Title: Machine Layout Analysis of Nal Plastic Co & Comparison to a Proposed Model

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Abstract: With this project, the author has taken a difficult problem of plant layout in an emerging industrial country, analyzed many different potential solutions to efficiency, and considered aspects of the plant layout from engineering, architecture and business management perspectives. The objective of this project was to improve labor usage efficiency in the company, compare the current layout efficiency level with proposed configurations, and enable the company owners to configure their floor easily to other combinations.

The Machine Layout Analysis of Nal Plastic Co. & Comparison to a Proposed Model

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The Machine Layout Analysis

of

Nal Plastic Co.

&

Comparison to a Proposed Model

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Introduction

After the industrial revolution factories have become a complex manufacturing places where goods have been produced by putting several different parts together. Some factories were so large that usually labors in working cells didn't know what he/she was making.

With the petrol crisis in 1970 world has begun to change, efficiency has become the most important factor in manufacturing while using the resources. This has forced engineers to analyze the layout of the plants in order to increase the efficiency by changing the routing of the parts or creating work cells.

There is no one sequence solution that can help engineers to solve their layout problems. There are many aspects of the plant layout like engineering, architecture, and business management. Each one has a different effect on the layout design. Therefore it is (or at least it was) difficult to analyze a layout problem without having a powerful tool.

Several analytic researches had been done in the past, but the most efficient and fast way has come up with the introduction of the computers. Specially made layout simulators have helped engineers to build the plant layouts and make necessary changes in a very short time with a very limited resources.

Problem Definition

Nal Plastic Co. is a family owned company where it is produced plastic bottles, automobile parts, and some other plastic part for appliances. It has been found in 1969 in Istanbul.

Due to the limited resources (capital, specialist) there has never been done an efficiency control for the layout of workshop. The layout has been done without any calculation for the efficiency just by repetition of the classical layout form that has been thought as the least expensive combination.

In 1992 the company moved to its new building. This has created a chance to analyze and find the best configuration for the machines. Even though they have placed the machines to the new building because of unexpected circumstances, they plan to move one floor up.

The classical way to place the machines is to put them in line, along the walls. This is the easiest configuration to bring the coolants and compressed air for each of the machines in a limited space, but of course there is no scientific proof of this.

The aim of this project is to study different combination of layouts and study the efficiency of them while comparing the results with the current classical formation. The efficiency measure will be the number of labor used in each combination and their total idle time. For that purpose we will use the Promodel simulation software package as the main tool.

The relative easiness of the new generation simulation softwares allows you to see the production in action while giving the necessary statistical parameters to control the efficiency of the company throughput. In this project, because of the limited capacity of the Promodel Student version, we will simulate a small percentage of the Nal Plastic machine layout.

The areas that will be focused on are:

- the transportation of the raw material to the machines
- transportation of the scrap produced by the machine to the cruncher
- transportation of the bottles made to the inventory.

The objective of the project will be to improve labor usage efficiency of the company. The study will allow us to measure the differences between the current layout efficiency level-concerning the workers-and the proposed layout configurations. Once we setup the layout, we will be able to configure it easily to other combinations.

Definition of the Operations

There are two main operations that have to be taken care of by workers:

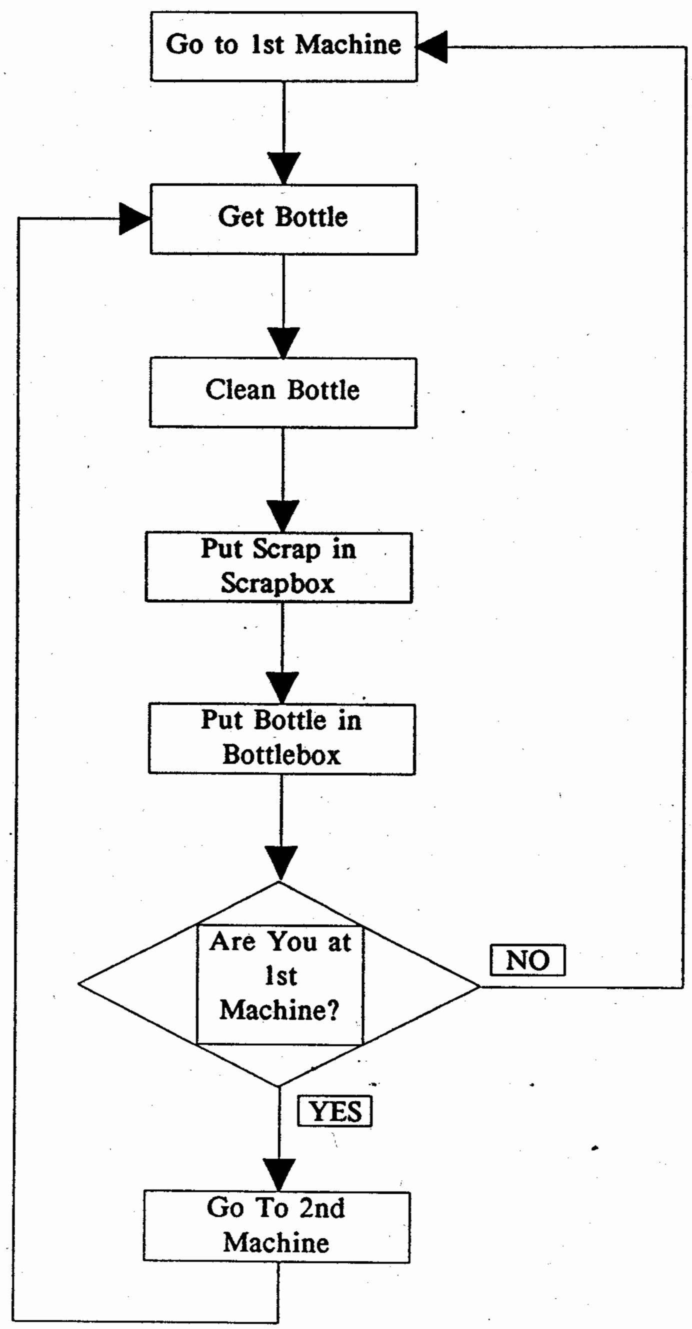
- Moving the bottles and scraps from machine to their respective locations: bottle boxe and scrap box

Since there is no possibility to move the box and scrap containers away from machines, we will not deal with this operation in measuring the layout of the company; rather we will be concerned of the following operation;

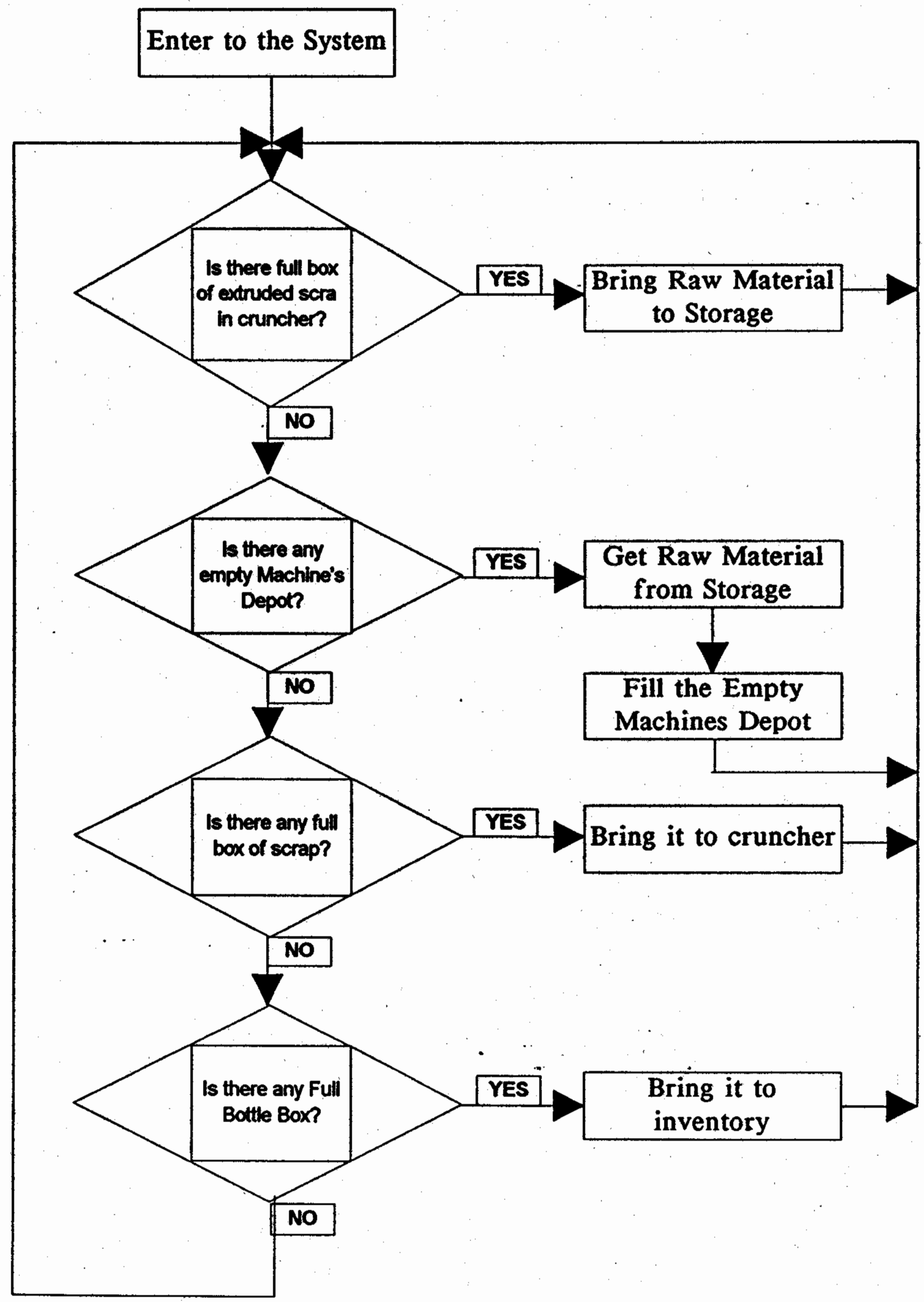
- Feeding machines with raw material, moving the boxes of scrap and bottles to their respective locations: Cruncher and inventory; and moving the raw material from cruncher to storage.

