INTEGRATING SIMULATION AND DESIGN OF EXPERIMENTS TO IDENTIFY FACTORS FOR LAYOUT DESIGN

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Abstract

In this paper, the facilities design of a manufacturing layout is conducted by integrating simulation and design of experiments to study the influence of process parameters on the performance of the plant. This research study involves a shop floor wherein the parts contributing to 75% – 80% of the annual revenue are analyzed. This is achieved by selecting a few potential parameters/factors that could affect the time in system of these parts in the plant, and a 2^8 factorial experimental design is conducted to measure the main effects and interactions between these factors. The eight experimental factors include the location of machines, batch sizes of the parts, downtimes and setup times on machines, number and type of transporters, work-in-process container size, and machine utilization. The responses from the designed experiment help us relate the factors affecting the output of each part to improve the productivity of the plant.

Keywords: Facilities Design, Simulation, and Design of Experiments

1. Introduction

The past few decades have seen an increase in evaluating new mathematical techniques for designing new plant facilities. A study of the literature on facilities design shows that several heuristic algorithms have been proposed and many software packages also exist for solving the layout problem. Most of these techniques try to locate the machines in the facility with an objective to reduce the distance traveled by the part types. But the performance of the new facility can also depend on other factors such as the batch sizes of parts, downtimes and setup times on machines, etc. So, there is a need to identify other parameters that could influence the performance of a layout and then design an efficient facility. This school of thought has been put into practice in this research work.

The main objective of this research work is efficiently to design a layout by conducting a full factorial designed experiment between the factors that could affect its performance. The performance of the layout is measured in terms of the time in system of the part types. The parts that contribute 75%-80% of the annual revenue of the plant are first identified, and eight different factors that could affect the time in system of these parts are selected. A factorial designed experiment is conducted by simulating the system using the Arena simulation software (Kelton, Sadowski, and Sadowski[1]). The role of simulation as a tool for system analysis is exhibited in this study. The responses from the experiment are analyzed to measure the main effects and interactions between the factors. This analysis helps identify the significant factors affecting the time in system for each part type. The values of these factors can be changed accordingly and the experiment can be iteratively conducted. Based on the results from these experiments, the new facility can be designed efficiently.

This research work is carried out for an automotive accessories plant. The anonymity of the plant facility, part, and machine names is maintained in this research work. However, the information used for conducting this research work is real and not hypothetical.

Section 2 contains a literature survey of existing facilities-design techniques. Section 3 describes the problem description and data collection, data analysis, and gives an overview of the potential factors considered in this experiment that could affect the given system. Section 4 discusses the type of experimental design conducted, and also gives a brief procedure of how the system was modeled. This is followed by Section 5, which describes the analysis of the responses obtained for each part type from the designed experiment. Finally, the conclusions and the application areas for this research are described.

2. Facilities Design and Literature Review

The determination of the best layout for a facility is a classical industrial-engineering problem. The prime interest in a facilities-design problem is to determine a layout that optimizes some measure of production efficiency. The layout problem is applicable to many environments like warehouses, banks, airports, manufacturing systems, etc. Each of the above applications has distinct characteristics. Some of the common objectives in any facilities-design problem as seen in Nahmias[2], would be to minimize cost investment for production, to utilize available space efficiently, to minimize material handling cost, and to reduce work in process. As noted before, this research work involves a facilities-design problem for a manufacturing facility where the main objective is to minimize the time in system of the parts.

Extensive research has been done in designing layouts, including recent studies to compare the performance of process layouts and cellular layouts. Earlier concepts that cellular layouts outperform job-shop layouts in all aspects have been demonstrated to be false. Flynn and Jacobs[3] have done a comparison between job-shop layout and group-technology layout using simulation. Their study reveals that the performance of group technology was better in terms of average set-up time and average distance traveled per move, but there were serious problems in the performance of group-technology shops in other respects. This was attributed to long part queues in shops having dedicated machines. This in turn increased the average time in system for parts being produced in the cellular layout. Burgess, Morgan and Vollmann[4] have also done a study that compares a factory structured as a traditional job shop and as a hybrid factory containing a cellular manufacturing unit. A systematic evaluation of cellular manufacturing was conducted and the results revealed the particular circumstances that favored the use of group technology. Shambu and Suresh[5] have done a comparative study of hybrid cellular manufacturing systems with traditional job-shop layouts under a variety of operating conditions. Their study was conducted for the entire shop floor and revealed that the performance of the remainder of the shop deteriorated with increasing conversion of functional layouts into cellular manufacturing due to erosion of pooling synergy.

Studies have also identified methods to increase the performance of cellular layouts. Sassani[6] conducted a simulation experiment to demonstrate that the utilization of group-technology cells can be improved through sub-batch workload transfer. The study also showed that a detailed and practically oriented computer-simulation analysis could be a useful aid in management decision-making. Several scheduling heuristics have also been proposed for cellular manufacturing environments. Mahmood, Dooley and Starr[7] proposed dynamic scheduling heuristics for manufacturing cells and showed that these rules increase the performance of the cell layouts.

Unlike previous studies, the research reported here is undertaken to demonstrate that different manufacturing parameters including the location of machines, batch sizes of parts, downtimes of machines, etc. can influence the design and performance of layouts for manufacturing facilities.

