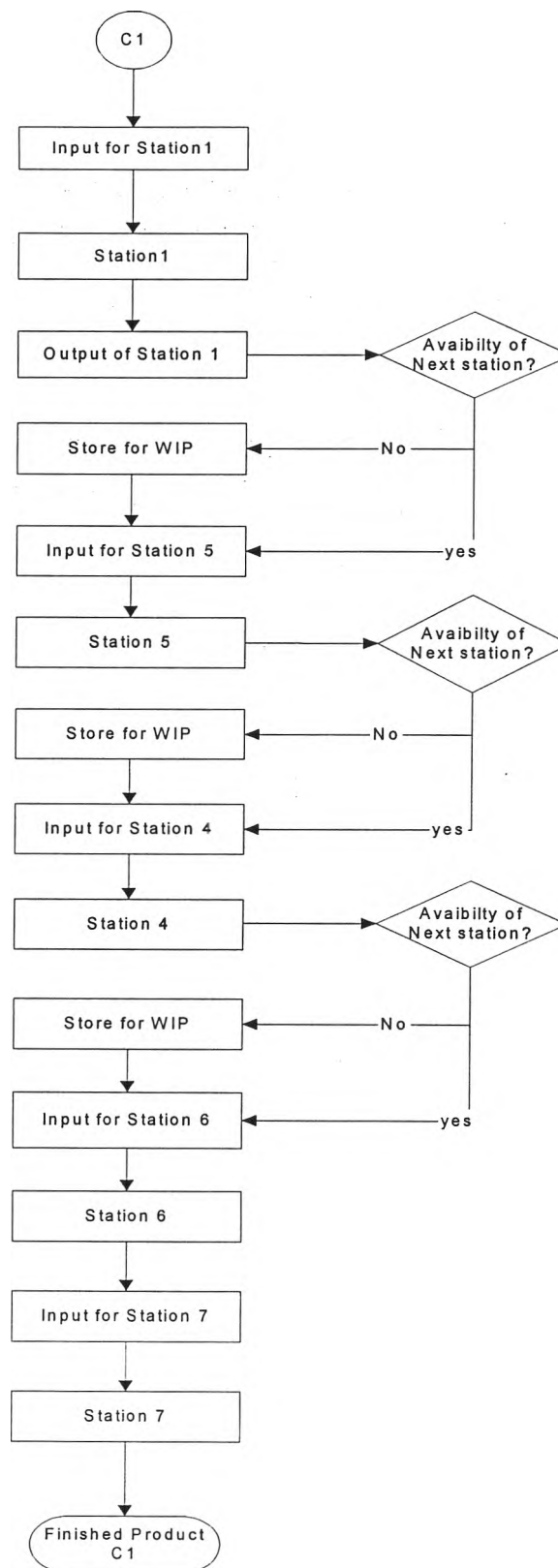


Figure 4-2h: Sub-model of production for bottle C 100 ml.

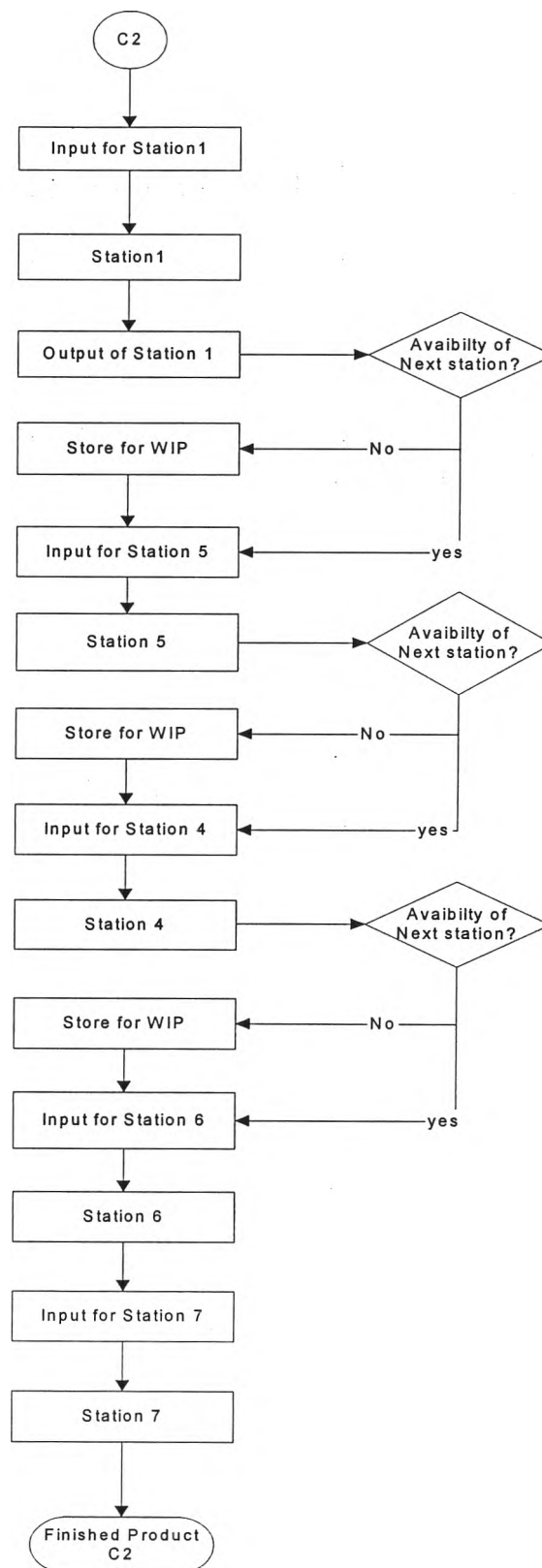


Figure 4-2i: Sub-model of production for bottle C 200 ml.