The charts of these two operations are in the following figures:

Cleaner Flow Chart



Carrier Flow Chart



Proposed model for Nal Plastic Co.

Objective:

To find out, whether the proposed layout should be implemented or not.

Alternatives:

Improve the layout so that

it will decrease the number of labor or

Improve automation

Criteria:

Throughput : amount of bottle produced

Number of labor used

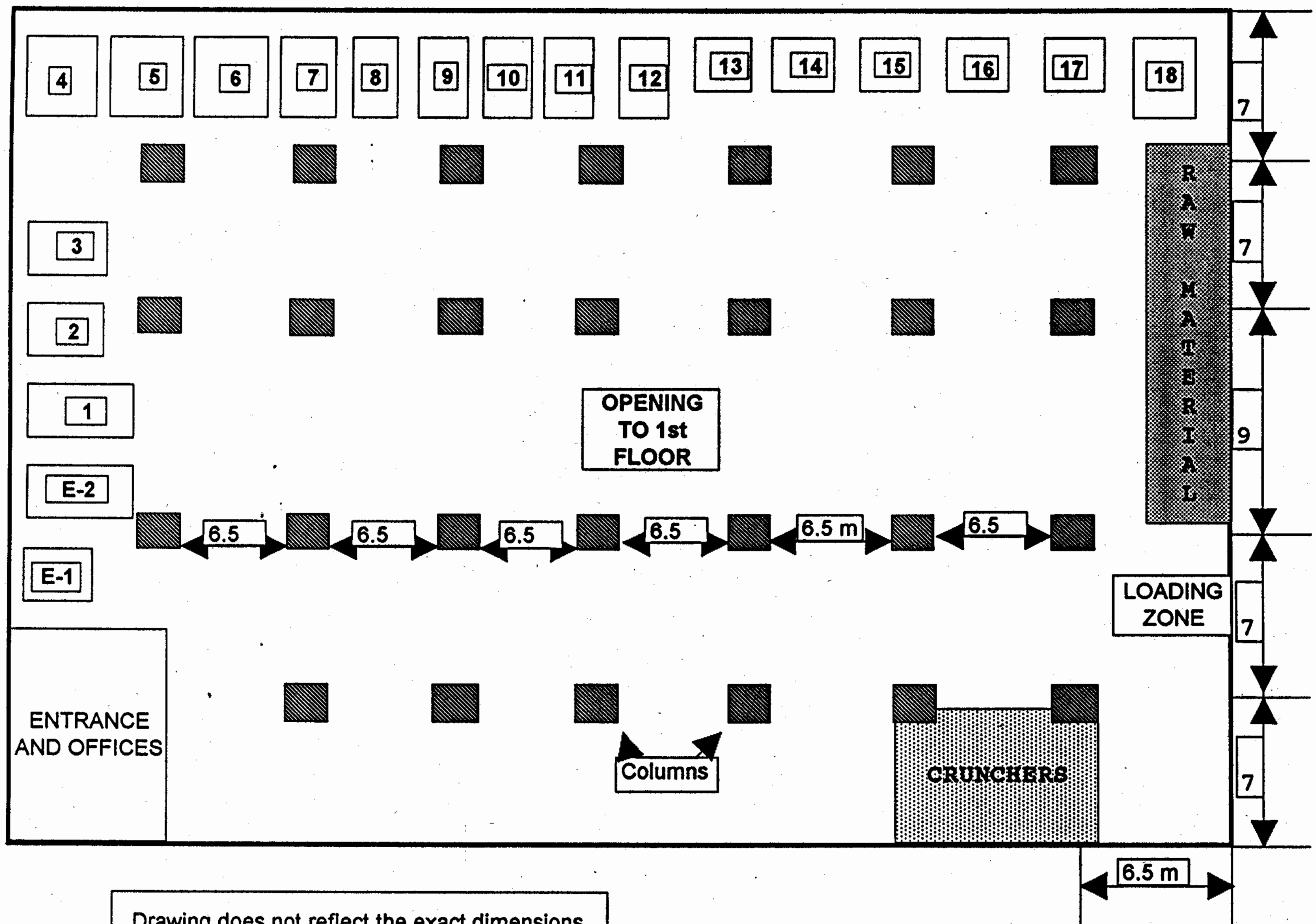
Efficiency level of labors-in number of hours worked