3. Problem Description

Our objective is to design an efficient layout with appropriate values for the process parameters, so that the flow time of the parts is minimized. *Flow time* is the time that a part spends in a system, from the raw-materials stage to the finished-goods area. The *process parameters* include the location of machines, batch sizes, work in process, machine downtimes, transporters, etc. The problem is solved by identifying different parameters that could influence the flow time of the parts and then simulating the model using different levels of these parameters. The *responses* from the simulation are then studied using *design of experiments* to analyze the main and interaction effects of these parameters. It should be noted that the approach and the methods used in this research problem could also be applied to a wide class of manufacturing systems. This section describes the preliminary analysis done before simulating the model. It includes the problem definition, data collection, data analysis, part routings, and a brief description of the potential parameters that could influence the flow time of the parts.

3.1. Problem Definition

The open facility (without the machines) is shown in Figure 1. The new layout has to accommodate thirty machines and sixty different part types. The thirty machines include progressive presses, secondary presses and machines, welders, and some special machines. There are two types of transporters, forklifts and pushcarts, and the number of those transporters to be used is also to be determined. Figure 1 also shows the fixed positions of the loading, receiving and trash-dumping docks. This research involves only

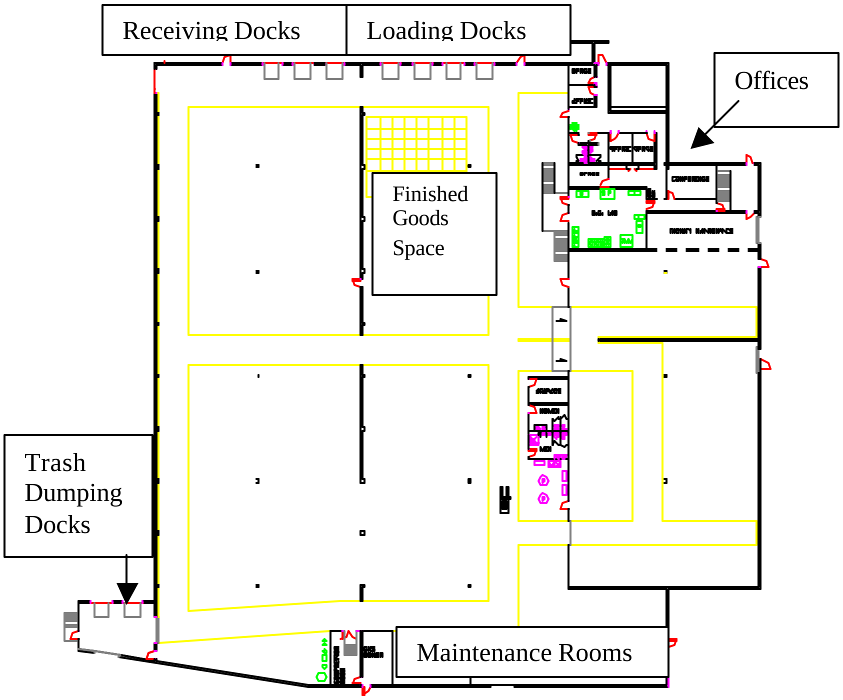

Figure 1. Open Layout Without the Machines

the location of machines and it is assumed that the locations of the offices, restrooms, tool maintenance rooms, and other auxiliary equipment have been decided.

3.2. Data Collection and Analysis

Data collection is one of the first steps involved in solving a manufacturing layout problem. The accuracy and the extent of the data collected reflect the precision of the results. It is important that all the necessary data required for modeling the layout be collected for the parts that will be manufactured and the machines that will be used for production during the time horizon for which the layout is planned. So, proper analysis of the collected data is required before modeling the layout.

3.2.1. Data Collection

The basic data were collected from personnel on the shop floor: operators, supervisors, and process managers, and was directed to the management information systems department. The dimension of the open facility was first collected. The data on the sixty parts were their routings, sales volume, sales price, and part life. (Part life is the number of years it will be produced before it becomes extinct.) The data collected on the machines were their dimensions, process times for the parts they processed, downtimes, setup times, and maintenance times. The speed and downtimes of both types of transporters is collected. The speed and capacity of the washers and the space available for finished goods inventory is also gathered.

3.2.2. Data Analysis

The first step in data analysis is to identify the top parts in terms of their contribution to the annual revenue of the company. This is done by Pareto analysis, which states that a company that makes multiple products often generates most of its revenues, say 80%, from 20% of its products. Figure 2 shows a pie chart indicating the distribution of parts according to their annual revenue contribution.

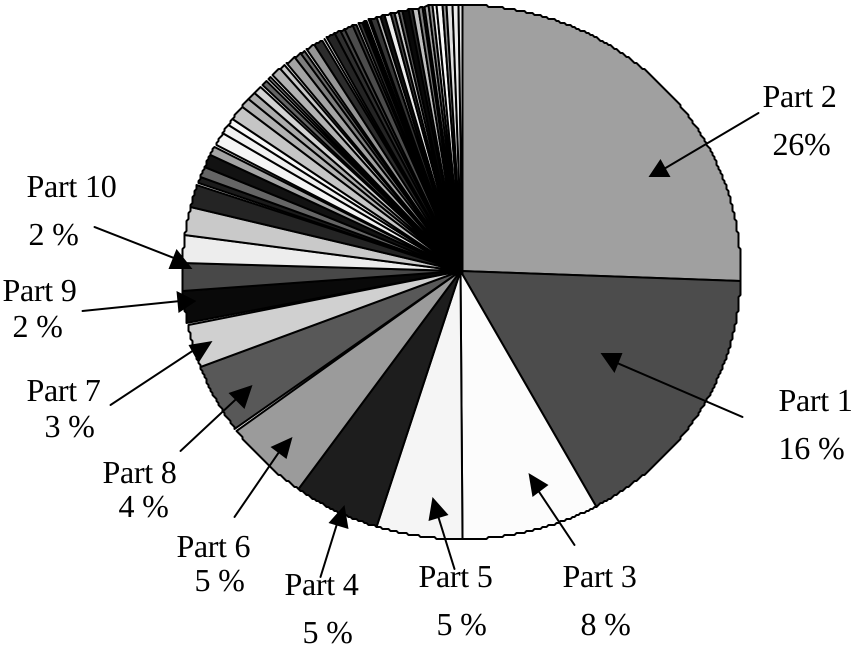

Figure 2. Contribution of Parts Towards Annual Revenue

The first ten parts, namely part 1 to part 10, contribute more than 75 % of the revenue, so these parts are chosen for further investigation. It was ensured that these parts would be produced for at least five years in the new layout.