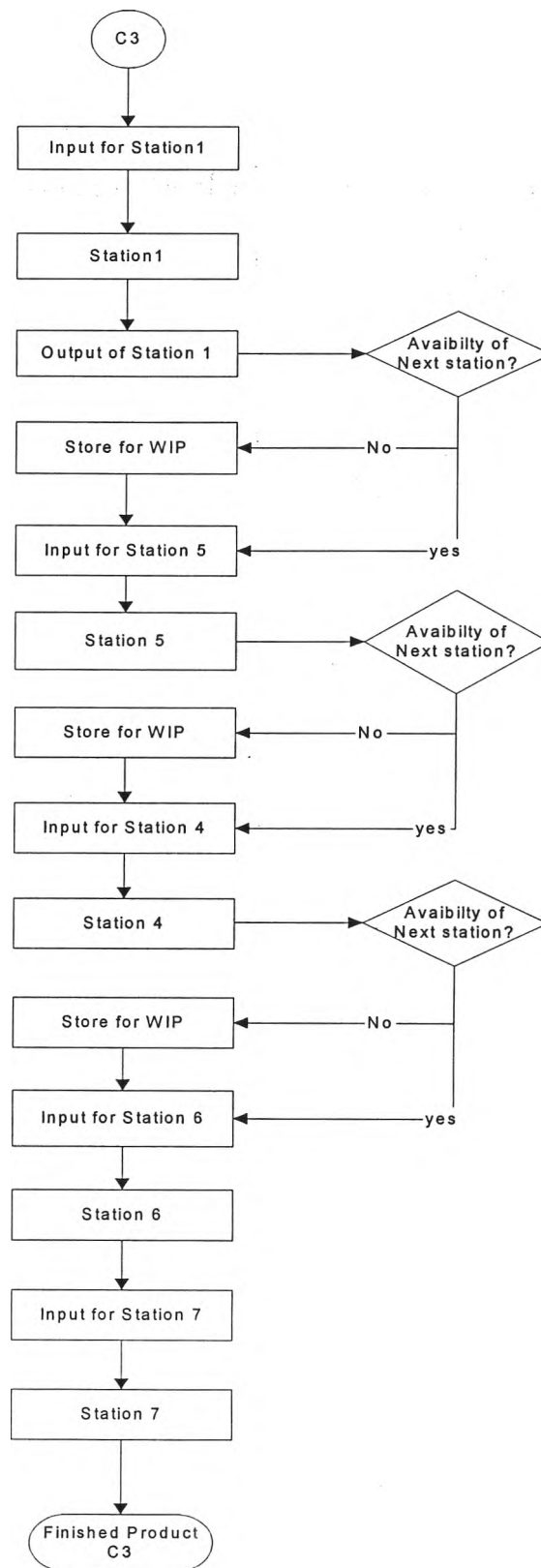


Figure 4-2j: Sub-model of production for bottle C 300 ml.

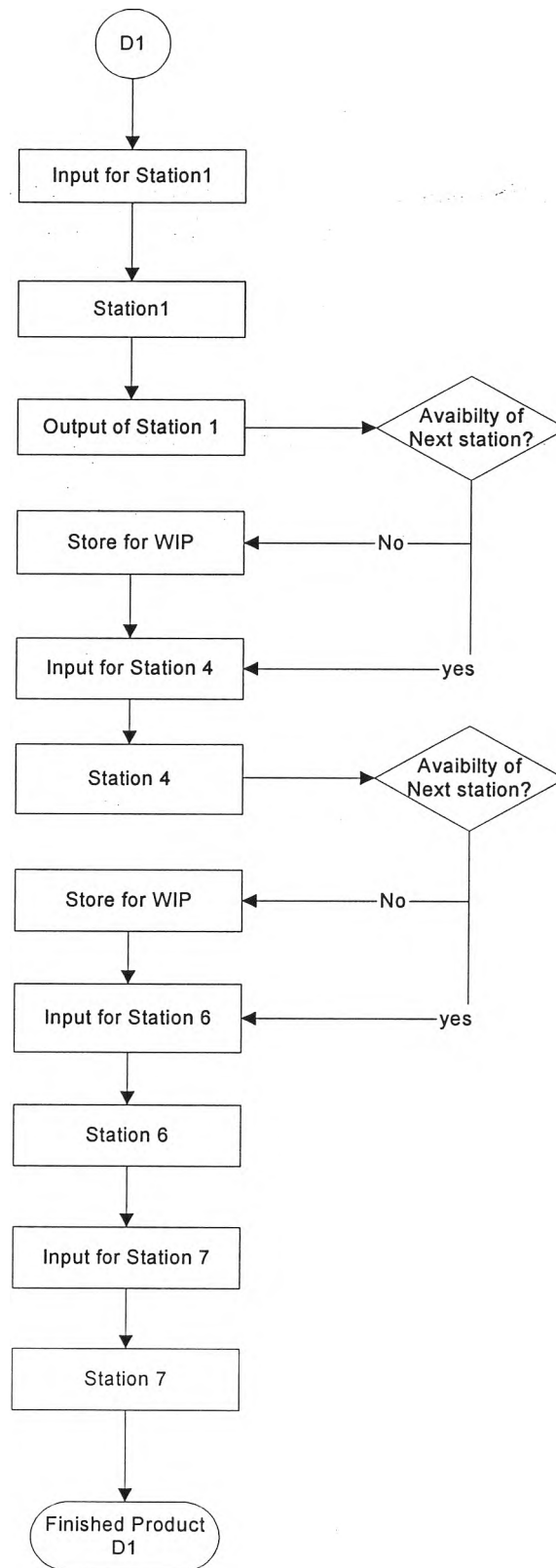


Figure 4-2k: Sub-model of production for bottle D 100 ml.