Entities	**Attributes**
Raw Material	Location relative to machines
	Amount used by machines
Bottle	Location relative to inventory
	Location relative to storage
	Number of bottles produced
Scrap	Location relative to cruncher
	Number of scraps produced

Events	Attributes
Transfer of raw material from inventory to machines	Distance
Production of bottle	Machine speed
Separating scrap from bottle	Machine speed
Deposing bottles into boxes	Machine speed
Deposing scraps into scrap box	Machine speed
Transfer of bottles to inventory	Distance Labor speed
Transfer of scraps to cruncher	Distance Labor speed
Conversion of scrap to raw material	Cruncher speed
Transfer of raw material to storage	Distance Labor speed

Current machine layout, proposed machine layout and the related distances between locations and machines are as in the figure:

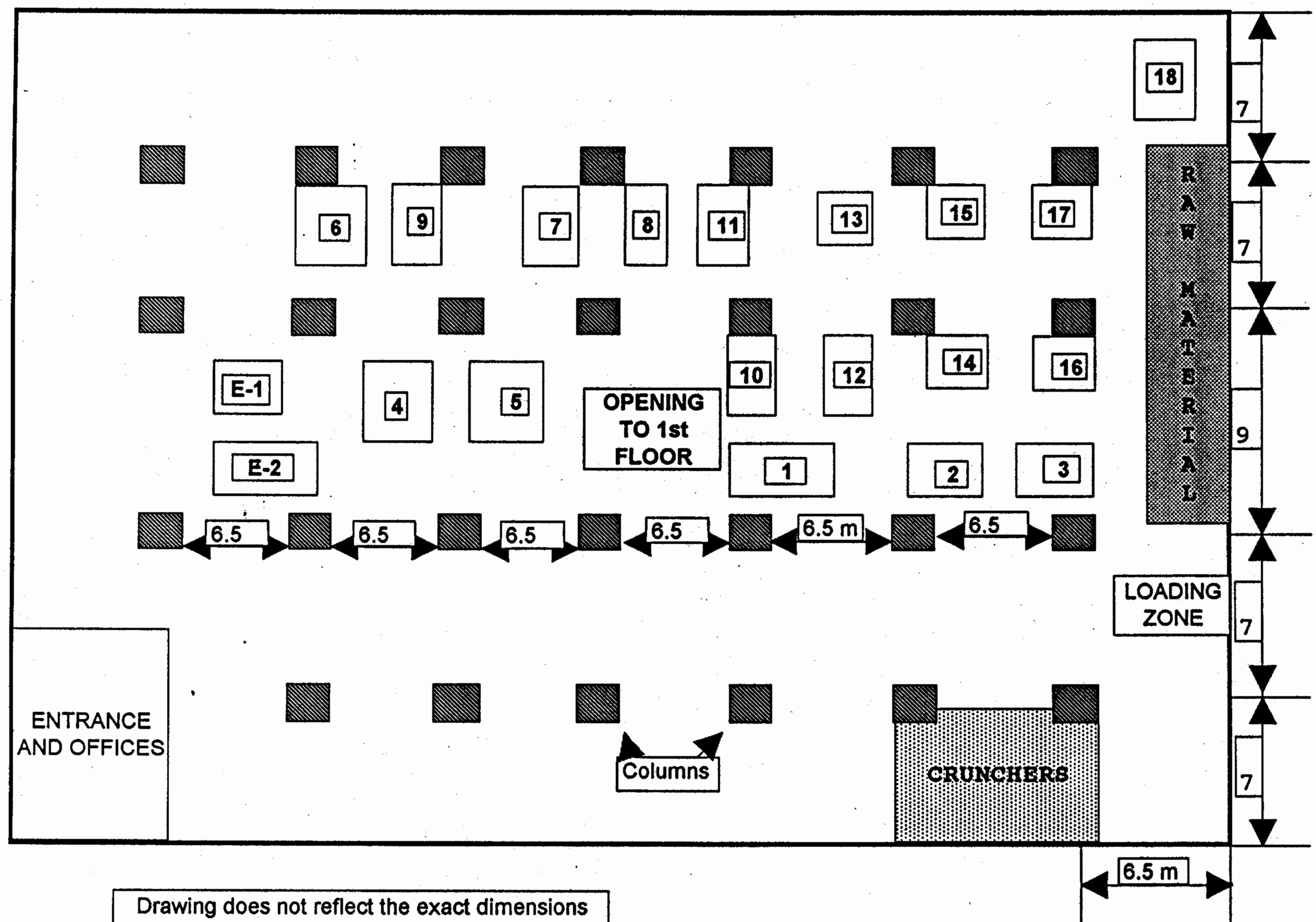
NAL PLASTIC MACHINE LAYOUT



Drawing does not reflect the exact dimensions.

Figure 1

NAL PLASTIC PROPOSED MACHINE LAYOUT



Drawing does not reflect the exact dimensions but the proportions are correct.

Figure 1

Distance of the machines to the locations (current layout)

Machine No	Cruncher	C x	C y	Raw material Storage	RM x	RM y	Inventory	I x	I y
12	34.623691	16.2	30.6	22.98369	22.7	3.6	14.4	0	14.4
13	33.246955	13	30.6	19.829523	19.5	3.6	14.751271	3.2	14.4
14	31.282743	6.5	30.6	16.59518	16.2	3.6	15.799051	6.5	14.4
15	30.766865	3.2	30.6	13.489255	13	3.6	17.362316	9.7	14.4

Distance of the machines to the locations (proposed layout)

Machine No	Cruncher	C x	C y	Raw material Storage	RM x	RM y	Inventory	I x	I y
12	22.048356	9.7	19.8	13.489255	13	3.6	7.9056942	6.5	4.5
13	25.330811	9.7	23.4	13.489255	13	3.6	10.385567	6.5	8.1
14	19.8	0	19.8	10.346497	9.7	3.6	10.692988	9.7	4.5