3.3. Part Information

Table 1 shows the part information for the top ten parts chosen above. This table indicates the part routing, capacity of the machines per cycle, the process times and the setup times of the machines in minutes. Presses 1 to 9 are considered progressive machines, while all other machines are secondary machines.

Table 1.
Part Information.

Part information					
Part number	**Part routing**	**Capacity/ cycle**	**Process time in minutes**	**Setup time in minutes**	
				Frequency (in minutes)	**Duration (in minutes)**
Part 1	Press 1	1	0.167	500	20
	Press 9	1	0.167		
	Press 10	1	0.167		
	Washer 1				
	Press 11	1	0.167		
	Press 12	1	0.167		
Part 2	Press 2	2	0.0125	480	20
	Washer 2				
Part 3	Press 3	1	0.0125	400	30
	Press 13	1	0.05		
	Special M/c 1	1	0.05		
	Washer 3				
Part 4	Press 5	1	0.026	480	20
	Special M/c 2	1	0.2		
Part 5	Press 8	1	0.0357	300	20
Part 6	Press 4	1	0.023	500	20
	Washer 4				
Part 7	Press 6	1	0.0333	480	20
	Welder 1	1	0.3		
Part 8	Press 7	1	0.0275	500	20
	Hyd. Press 1	1	0.15		
	Hyd. Press 2	1	0.15		
	Hyd. Press 3	1	0.15		
	Hyd. Press 4	1	0.15		
	Hyd. Press 5	1	0.15		
Part 9	Press 2	2	0.0125	450	20
	Washer 2				
Part 10	Press 6	1	0.0333	480	20
	Welder 1	1	0.3		

3.4. Parameters

This section describes the potential parameters that could affect the flow time of parts. Eight different parameters, namely layout (location of machines), batch sizes, WIP container size, number of transporters, types of transporters, machine downtimes, coil-change times, and machine utilization, are chosen and the experiment is conducted with two levels for each factor. Table 2 shows the coding for the values corresponding to the "+" and "-" levels for each of the eight parameters.

***Table 2*.**

Values of the Parameters.

Factors		Codes	Values
1	Layout	-	Job-shop layout
		+	Hybrid layout
2	Batch sizes[1]	-	High value
		+	Low value
3	WIP container size[1]	-	High value
		+	Low value
4	Type of transporter	-	Push-cart
		+	Forklift
5	Number of transporters	-	4
		+	2
6	Machine downtimes[1]	-	High value
		+	Low value
7	Coil Change time[2]	-	30 minutes
		+	5 minutes
8	Machine Utilization	-	90%
		+	60%

1 - Refer to their individual tables

2- Applicable only for the progressive presses

3.4.1. Layout

This parameter refers to the location of machines in the facility. This is one of the important parameters that could affect the flow time of the parts. This is primarily because the objective is to design an efficient layout to reduce the time spent by the parts in the system. As seen in table 2, two levels of this factor are taken into consideration, process layout and hybrid layout. Though the hybrid layout could outperform the process layout, the given system is not simple enough to decide if this factor alone would affect the flow time for all the ten parts. It should be remembered this was the objective of the research problem.

Process layout, also known as *job-shop layout*, is one in which similar machines are located together. This would imply that the progressive presses are located in one portion of the facility and the secondary machines/presses are located at the other end of the facility. Figure 3 shows a job-shop layout.