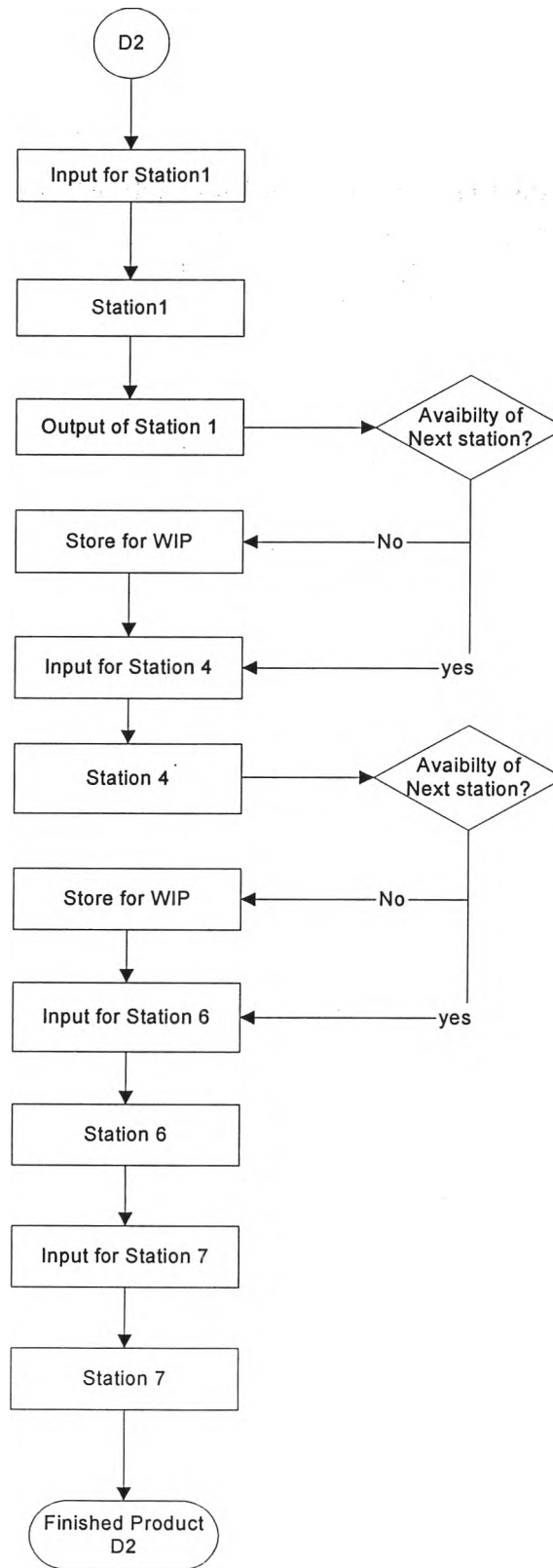


Figure 4-21: Sub-model of production for bottle D 200 ml.

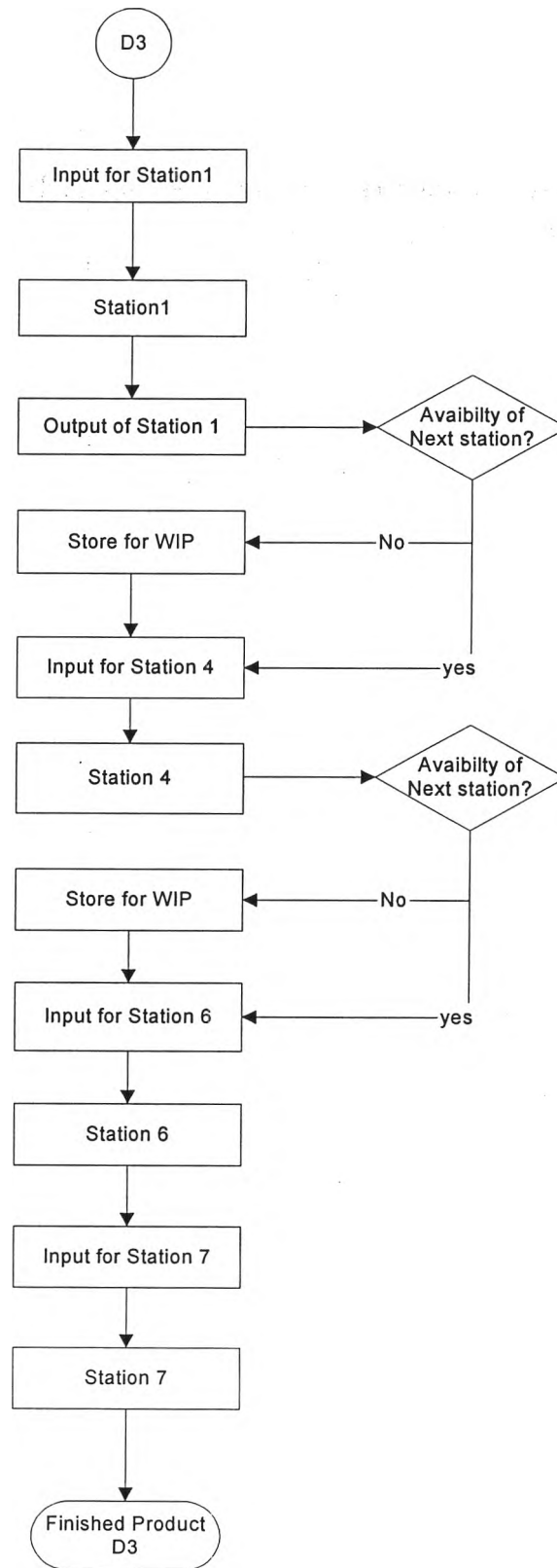


Figure 4-2m: Sub-model of production for bottle D 300 ml.

4.3.3 Processing time: processing time/ 1 order

Generally, the processing time of the machine is the time required to produce one product at the specific machine. In this case, the processing time doesn't mean the processing time of 1 product but it means the processing time of 1 order. The reason of using this idea is the schedule of production for each station is prepared to produce the product of the same order until finish the order. Thus, the time in table 3.3 can't be used in this case.