15	23.4	0	23.4	10.346497	9.7	3.6	12.637247	9.7	8.1

- The assignment of workers to the machines and jobs are showed in the following list

Worker	Job
1	Machine E-1 and E-2
2	Machine 1
3	Machine 2 and 3
4	Machine 5 and 6
5	Machine 7
6	Machine 8 and 9
7	Machine 10 and 11
8	Machine 12 and 13
9	Machine 14 and 15
10	Machine 16 and 17
11	Plastic ball department
12	Plastic ball department
13	Plastic ball department
14	Plastic ball department
15	Plastic ball department
16	Plastic ball department
17	Loading and unloading of the materials
18	Loading and unloading of the materials
19	Cruncher
20	Cruncher
21	Formen
22	Formen
23	Raw material, scrap and product carrier
24	Raw material, scrap and product carrier
25	Raw material, scrap and product carrier
26	Raw material, scrap and product carrier
27	Raw material, scrap and product carrier
28	Raw material, scrap and product carrier
29	Raw material, scrap and product carrier

Data Gathering

Nal plastic has had not any data collection system, related to the production. Since the company make the same product for several customers, for example a bottle, usually machines have kept working all day, for weeks and months. Nobody has conrolled or registered the amount of goods made until Mr Kaan Uslu's arrive. After then, he has tried to implement a rough control on the inventory by collecting the amount of bottle produced per machine per day as frequent as possible.

The data that has been recieved from the company, spread all over the year with different time increments, sometime 2 days per week sometimes none.

Because of abscence of necessary data, it is preferred to pick the triangular distribution and therefore it is tried to find the maximum, minimum and average values that will be used, covering a whole year.