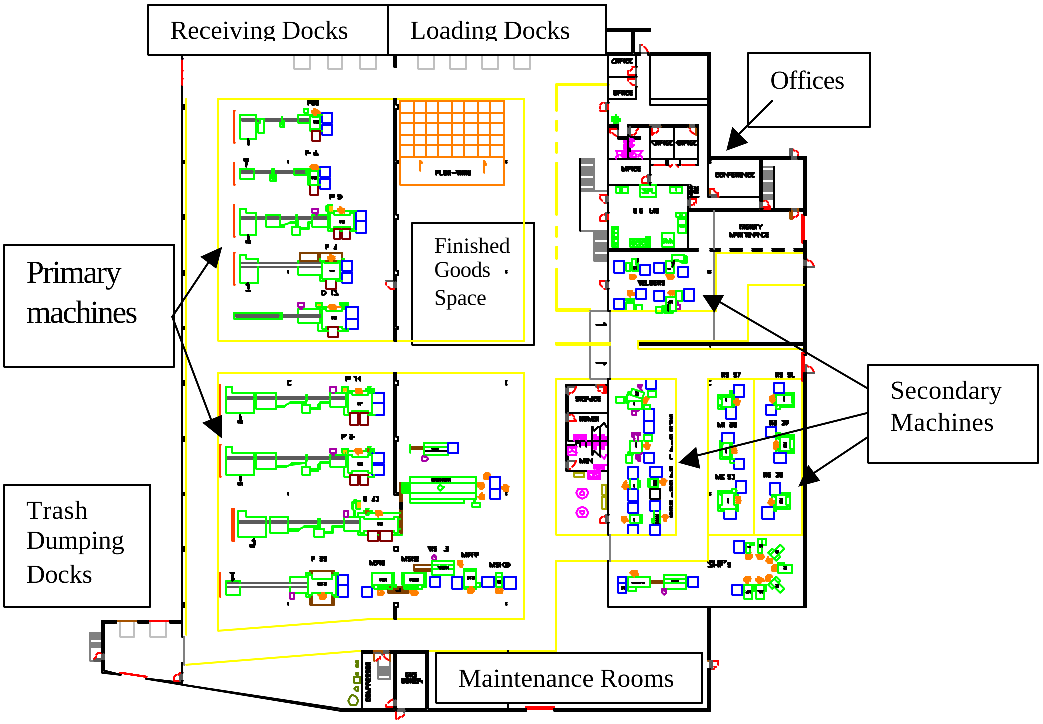

Figure 3. Job-Shop Layout with Progressive and Secondary Machines at Different Sides.

The *hybrid layout* combines the process and cellular layouts. *Cellular layout* is based on group-technology principles, where the machine cells and part families that are independent of the others are identified and a number of subsystems are formed. Figure 4 shows a hybrid layout where a few machines are grouped together as cells, and the others are placed as in a job-shop layout.

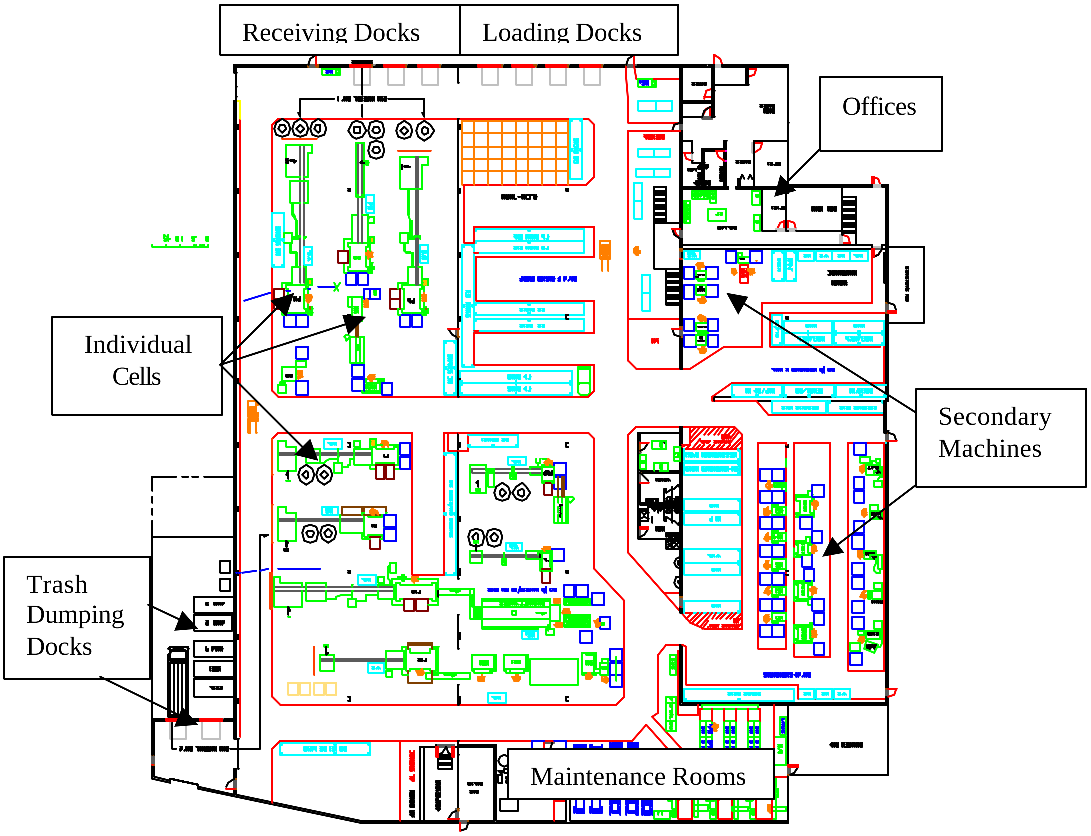

Figure 4. Hybrid Layout Showing a Combination of Job-Shop and Cellular Layouts.

This hybrid layout is designed by forming a part-machine matrix, which indicates the volume and flow of parts between machines. From this matrix, the part families processed in unique machine cells are easily identified and thus cells are formed. But not all the parts are produced in unique machine cells, which lead to the combination of a job-shop and a cellular layout known as the hybrid layout. The other techniques used to design the hybrid layout are not described in detail in this paper.

3.4.2. The Other Seven Parameters

Batch Sizes - *Batch sizes* refer to the quantity of a single part type to be produced by a machine before it is set up for another part type. So, this factor can affect the flow time of the parts produced at the end of a batch. Table 3 shows the "+" and "-" levels for the batch sizes for the ten parts. It can be seen that the "-" level for all the ten parts is a 'no limit' value. This means that the part would be continuously produced in the machine until the end of the shift. The demand for all the parts is taken into consideration while assigning the batch sizes.

Table 3.
Batch-Size Levels.

Code	Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7	Part 8	Part 9	Part 10
-	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit
+	2700	18000	6000	15000	6000	18000	10000	5000	18000	10000

WIP Container Size – This factor refers to the capacity of the work-in process containers for each part type. Table 4 illustrates the capacities of the WIP containers for each part type. It is assumed that, for a single part type, the capacity of the WIP containers remains the same throughout the facility.