To get the new processing time, the data of time used to process 1 order in each station is collected. Then, the goodness of fit test is used to check the fitting distribution of processing time for each station. In this case, the Chi-square test is chosen to test the fitting distribution. The hypothesis of the fitting distribution is accepted if Chi-square values are less than critical point from Chi-square table at a certain value of degree of freedom and significant level set to be 0.05. The details of test are shown in appendix A-2. According to the test, we found that all of the fitting distributions are the normal distribution. Their means and standard deviations are shown in the table below.

Table 4-1: Processing time per 1 order of each station and each type of product

Product	Processing time per 1 order (hours / 1 order)									
	Station 1 & 2		Station 5		Station 4		Station 6		Station 7	
	Means	S.D.	Means	S.D.	Means	S.D.	Means	S.D.	Means	S.D.
A-1	10.175	2.2	4.94	1.07	5.4	1.15	4.15	0.887	4.05	0.887
A-2	11.55	2.47	3.53	0.77	3.775	0.78	2.95	0.67	2.88	0.62
A-3	18.51	4.21	2.15	0.48	2.25	0.48	3.86	0.843	3.66	0.84
B-1	8.06	1.75			3.51	0.75	2.84	0.625	2.74	0.625
B-2	18.25	3.8			3.14	0.69	4.8	1.03	4.45	0.922
B-3	12.69	2.78			1.66	0.36	2.58	0.6	2.375	0.484
C-1	15.425	1.2	17.26	2.69	18.84	2.92	15.37	1.2	14.76	1.08
C-2	15.85	1.24	10.2	1.56	11.04	1.53	9.3	0.743	9.05	0.74
C-3	12.55	0.97	6.97	1.03	7.71	1.24	6.125	0.483	5.92	0.48
D-1	8.34	0.625			6.35	0.82	5.56	0.45	5.3	0.375
D-2	8.54	0.711			6.32	0.83	5.125	0.483	4.89	0.42
D-3	10.88	0.79			6.14	0.42	5.29	0.384	5.19	0.39

Note:

Processing time here includes set-up time.

4.3.4 Orders

Orders are needed to be the input of the simulation system. In this case, there are 3 types of order data needed.

1. Arrival of orders

Coming of orders from headquarter were recorded in every 6 hours, so the interarrival times needed in minutes could not be available. Thus, the only solution for the collected data is to check what is the reliability for use of Poisson

process to simulate the arrival process. That is done by letting Poisson variable denote the number of orders coming in every 6 hours, and then using Chi-square test to check. The hypothesis of the fitting distribution is accepted if Chi-square values are less than critical point from Chi-square table at a certain value of degree of freedom and significant level of 0.05. The result obtained is the Poisson distribution with average number of order equal to 0.767 orders per 6-hour day. More details of test can be found in appendix A-3.

2. Categories of Orders

In this case, the orders come in mode of one category arrival and supposed to be one arrival at a time. There are 4 main categories and each category is divided into 3 sub-categories. That means there are total 12 categories. According to the collected data, we can estimate the ratio between the orders as the figure below.

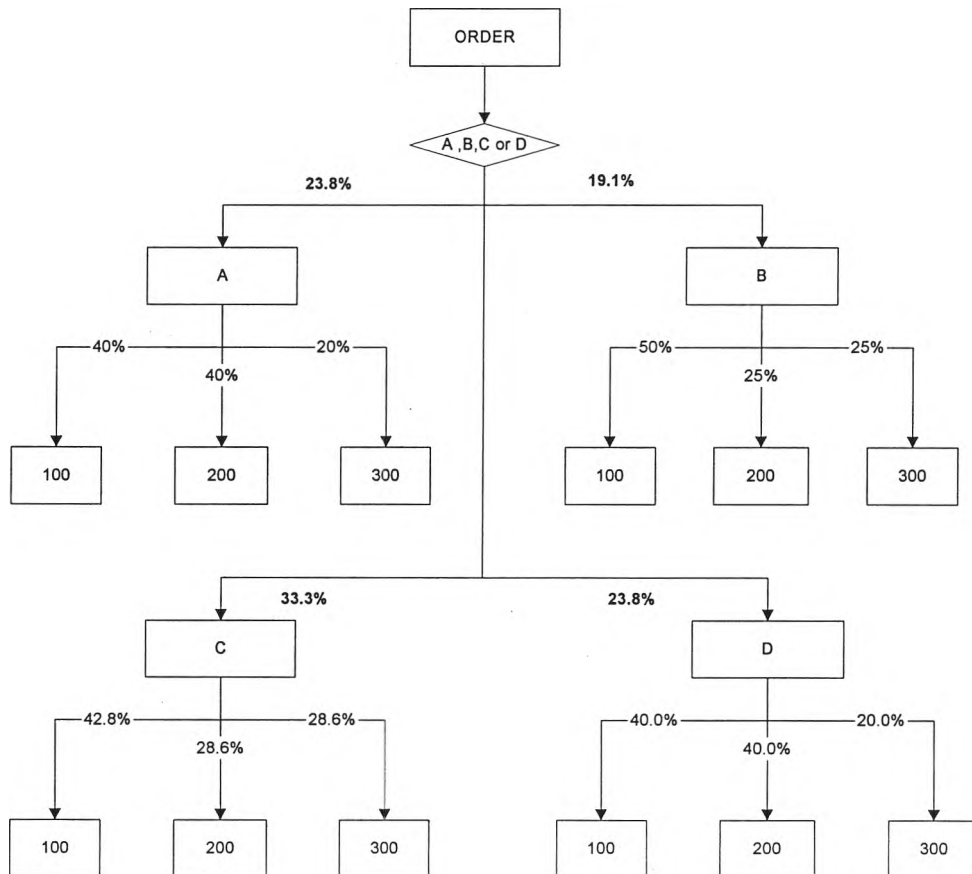


Figure 4-3: Ratio of order categories

4.3.5 Move time between station

The move time between stations used in this case can't be the move time per one round between stations because of the same reason with the processing time. So, the move time is calculated from the total move round between stations in each order multiplied by the move time in one round. The total move round can be calculated

from the number of WIP or material in each order divided by the number of WIP or Material moved in one round. The number of WIP and Material can be calculated from section 5.2.3. Thus, Table 4-2 shows the number of rounds used to move WIP and material between the stations or warehouse.