Following table shows the data obtained from the company for 20 machines:

Machine Production Rates and Related Datas

Machine No	Bottle weight with scrap (gr)	Bottle weight (gr)	scrap (gr)	Operation Time for 1 bottle (sec)	Production per day (min)	Production amount per day (mean)	Production per day (Max)	Raw materail used per day (kg)	Scrap box capacity (piece of scrap)	Bottle per package	Scrap produced per day (kg)	Depot capacity (number of bags)	Amount of bottle produced per depot
1	32	21	11	23	1250	1408	1500	45	327	150	15	1	781
2	50	36	14	11	2800	2945	3100	147	257	100	41	2	1000
3	33	24	9	30	980	1080	1150	35	400	150	9	1	757
4	40	22	18	28	1060	1157	1270	46	200	30	20	2	1250
5	48	39	9	17	1850	1905	1970	91	400	50	17	1	520
6	135	90	45	62	440	522	580	70	80	45	23	2	370
7	43	30	13	23	1350	1408	1460	60	276	100	18	2	1162
8	33	25	8	11	2700	2945	3150	97	450	100	23	2	1515
9	170	71	99	29	950	1060	1110	189	36	150	110	2	294
10	236	170	66	39	790	830	900	195	54	20	54	2	211
11	236	150	86	45	680	720	780	169	41	25	61	2	211
12	48	39	9	29	1030	1117	1330	53	400	50	10	1	520
13	139	93	46	36	840	900	950	125	78	25	41	1	179
14	248	164	84	37	825	875	940	217	42	20	73	2	201
15	148	97	51	36	860	900	1020	133	70	30	45	2	337
16	164	110	54	54	540	600	690	98	66	205	32	1	152
17	93	58	35	34	930	952	1120	88	102	150	33	2	537
18	Not Working												
E-1	36	27	9	4.5	7000	7200	7350	32	400	x	8	1	694
E-2	35	29	6	11	2800	2945	3100	26	600	x	5	1	714

Bottle Production Times (in minutes)

	Time spent for one bottle, in minute			
	Working hour		9	
Machine No	Min	Mean	Max	
1	0.36	0.38352273	0.432	
2	0.17419355	0.18336163	0.1929	
3	0.46956522	0.5	0.551	
4	0.42519685	0.46672429	0.5094	
5	0.27411168	0.28346457	0.2919	
6	0.93103448	1.03448276	1.2273	
7	0.36986301	0.38352273	0.4	
8	0.17142857	0.18336163	0.2	
9	0.48648649	0.50943396	0.5684	
10	0.6	0.65060241	0.6835	
11	0.69230769	0.75	0.7941	
12	0.40601504	0.48343778	0.5243	
13	0.56842105	0.6	0.6429	
14	0.57446809	0.61714286	0.6545	
15	0.52941176	0.6	0.6279	
16	0.7826087	0.9	1	
17	0.48214286	0.56722689	0.5806	
18	0	0	0	
E-1	0.07346939	0.075	0.0771	
E-2	0.17419355	0.18336163	0.1929	

Scale Reduction of the Project

Due to the limited time and limited software capabilities, there is a need of reduction in the scale of the project. It is not possible to represent all of the 20 machines and 29 workers in the simulation project and analyze the results.

Since the assignments of the workers are defined, the capacity of the machines are similar (except distances, and their performance), the reduced scale of the simulation will be able to represent the exact scale of the operations. This will also allow us to implement the possible solutions received from the reduced scale simulation, to the real scale to increase the efficiency level of the workers.

Following list is the assumpitons made to simplify the problem without affecting the results:

Number of machines 4

Machines number12,13,14,15 have been choosen to analyze the efficiency of the workers. The idea in choosing these four machines is that they are the ones that will be affected at the least degree after the layout change. There fore if simulation can provide enough proof that the worker efficiency level increased, it could be said that the effect of the layout change will have a greater impact on other workers working for other machines.

Number of workers 4

1 person for two blow molding machines, to move scrap from machine to boxes

1 person to move the raw material to machine, the scrap to cruncher, the bottles to inventory

Every machine uses same kind of raw material

There is no down time

down times are included in the output of the machines

There is no rejected bottles

they are included in the output of the machines

There is no break for workers

Infinite resource of raw material

There is no warmup time

Crunchers have infinite capacity

Workers have constant speed when they carry something or when they are empty

Distribution Parameters

Following section contains the calculations made with the datas concerning the four machines that have been choosen.

A software called UNIFIT 2 has been used to find the necessary parameters of the distributions for the machine production rates, to use in the Promodel simulation program.