Table 4.

WIP-Container-Size Levels.

Code	Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7	Part 8	Part 9	Part 10
-	300	3600	5000	5000	3000	5000	3400	500	3600	3400
+	1	1800	2500	2500	1500	2500	1700	100	1800	1700

Type and Number of Transporters – This is an important factor because the raw materials, work in process and the finished goods are moved via transporters, so availability of transporters can influence the average flow time of the parts. The two types of transporters, forklifts and pushcarts, differ by their speed. The speed of the forklift is 444.44 feet/minute and speed of the pushcart is 266.66 feet/minute. The number of transporters is varied between two and four.

Machine Downtimes – Table 5 indicates the downtimes of the progressive and the secondary machines in terms of a percentage. It can be seen that the progressive machines have more downtime than the secondary machines. It is assumed that the interarrival times between machine failures and the repair times are deterministic, consistent with our data from the plant. This factor would give an indication to the plant manager to check if preventive maintenance measures should be carried out in order to reduce machine downtimes.

Table 5.

Downtime Levels.

Code	Progressive M/c's	Secondary M/c's
-	33.33%	10%
+	8.33%	5%

Coil-Change Time – This factor is applicable only for the progressive presses. The raw material for these progressive presses is in the form of large sheet-metal coils and so a setup time is involved to replace the coils. The time taken for changing the coil could be reduced from 30 minutes to 5 minutes by procuring an automatic coil changer that can hold two coils at a time. After the machine runs out of the first coil, the second coil can be placed immediately, which in turn reduces the coil-change time.

Machine Utilization – As seen in Table 2, the utilization of all the machines is set at levels of 90% and 60%. This factor should not be confused with the machine downtimes. The machine utilizations are assigned with the consultation of the plant managers and supervisors. The effect of this factor on the flow time of the parts would indicate if the machines have been utilized properly and if not, how much less or more utilization is required.

4. Experimental Design

The system under study is quite complex, which makes it difficult for a plant manager to identify the parameters that could affect the flow time of the ten part types. In the case of a job-shop layout, all the parts have to be moved from the progressive presses to the secondary machines. This could depend heavily on the availability of transporters, but it is difficult to say if this factor alone could influence the flow time of the parts. In fact, the layout is also considered as a factor in this problem. In the case of a hybrid layout, the transporter might not be a big factor because of the presence of machine cells, where the parts move within these cells. This complexity in identifying a factor can be solved by using design of experiments. The output obtained from the experimental design would help the plant managers to identify the main factors responsible for affecting the flow time and also indicate the interactions between these factors. This, in turn, would help him to change the values for these factors to reduce the flow time of parts.

The part routing (Table 1), the batch sizes (Table 3) and the WIP container information for part 2 and part 9 are the same. So, it is assumed that the output obtained for part 2 would be same for part 9 and the same can be noted for part 7 and part 10 and so further analysis is done only for first eight part types instead of the original ten. This section describes the type of experimental design conducted and also the method by which it is carried out.

4.1. 2^8 Factorial design experiment

The input parameters that compose the given system are known as *factors* of the experimental design. All the factors considered in this experiment are controllable in the sense that the operators and the plant managers can bring about a change in the values of these parameters. As seen in the previous section, we have eight different factors, each varying between two levels. This leads to a 2^8 factorial design experiment, where an experiment is conducted with all 256 combinations of the eight factors. A design matrix, as shown in Table 6, is formed to indicate each combination with the different combinations of the eight factors. The “+” and “-” signs indicate the values assigned for these factors and can be referred from Table 2. The output performance measure is the flow time of the parts and it is known as the *response* of one experiment. So eight responses, corresponding to the eight parts, are collected from each experiment, and are tabulated.

Table 6.

Design Matrix and Responses for Part 1.

	Factors								Response
	Layout	Batch sizes	WIP container size	Type of transporter	Number of transporter	Downtimes on M/c	Coil change time	M/c utilization	(in minutes) Part 1
Scenarios									
1	-1	-1	-1	-1	-1	-1	-1	-1	102
2	1	-1	-1	-1	-1	-1	-1	-1	101.98
3	-1	1	-1	-1	-1	-1	-1	-1	57.025
4	1	1	-1	-1	-1	-1	-1	-1	56.991
5	-1	-1	1	-1	-1	-1	-1	-1	101.99
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
255	-1	1	1	1	1	1	1	1	53.324
256	1	1	1	1	1	1	1	1	53.5

4.2. Conducting the Experiments

The given system is modeled using the Arena 3.0 simulation software[1]. As noted before, only the equipment processing the eight part types was modeled. This leads to the modeling of eight progressive presses, fourteen secondary machines, and four washers, which correspond to eight different manufacturing lines. The machine downtimes, utilization and the coil-change time are modeled as individual downtimes on the machines. The washers are modeled as accumulating conveyors and are defined by their speed and cell size. The transporters are defined by their speed and capacity, and the downtime on the transporters is also modeled. If the parts require a transporter, they are batched according to their WIP container size and wait for a transporter according to the queue discipline. The priority is cyclical for all the part types requesting a transporter. Distance sets are suitably defined to indicate the distances between the machines, loading docks, receiving docks, and the finished-goods area. It is assumed that there is no shortage of raw materials. The finished-goods area is large enough to accommodate the varying batch sizes of all the part types.