Table 4-2: the number of Move rounds of WIP and Material between station and warehouse per 1 order

Product	Means		S.D.	
	Mat	WIP	Mat	WIP
A-1	12.21	50.875	2.64	11
A-2	10.395	74.25	2.223	15.8786
A-3	12.957	129.57	2.947	29.47
B-1	9.672	40.3	2.1	8.75
B-2	16.425	117.321	3.42	24.4286
B-3	8.883	88.83	1.946	19.46
C-1	35.786	149.108	2.784	11.6
C-2	32.334	230.957	2.5296	18.0686
C-3	21.335	213.35	1.649	16.49
D-1	19.3488	80.62	1.45	6.04167
D-2	17.4216	124.44	1.45044	10.3603
D-3	18.496	184.96	1.343	13.43

The material move time is the time required to move the material from the material warehouse to the first station. The WIP move time is the time used to move WIP between stations.

4.3.6 Summary list of Factors in Models

1. Simplified Phase

There exist some factors with a little bit of changes over time in the operation. The list of factors to be simplified is shown in Table 4-3.

Table 4-3: List of Simplified factors

No.	Factors	In Reality	Simplifying Treatment
1	Dispatching rule at station queue	Seldom other rules different from FIFO could be used.	FIFO only used for the transportation.
2	Starting and Ending point of movement between stations	The point is flexible according to the facility in that area.	Determining the central point as unique reference point.
3	History of machine breakdowns and duration between them	Machine breakdowns are rare to happen.	Consider the affect of this factor negligible.
4	History of reworks	This is not recorded, however, it's negligible.	Same the reason in item no 3.

2. Stochastic factors

In this section, the stochastic factors and the corresponding distributions will be summarized from previous section of data analysis as follow:

Table 4-4: List of Stochastic factors

No.	Stochastic Factors	Fitting Distributions	Parameters
1	Processing time of station1	Normal Distribution	See in Table 4-5
2	Processing time of station1	Normal Distribution	See in Table 4-5
3	Processing time of station1	Normal Distribution	See in Table 4-5
4	Processing time of station1	Normal Distribution	See in Table 4-5
5	Processing time of station1	Normal Distribution	See in Table 4-5
6	Processing time of station1	Normal Distribution	See in Table 4-5
7	Processing time of station1	Normal Distribution	See in Table 4-5
8	Interarrival of orders	Exponential Distribution	469 min.
9	Move time between station	Normal Distribution	See in Table 4-6 and 4-7

The stochastic factors used in the model fit very well with the supposed distributions (significance level of tests is at 5%).

4.4 Model Development

The data collected is used to develop the model. There are 4 processes of model development as follows.

4.4.1 Preparatory description

ProModel is the user-friendly tool for simulation because it's not complicate to use it. It separates the parameters into two groups: Input and Output. Input consists of Part and Location. Part is the input of Next Location. In this model, the first part is the orders from headquarter. Location is the place where Part locates at the moment. Output consists of Next Location and Output Part. Next Location is the place where Part will be moved. Output Part is the name of Part after it has been passed Location. Output Part can be used the same name as Part or the new name.

Moreover, the ProModel also provide the Move Time and Operation Time that can be used to specify the operation time of each station or the move time between Location and Next Location.

To make the model of this plant, the process charts shown in figure 4-2 are implemented as the routing of plant. Additionally, the interarrival orders are also used as the part schedule of system.

Due to the limitation of the name length of the location and part in the Promodel, the workstation, product, order and WIP are named as follows:

- ORDER: order sent from headquarter to factory A
- A1: product A with size 100 ml
- A2: product A with size 200 ml
- A3: product A with size 300 ml
- B1: product B with size 100 ml
- B2: product B with size 200 ml
- B3: product B with size 300 ml
- C1: product C with size 100 ml
- C2: product C with size 200 ml
- C3: product C with size 300 ml
- X1: product D with size 100 ml
- X2: product D with size 200 ml
- X3: product D with size 300 ml
- DEPT: headquarter of company who provide the order to the factory A
- STORE: Material Warehouse
- INE: Input of station 2
- EXT: Station 2
- STOREL, STOREI and STOREP: WIP warehouse
- INL: Input of station 5
- LABEL: Station 5
- PRINT: Station 4
- INP: Input for station 4
- INI: Input for station 6
- Inspec: Station 6
- INPK: Input for station 7
- PACK: Station 7
- INS: Input for station 1
- STRETCH: Station 1

4.4.2 Description of Orders

The Part Scheduling module will be used to generate the orders by trigger of Arrival Frequency parameter. In this model, the arrival frequency can be presented by the Exponential distribution with mean equal to 469 min per 1 order.

Then, order will enter to DEPT where we use the possibility method to categorize the type of orders. The result from this is the type of orders such as A1, A2, and so on. With the type of orders, we can use for routing to the different processes.

4.4.3 Description of processing times

After the orders are routed to different routes by organizing of DEPT, the processing time is used in each station where the orders pass. Because ProModel accepts only the operation time in term of minute, the unit of value in table 4-1 is hour so it must be changed from hour to minute. The Table 4-5 shows the means and standard deviation of the processing time in each station in unit of minute.