Task (Activity) Time Models For Task: Machine 1

A model has been specified based upon:

Minimum possible task time in Minutes	.41000	(specified)
Most likely task time in Minutes	.48000	(specified)
Average task time in Minutes	.47000	(calculated)
Maximum possible task time in Minutes	.52000	(specified)

Task-Time Model For Task: Machine 1

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter .41000

Upper Endpoint Parameter .52000

Shape Parameter (Mode) .48000

Percentiles of Task-Time Model For Task: Machine 1

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter .41000

Upper Endpoint Parameter .52000

Shape Parameter (Mode) .48000

Model Characteristic	Task-Time Model
Mean value	.47000
Minimum possible value	.41000
25th percentile	.45387
50th percentile	.47205
75th percentile	.48683
90th percentile	.49902
95th percentile	.50517
99th percentile	.51337
Maximum possible value	.52000

(all in Minutes)

Representation of Task-Time Model for Task: Machine 1

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter .41000

Upper Endpoint Parameter .52000

Shape Parameter (Mode) .48000

ProModel for Windows Representation:

Use T(.41000, .48000, .52000, <stream>)

Task (Activity) Time Models For Task: Machine 2

A model has been specified based upon:

Minimum possible task time in Minutes	.56842	(specified)
Most likely task time in Minutes	.60000	(specified)
Average task time in Minutes	.60377	(calculated)
Maximum possible task time in Minutes	.64290	(specified)

Task-Time Model For Task: Machine 2

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter	.56842
Upper Endpoint Parameter	.64290
Shape Parameter (Mode)	.60000

Percentiles of Task-Time Model For Task: Machine 2

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter	.56842
Upper Endpoint Parameter	.64290
Shape Parameter (Mode)	.60000

Model Characteristic	Task-Time Model
Mean value	.60377
Minimum possible value	.56842
25th percentile	.59267
50th percentile	.60293
75th percentile	.61464
90th percentile	.62502
95th percentile	.63026
99th percentile	.63725
Maximum possible value	.64290

(all in Minutes)

Representation of Task-Time Model for Task: Machine 2

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter .56842

Upper Endpoint Parameter .64290

Shape Parameter (Mode) .60000

ProModel for Windows Representation:

Use T(.56842, .60000, .64290, <stream>)

Task (Activity) Time Models For Task: Machine 3

A model has been specified based upon:

Minimum possible task time in Minutes	.57447	(specified)
Most likely task time in Minutes	.61714	(specified)
Average task time in Minutes	.61537	(calculated)
Maximum possible task time in Minutes	.65450	(specified)

Task-Time Model For Task: Machine 3

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter	.57447
Upper Endpoint Parameter	.65450
Shape Parameter (Mode)	.61714

Percentiles of Task-Time Model For Task: Machine 3

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter	.57447
Upper Endpoint Parameter	.65450
Shape Parameter (Mode)	.61714

Model Characteristic	Task-Time Model
Mean value	.61537
Minimum possible value	.57447
25th percentile	.60369
50th percentile	.61579
75th percentile	.62716
90th percentile	.63721
95th percentile	.64227
99th percentile	.64903
Maximum possible value	.65450

(all in Minutes)

Representation of Task-Time Model for Task: Machine 3

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter .57447

Upper Endpoint Parameter .65450

Shape Parameter (Mode) .61714

ProModel for Windows Representation:

Use T(.57447, .61714, .65450, <stream>)

Task (Activity) Time Models For Task: Machine 4

A model has been specified based upon:

Minimum possible task time in Minutes	.52941	(specified)
Most likely task time in Minutes	.60000	(specified)
Average task time in Minutes	.58577	(calculated)
Maximum possible task time in Minutes	.62790	(specified)

Task-Time Model For Task: Machine 4

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter	.52941
Upper Endpoint Parameter	.62790
Shape Parameter (Mode)	.60000

Percentiles of Task-Time Model For Task: Machine 4

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter	.52941
Upper Endpoint Parameter	.62790
Shape Parameter (Mode)	.60000

Model Characteristic	Task-Time Model
Mean value	.58577
Minimum possible value	.52941
25th percentile	.57110
50th percentile	.58837
75th percentile	.60169
90th percentile	.61132
95th percentile	.61618
99th percentile	.62266
Maximum possible value	.62790

(all in Minutes)

Representation of Task-Time Model for Task: Machine 4

Task-Time Model: Triangular Distribution

Lower Endpoint Parameter .52941

Upper Endpoint Parameter .62790

Shape Parameter (Mode) .60000

ProModel for Windows Representation:

Use T(.52941, .60000, .62790, <stream>)

Verification

It has been put four variables to control the throughput of the machines. The simulation has been designed so that the machines produce an output which is in the range of the distribution as long as the workers do what they are intended to do; if not should the throughput of the machine have dropped.