The model was run using a Pentium 300 MHZ processor with 128 MB of RAM. Each experiment was run for one simulated day (1440 minutes) and it took approximately 15 minutes of computer time for each of them. The run length of 1440 minutes for each experiment was chosen from proper understanding of the day-to-day operations occurring in the plant. Moreover, the batch sizes of the parts were selected for one day according to the demand. Since all the input values to the simulation are deterministic, each experiment is run only once and is not replicated. The flow times, known as *responses* in the experimental design, for all the eight parts were noted after each experiment and tabulated for further analysis.

5. Interpreting the Responses

It is important to analyze properly the results obtained from the above experiments to establish the influence of the factors for the eight part types. The effects of the factors can be categorized into their main effects and the interactions among them. This section explains the main effects of the factors on the flow time of all the eight parts and also the interactions among the factors influencing the output.

The *main effect* of a factor is the average change in the output due to the factor shifting from its "-" level to its "+" level, while holding all other factors constant. Table 7

Table 7.
Top Three Factors Affecting the Flow Time of the Top Eight Parts, Arranged in Decreasing Order of Effectiveness.

	Factors		
	1	2	3
Part 1	Batch sizes	M/c utilization	WIP container size
Part 2	Batch sizes	WIP container size	Downtimes on m/c
Part 3	Layout	WIP container size	Downtimes on m/c
Part 4	WIP container size	Layout	Type of transporter
Part 5	Batch sizes	Downtimes on m/c	Coil change time
Part 6	WIP container size	Layout	Type of transporter
Part 7	WIP container size	Layout	Number of transporters
Part 8	Batch sizes	WIP container size	Layout

indicates the top three factors influencing the flow time of the parts. It can be seen that each part type generally has a different sequence of factors affecting its flow time.

Analysis of the main effects alone would not suffice as the effect of one factor could depend on the level of some other factor, which is *interaction* between the factors. In this study, interactions between the factors are computed starting from two-factor interactions all the way up to the eight-factor interaction. This would help to conduct a thorough analysis of identifying the most significant factor affecting the time-in-system for each part type.

Analysis for Part 1

The responses obtained for part 1 from the 256 simulation experiments is shown in Figure 5. It can be seen that there is a strong and consistent pairing of the responses - two high values, followed by two low values and then followed by two high values, etc.

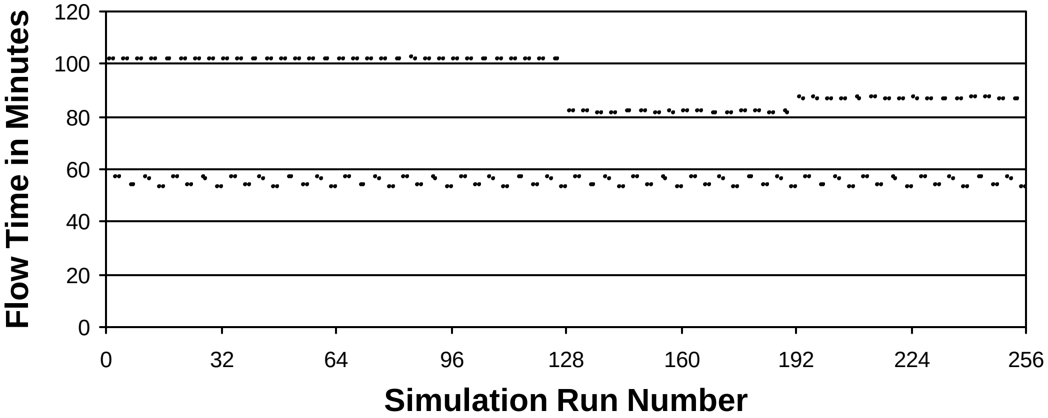

Figure 5. Responses of Part 1.

From Table 6, which shows the design matrix, it can be seen that this pattern follows the level changes of the second factor, the batch sizes. This means that the most important factor affecting the flow time of part 1 is batch sizes. Thus, the plant manager should decrease the batch sizes of part 1 in order to reduce its flow time. It is a well known that reducing the batch size of a part will reduce its flow time, but this experiment also ensures that the demand of the part is satisfied.

Figure 6 shows the main effects and interactions between the factors for part 1. As inferred before, the batch sizes play a significant role in determining the flow time for part 1. This is because the value of the main effect of the second factor (batch sizes) is -38, which completely overwhelms the other main effects and all interactions. The value of this main effect being negative indicates that the low value ("+" coding) of the batch sizes would decrease the flow time of part 1. Since the objective is to reduce the flow time of the part, lower batch sizes should be used.