Table 4-5: Processing time in unit of minute

Product	Processing time per 1 order (minutes / 1 order)									
	Station 1 & 2		Station 5		Station 4		Station 6		Station 7	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A-1	610.5	132	296.4	64.2	324	69	249	53.22	243	53.22
A-2	693	148.2	211.8	46.2	226.5	46.8	177	40.2	172.8	37.2
A-3	1110.6	252.6	129	28.8	135	28.8	231.6	50.58	219.6	50.4
B-1	483.6	105			210.6	45	170.4	37.5	164.4	37.5
B-2	1095	228			188.4	41.4	288	61.8	267	55.32
B-3	761.4	166.8			99.6	21.6	154.8	36	142.5	29.04
C-1	925.5	72	1035.6	161.4	1130	175.2	922.2	72	885.6	64.8
C-2	951	74.4	612	93.6	662.4	91.8	558	44.58	543	44.4
C-3	753	58.2	418.2	61.8	462.6	74.4	367.5	28.98	355.2	28.8
D-1	500.4	37.5			381	49.2	333.6	27	318	22.5
D-2	512.4	42.66			379.2	49.8	307.5	28.98	293.4	25.2
D-3	652.8	47.4			368.4	25.2	317.4	23.04	311.4	23.4

4.4.4 Description of move time

According to the table 4-2, the move rounds between station and warehouse of all orders are shown. With these values, the total move time in each order can be calculated by multiplying these values with the move time per 1 round. Thus, the move time per one round should be calculated first. The calculation method is the use the distance between stations of current layout divided by speed of move. The table 4-6 on the next page shows the move time per one round.

Table 4-6: Move time between stations per round

Activity	Distance	Average Speed (m/min)	Move time/1 ROUND
	Current (m)		Current (min)
S-2	28.7	20	1.435
S-1	12.6	20	0.63
S-3	31.5	20	1.575
2-W	38.5	20	1.925
1-W	40.6	20	2.03
3-W	24.5	20	1.225
5-W	24.5	20	1.225
4-W	10.5	20	0.525
6-7	11.9	20	0.595
W-5	24.5	20	1.225
W-4	10.5	20	0.525
W-6	24.5	20	1.225
7-S	8.4	20	0.42

With the data from Table 4-6, we can calculate the move time between stations of each order in the following table.

Table 4-7a: Total Move time between station per 1 order (mean)

Activity	A-1	A-2	A-3	B-1	B-2	B-3
S-2	18.7	15.8	18.7	14.4	24.4	12.9
S-1						
S-3						
2-W	98.2	144	250	78.9	227	171
1-W						
3-W						
5-W	62.5	91.9	159			
4-W	26.8	39.4	68.3	21.5	62	46.7
6-7	30.3	44.6	77.4	24.4	70.2	53
W-5	62.5	91.9	159			
W-4	26.8	39.4	68.3	21.5	62	46.7
W-6	62.5	91.9	159	50.2	145	109
7-S	21.4	31.5	54.6	17.2	49.6	37.4

Table 4-7b: Total Move time between station per 1 order (mean)

Activity	C-1	C-2	C-3	D-1	D-2	D-3
S-2						
S-1	22.7	20.8	13.9	12.6	11.3	12
S-3						
2-W						
1-W	305	471	434	164	254	376
3-W						
5-W	184	284	262			
4-W	78.8	122	112	42.5	65.6	97.1
6-7	89.3	138	127	48.2	74.4	110
W-5	184	284	262			
W-4	78.8	122	112	42.5	65.6	97.1
W-6	184	284	262	99.2	153	227
7-S	63	97.4	89.9	34	52.5	77.7

Table 4-8a: Total Move time between station per 1 order (S.D.)

Activity	A-1	A-2	A-3	B-1	B-2	B-3
S-2	4.305	4.305	4.305	4.305	5.74	2.87
S-1						
S-3						
2-W	21.175	30.8	57.75	17.325	48.125	38.5
1-W						
3-W						
5-W	13.475	19.6	36.75			
4-W	5.775	8.4	15.75	4.725	13.125	10.5
6-7	6.545	9.52	17.85	5.355	14.875	11.9
W-5	13.475	19.6	36.75			
W-4	5.775	8.4	15.75	4.725	13.125	10.5
W-6	13.475	19.6	36.75	11.025	30.625	24.5
7-S	4.62	6.72	12.6	3.78	10.5	8.4

Table 4-8b: Total Move time between station per 1 order (S.D.)

Activity	C-1	C-2	C-3	D-1	D-2	D-3
S-2						
S-1	1.89	1.89	1.26	1.26	1.26	1.26
S-3						
2-W						
1-W	24.36	38.57	34.51	14.21	22.33	28.42
3-W						
5-W	14.7	23.275	20.825			
4-W	6.3	9.975	8.925	3.675	5.775	7.35
6-7	7.14	11.305	10.115	4.165	6.545	8.33
W-5	14.7	23.275	20.825			
W-4	6.3	9.975	8.925	3.675	5.775	7.35
W-6	14.7	23.275	20.825	8.575	13.475	17.15
7-S	5.04	7.98	7.14	2.94	4.62	5.88

4.5 Model Validation

4.5.1 Validation Method

The validation method for this model is to use the statistical method to test the mean of the number of the finished orders per one month in the real system with the output of model. The mean of the finished orders from the real system is shown in Table 4-9. This data had been collected since March 01 until June 01.

Table 4-9: the Historical mean of the number of the finished orders

Month	A	B	C	D
Mar.	21	17	17	21
Apr.	17	14	22	20
May	16	13	21	19
June	18	18	20	17
July	15	19	23	15

4.5.2 Results of Simulation

Simulation model of the current layout is run 10 times to collect output data. The table below presents the obtained results from the simulation model.

Table 4-10: the number of the finished orders from simulation model

TYPE	RUN NUMBER									
	1	2	3	4	5	6	7	8	9	10
A	16	18	10	19	21	29	23	13	12	19
B	18	14	20	9	15	14	14	16	10	20
C	22	23	20	27	20	22	27	24	24	20
D	20	20	18	15	21	12	14	17	20	16

4.5.3 Conclusion

According to Table 4-9 and 4-10, the distribution of data from real system and simulation model seem to be the normal distribution. Moreover, they constitute independent random samples and are the continuous distribution. Thus, Aspin-Welch test or Student's t-Test should be used to test the mean. The variance is used to choose Aspin-Welch test or Student's t-Test. According to the rule, we can use Aspin-Welch test if the difference of the variances between both groups is high. On the other hand, we can use Student's t-Test when their difference of variances are low or the variance ratio is less than or equal to F value at the specified degree of freedom. According to the appendix A-4, the results of test are all of the variance ratios are less than F value. So, Student's t-Test is chosen to test. This appendix also shows the details of Student's t-Test for product A, B, C and D. The results from tests are shown in Table 4-11.