The production rates obtained from machines are consistent with data received from the company. The increase in the idle time of the workers-comparing current layout with the proposed one- prove that the simulation works as expected

Also depending on my experience, the results are satisfactory to be able to use it on larger scales.

Validation

All operations that were expected to simulate have run as it should . The animation mode of the Promodel has been designed so that the movement of the workers could be observed. There was no flaw on the displacement of the materials.

As it has been mentioned in the 'Scale Reduction' part, this is a just a small part of the whole system, but it contains all the specifications of the full system. Since each machine could be accepted as an individual work cell with its own workers, the output of the machines is not dependent on each other. Therefore the real system can be scaled up or scaled down as the wishes of the user.

It can also be said that the project itself is a sensitivity analysis. The change in distance data, for the new layout, has showed the expected changes in the efficiency level of the workers.

Conclusion

Simulated system has been run three times for each of the layouts (current and proposed). The results- as it can be seen on the graphs- for the ***idle time*** of the resource in one day are:

	Current Layout			***New Layout***		
Run	**1**	**2**	**3**	**1**	**2**	**3**
Res1 (responsible of machine 12 and 13)	60.39%	59.92%	60.36%	64.95%	65.10%	64.85%
Res2 (responsible of machine 14 and 15)	36.47%	36.24%	36.28%	44.27%	44.40%	44.17%

Idle Times in one day (9 hours) in minutes are:

	Current Layout			***New Layout***		
Run	**1**	**2**	**3**	**1**	**2**	**3**
Res1 (responsible of machine 12 and 13)	326.106	323.568	325.944	350.73	351.54	350.19
Res2 (responsible of machine 14 and 15)	196.938	195.696	195.912	239.058	239.76	238.518

Project History

23 September 1993	1st day of the class
23 September/ 04 November	Researches for a project subject
04 November	Assignment gave an idea of project: Layout design of the Nal Plastic Co.
16 November	Data concerning the layout design, machine production rates, and some financial information have been sent from Istanbul to Portland
11 November/20 November	Studies on Promodel simulation program
18 November	Class discussion on projects/Approval
20/21 November	Data analysis, distribution fit and design of two different layouts and runs. (all has been done in one night 28 hours)
21/28 November	Typing
1/2 December	Printing
02 December 1993	Project due

It was difficult to handle this project, without having an idea from where to begin. When you had the idea you realize that it is too late. You become more 'realized' when you begin to program your model on Promodel. It took me one whole week-at least 6 hours per day- to learn how it works.

My greatest mistake was to begin to model the project from what it should be at the end. Of course I couldn't simulate it. Then I have started from one machine and one worker, by trying to load the raw material to the machine without expecting any other operation.

Next step was to improve this model step by step: I made the machine produce bottles, define scraps, bottles, form second worker, make him carry the bottles and scrap to the boxes (I realized that this has no effect on project but I didn't delete it).

Third step was to order to the first worker to carry the scrap and bottles to their places. Now the rest seemed easy but it wasn't. I had to add 3 more machines and three more workers. That took me a day to figure out that when you click a location to define a second path from that location, you should be really careful to not click another place other than already clicked dot, smaller than (.) this. Because if you don't click the exact point computer understands this location as a different one.

Any way, I figured out that at last. The last problem was how to save the program because of the limitations: I couldn't . So I have stood awake until morning, from 6 p.m. and I have finished all runs and got the output- hoping that I didn't make a mistake. To see the simulation working, and give the results consistent with the data I was given, was a great pleasure.

The rest was just analysis of the reults and the typing of the conclusion.

In the following output tables

1.res	=	first run for current layout
2.res	=	second run for current layout
3.res	=	Third run for the current layout
4.res	=	First run for proposed (new) layout
5.res	=	Second run for proposed (new) layout
6.res	=	Third run for proposed (new) layout
Depot_x (x=1,2,3,4)	=	The depot of the the machine_x for raw material
Scrap_x (x=1,2,3,4)	=	The box for scrap of machine_x
Box_x (x=1,2,3,4)	=	The box for bottles of machine_x
Res_x (x=1,3)	=	Workers who are responsible of carrying the raw material, scrap and bottle
Res_x (x=2,4)	=	Workers who are responsible with the machine
Var x (x=1,2,3,4)	=	The output of the machine_x