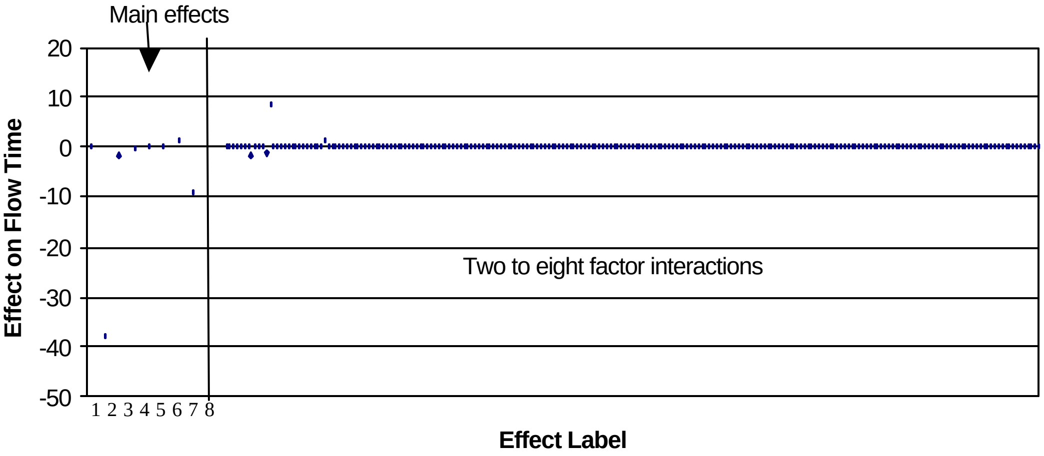

Figure 6. Main Effects and Interactions of the Factors on Flow Time of Part 1

The next important observation on the main effects is the machine utilization, as seen from Figure 6 having a value of -8.75. This can also be inferred from Figure 5, where the responses have a different pattern after the first 128 experiment runs. The negative value of the main effect of machine utilization indicates that the utilization of the machines should be decreased from 90% to 60% to achieve a reduction in flow time. It should be noted that the interaction between the batch and machine utilization has a value of +8.74 that ties with the main effect of machine utilization. The positive sign of the batch size and machine utilization interaction indicates that having these two factors at the same level (so their product is +1) tends to increase flow times. So, having these two factors at opposite levels, and other things being equal, would help to reduce the flow time.

When factors have significant interactions, interpretation of the main effects becomes unclear since the response is nonlinear in one or both of the factors. But in this case since the magnitude of the main effect of batch size is much bigger than the other values, it is clear that smaller batch sizes have a significant effect on reducing the flow time. Though setting the machine utilization at its "+" level (60%) lowers the flow time by about 8.75, the unfavorable interaction with the small batch size increases the flow time by about the same amount (9). Also, the main effects of other factors and the two-factor interaction effects of these factors are negligible. The three-factor to eight-factor interactions do not have any significant contribution and are almost zero. So, a practical conclusion could be that, if the plant manager doesn't have the luxury of decreasing batch sizes for some other reason, then low utilization would be helpful. The layout is not an important factor for this part because there is little change in the two layouts for the machines processing this part type.

Analysis for Part 2

Figure 7 shows the responses obtained for part 2 from the simulation runs. As seen in the previous case, that there is a strong and consistent pairing of the responses - two high values, followed by two low values and then followed by two high values, etc. So, once again the batch sizes (the second factor) become the most important factor affecting the flow time of part 2.

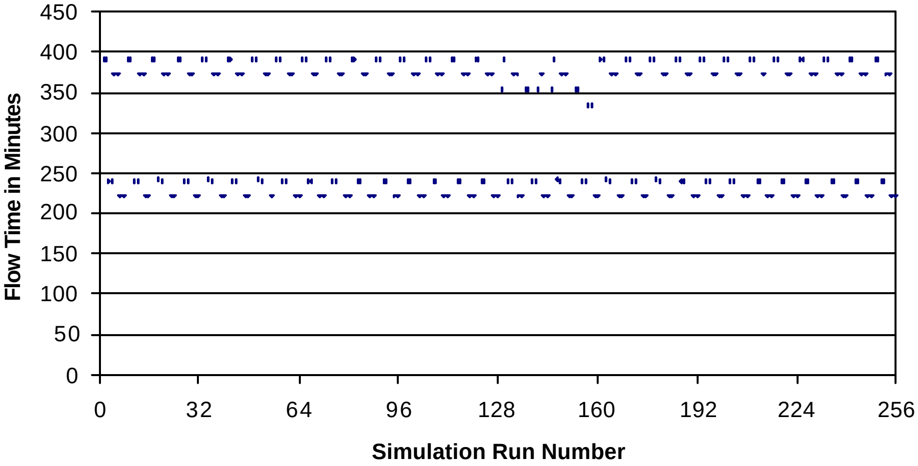

Figure 7. Responses of Part 2.

This can also be inferred from Figure 8, which shows the main effects and interactions of the factors on the flow time of part 2. The value of the effect of batch sizes is -147 and it is the most dominating effect for part 2. Since this value is negative, smaller batch sizes ("+" coding) should be used to reduce the time in system. The next most significant factor affecting the flow time for part 2 is the WIP container size. Figure 7 also shows that the responses follow a repeating pattern after every four values.

The value of its main effect is -17.77. Since this factor has a negative effect on the flow time (as seen from Figure 8), the number of parts batched between the machines should be reduced to reduce the flow time of part 2. Figure 8 also shows that the interactions (two-factor to eight-factor) do not have a significant effect on the flow time. So, the main objective of the plant managers would be to reduce the batch sizes. Also, since the information for part 2 and part 9 are the same, the same conclusion applies to part 9 also.