Table 4-11: Result of F- Ratio test and Student's t-Test

Product	Fobs	F from table	t obs	t from table
A	1.014	3.63	0.789	1.771
B	1.1094	3.63	0.204	1.771
C	2.995	3.63	-0.668	-1.771
D	0.9578	3.63	0.307	1.771

The results have provided a valuable insight into the adequacy of the simulation. Thereby, a conclusion is that this simulation model seems to be valid enough to go further for carrying out the objective of study.

4.6 Experiment

The aiming of this simulation implementation is to check the productivity of the suggested layouts, so the input factor of this experiment is the move time between stations or warehouse and the output from simulation is the productivity of system. The productivity in this case means the number of finished orders per one month. From the result in chapter 3, there are two suitable layouts. We can implement both layouts in model by using the new move time as input of model. Other factors will not be changed such as the machine capacity, the arrival of orders and so on. Therefore, we can compare the productivity of each product from the different move time of each layout. The experimental design is planned with 10 runs for each system. Simulation time for each run will last 1 month or 30 days.

4.6.1 Experimental Process

There are 4 followings steps for this experiment:

1. Measure the moving distance of both suggested layouts to calculate the move time between stations or warehouse. The table 6-1 and 6-2 show the move time between each station in the 2nd and 4th layout design.
- 2.

Table 4-12a: Total Move time between station per 1 order of 2nd design (mean)

Activity	A-1	A-2	A-3	B-1	B-2	B-3
S-2	15.93	13.48	15.93	12.25	20.83	11.03
S-1						
S-3						
2-W	62.48	91.88	159.3	50.23	144.6	109
1-W						
3-W						
5-W	44.63	65.63	113.8			
4-W	53.55	78.75	136.5	43.05	123.9	93.45
6-7	26.78	39.38	68.25	21.53	61.95	46.73
W-5	44.63	65.63	113.8			
W-4	53.55	78.75	136.5	43.05	123.9	93.45
W-6	48.2	70.88	122.9	38.75	111.5	84.11
7-S	17.85	26.25	45.5	14.35	41.3	31.15

Table 4-12b: Total Move time between station per 1 order of 2nd design (mean)

Activity	C-1	C-2	C-3	D-1	D-2	D-3
S-2						
S-1	44.1	40.43	26.95	24.5	22.05	23.28
S-3						
2-W						
1-W	157.5	243.6	224.7	85.05	131.3	194.3
3-W						
5-W	131.3	203	187.3			
4-W	157.5	243.6	224.7	85.05	131.3	194.3
6-7	78.75	121.8	112.4	42.53	65.63	97.13
W-5	131.3	203	187.3			
W-4	157.5	243.6	224.7	85.05	131.3	194.3
W-6	141.8	219.2	202.2	76.55	118.1	174.8
7-S	52.5	81.2	74.9	28.35	43.75	64.75

Table 4-12c: Total Move time between station per 1 order of 2nd design (S.D.)

Activity	A-1	A-2	A-3	B-1	B-2	B-3
S-2	3.68	3.68	3.68	3.68	4.9	2.45
S-1						
S-3						
2-W	13.5	19.6	36.8	11	30.6	24.5
1-W						
3-W						
5-W	9.63	14	26.3			
4-W	11.6	16.8	31.5	9.45	26.3	21
6-7	5.78	8.4	15.8	4.73	13.1	10.5
W-5	9.63	14	26.3			
W-4	11.6	16.8	31.5	9.45	26.3	21
W-6	10.4	15.1	28.4	8.51	23.6	18.9
7-S	3.85	5.6	10.5	3.15	8.75	7

Table 4-12d: Total Move time between station per 1 order of 2nd design (S.D.)

Activity	C-1	C-2	C-3	D-1	D-2	D-3
S-2						
S-1	3.68	3.68	2.45	2.45	2.45	2.45
S-3						
2-W						
1-W	12.6	20	17.9	7.35	11.6	14.7
3-W						
5-W	10.5	16.6	14.9			
4-W	12.6	20	17.9	7.35	11.6	14.7
6-7	6.3	9.98	8.93	3.68	5.78	7.35
W-5	10.5	16.6	14.9			
W-4	12.6	20	17.9	7.35	11.6	14.7
W-6	11.3	18	16.1	6.62	10.4	13.2
7-S	4.2	6.65	5.95	2.45	3.85	4.9

Table 4-13a: Total Move time between station per 1 order of 4th design (mean)

Activity	A-1	A-2	A-3	B-1	B-2	B-3
S-2	17.063	14.438	17.063	13.125	22.313	11.813
S-1						
S-3						
2-W	93.713	137.81	238.88	75.338	216.83	163.54
1-W						
3-W						
5-W	35.7	52.5	91			
4-W	58.013	85.313	147.88	46.638	134.23	101.24
6-7	31.238	45.938	79.625	25.113	72.275	54.513
W-5	35.7	52.5	91			
W-4	58.013	85.313	147.88	46.638	134.23	101.24
W-6	44.625	65.625	113.75	35.875	103.25	77.875
7-S	22.313	32.813	56.875	17.938	51.625	38.938

Table 4-13b: Total Move time between station per 1 order of 4th design (mean)

Activity	C-1	C-2	C-3	D-1	D-2	D-3
S-2						
S-1	22.05	20.213	13.475	12.25	11.025	11.638
S-3						
2-W						
1-W	131.25	203	187.25	70.875	109.38	161.88
3-W						
5-W	105	162.4	149.8			
4-W	170.63	263.9	243.43	92.138	142.19	210.44
6-7	91.875	142.1	131.08	49.613	76.563	113.31
W-5	105	162.4	149.8			
W-4	170.63	263.9	243.43	92.138	142.19	210.44
W-6	131.25	203	187.25	70.875	109.38	161.88
7-S	65.625	101.5	93.625	35.438	54.688	80.938

Table 4-13c: Total Move time between station per 1 order of 4th design (S.D.)

Activity	A-1	A-2	A-3	B-1	B-2	B-3
S-2	3.9375	3.9375	3.9375	3.9375	5.25	2.625
S-1						
S-3						
2-W	20.213	29.4	55.125	11.025	45.938	36.75
1-W						
3-W						
5-W	7.7	11.2	21			
4-W	12.513	18.2	34.125	9.45	28.438	22.75
6-7	6.7375	9.8	18.375	4.725	15.313	12.25
W-5	7.7	11.2	21			
W-4	12.513	18.2	34.125	9.45	28.438	22.75
W-6	9.625	14	26.25	8.505	21.875	17.5
7-S	4.8125	7	13.125	3.15	10.938	8.75

Table 4-13d: Total Move time between station per 1 order of 4th design (S.D.)

Activity	C-1	C-2	C-3	D-1	D-2	D-3
S-2						
S-1	1.8375	1.8375	1.225	1.225	1.225	1.225
S-3						
2-W						
1-W	10.5	16.625	14.875	6.125	9.625	12.25
3-W						
5-W	8.4	13.3	11.9			
4-W	13.65	21.613	19.338	7.9625	12.513	15.925
6-7	7.35	11.638	10.413	4.2875	6.7375	8.575
W-5	8.4	13.3	11.9			
W-4	13.65	21.613	19.338	7.9625	12.513	15.925
W-6	10.5	16.625	14.875	6.125	9.625	12.25
7-S	5.25	8.3125	7.4375	3.0625	4.8125	6.125

3. Feed these move time into the models concerned.
4. Run each alternative model 10 times for 720 hours at a time.
5. Treat the obtained data.

4.7 Model Run & Output Analysis

The results of simulation models with the suggested layout designs are shown in Tables 4-14 and 4-15.

Table 4-14: the number of the finished orders from simulation model with 2nd layout design

TYPE	RUN NUMBER									
	1	2	3	4	5	6	7	8	9	10
A	16	18	12	19	21	29	23	13	12	19
B	18	14	20	9	15	14	14	16	10	20
C	22	23	20	27	20	22	27	24	24	20
D	20	20	18	15	21	12	14	17	20	16

Table 4-15: the number of the finished orders from simulation model with 4th layout design

TYPE	RUN NUMBER									
	1	2	3	4	5	6	7	8	9	10
A	16	18	10	19	21	29	23	13	12	19
B	18	14	20	9	15	14	14	16	10	20
C	22	23	20	27	20	22	27	24	24	20
D	20	20	18	15	21	12	14	17	20	16

The output data from Tables 4-14 and 4-14 can be tested by the same statistical method as the verification process in section 4.5. Details of test are shown in appendix A-5.

Table 4-16: Result of F- Ratio test and Student's t-Test between the current layout and the suggested designs

Design	Product	Fobs	F from table	t obs	t from table
2 nd					
	A	2.175	3.18	1.75	1.734
	B	2.381	3.18	-0.727	-1.734
	C	0.522	3.18	0.714	1.734
	D	1.026	3.18	-0.778	-1.734
4 th					
	A	3.123	3.18	2.029	1.734
	B	1.281	3.18	-1.39	-1.734
	C	1.794	3.18	1.716	1.734
	D	2.844	3.18	0.267	1.734

Table 4-17: Result of F- Ratio test and Student's t-Test between the suggested designs

Product	Fobs	F from table	t obs	t from table
A	1.252	3.18	-0.414	-1.734
B	1.367	3.18	0.346	1.734
C	0.356	3.18	-1.156	-1.734
D	0.449	3.18	0.81	1.734

According to the result of simulation model in the above table, it is found that both suggested layout designs can help to improve the productivity of product A. Although they can help improve only one type of order, the trend of the productivity seems to be better. For instance, the productivity of product C in 4th design may be the same at the significant level of 10%. If we increase the significance level to 20%, the productivity of product C in 4th design will be better. When the suggested design are compared each other, it is found that the productivity are the same. That means we can't use the productivity to make decision for selection of the suggested layouts. Thus, the moving distance should be the criteria for decision. According the moving distance tested in chapter 3, the moving distance of the 2nd design is shorter than the 4th design. Therefore, the 2nd layout design should be the acceptable layout in aspect of the shortest moving distance and the productivity.

4.8 Final Result

Although the productivity and moving distance from the suggested layouts are proved, it is not enough information to decide to rearrange the plant layout because the cost for rearrangement is discussed. Thus, the last section discusses the rearrangement cost of each suggested layout. This information is proposed to management for further decision.

4.8.1 Cost for Moving Stations

The cost of rearranging the stations and warehouse are shown in Table 4-18. The vendors estimate this cost roughly.

Table 4-18: Cost of Moving the Stations and Warehouse

Station	Cost (x 1000 baht)
1	25
2	25
3	25
4	20
5	20
6	5
7	5
W	200
S	5

Thus, the costs for 2nd and 4th designs are 315,000.00 and 325,000.00 baht respectively.

4.8.2 Profit of Increasing Productivity

The productivities increased by the 2nd and 4th design are 11% and 14% of orders in 1 month respectively. When considering the number of products in each order in term of average, it may mean that the finished product increases around 6,300 pieces for 2nd design and 8,800 pieces for 4th design. Normally, the company can get the profit for 1 piece around 2 baht. That means the company can get more profit around 12,600 baht and 17,600 baht for 2nd design and 4th design respectively.

4.8.3 Conclusion

When comparing between the cost for moving stations and the profit, it is found that the investment return period of 2nd and 4th design is 25 and 18.5 months respectively. Therefore, the 4th design is the acceptable and acceptable layout in aspect of high productivity and short moving distance.