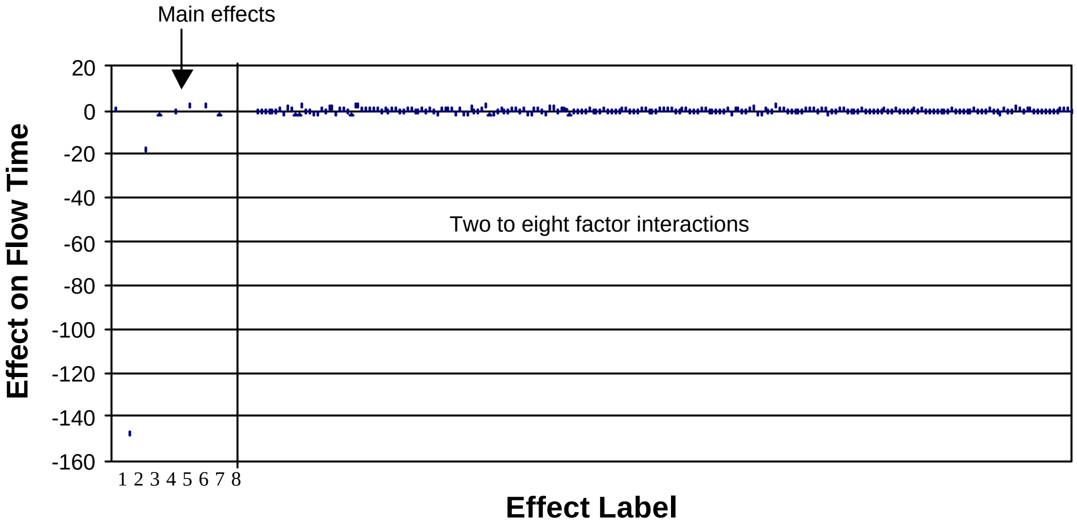

Figure 8. Main Effects and Interactions of the Factors on Flow Time of Part 2

Analysis for Part 3

Figure 9 shows the main effects and interactions for part 3. At least five factors have significant effects on the flow time of this part type. The most significant factor is the layout of the machines producing the part type. The value of this effect is -262 and since it is a negative value, this means that the layout should be changed from the job-shop to the hybrid layout to decrease flow time.

The next most significant factor is the WIP container size (having a main effect of -116), which nearly ties with the main effect of the machine downtimes (value of -114). The negative values of the main effects for these two factors suggest that the decrease in the WIP container size and the machine downtimes would decrease the flow time for part 3.

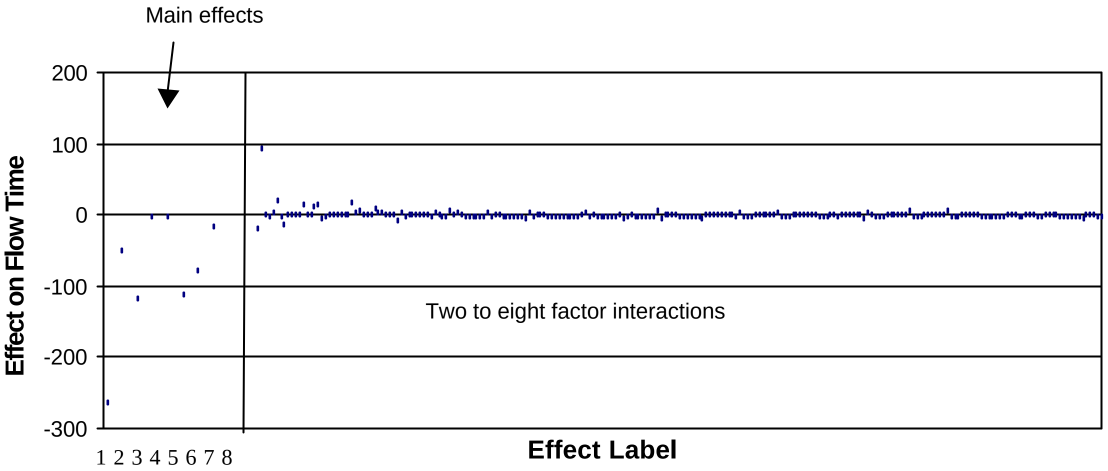

Figure 9. Main Effects and Interactions of the Factors on Flow Time of Part 3

The next important observation is that the two-factor interaction between layout and WIP container size has a value of +94. The positive value indicates that if these two factors are both at their “+” or “-” levels together, this tends to increase the flow time of this part, which is undesirable. Also, the main effects of coil change time and batch sizes have values of -79 and -49 respectively. Thus, decrease in coil-change time and batch sizes would reduce the flow time of this part. The other two-factor interactions and the three to eight factor interactions do not have significant effects on the flow time. So, since the main effect of layout overshadows all the other effects, the plant managers should design a cellular layout rather than a job-shop layout to produce this part type.

For **part 4**, the WIP container size (-247) and the layout (-75) are the two most significant factors affecting its flow time. The interaction between these two factors also has some effect (+24) on the flow time. But the main effect of WIP container size overshadows the other effects and the priority would be to reduce the WIP container size.

The flow time of **part 5** is significantly affected by batch sizes (-90) and machine downtimes (-69). Since there is some positive interaction between these two factors (+30), the plant manager should use his discretion when trying to reduce the flow time for this part.

Similar inferences can be made for the other part types. The plot diagrams showing the main effects for each part type should be properly interpreted with reference to the coding table (Table 1). The significant factors affecting the flow time of these parts can be seen from Table 7. Due to the enormity of information, the response plots and the main effects plots are not shown for the other part types, but can be seen in Kaushik[8].

6. Concluding Remarks

The factors affecting the flow time of each of the top ten parts have been identified. The next step would be to eliminate the least significant factors, manipulate the values of other important factors, and conduct further experiments iteratively to obtain better results. It is left to the discretion of the plant manager in selecting the significant factors during the iterative process. If there is a conflict in the layout of machines between two parts, the part contributing to higher annual revenue should be given the top priority. At the end of this process, he would be able to design an efficient layout and assign suitable values for the process parameters. The number and type of transporters required can be inferred from the responses. This work demonstrates that the manufacturing parameters also should be considered before designing the layout for a facility.

This research has integrated simulation and design of experiments to identify the parameters that would be responsible for affecting the flow time of parts in a plant layout. The reduction of flow time essentially implies that the parts are being produced faster and the work-in-process is also being reduced. This approach can be widely used for other applications that have an objective of reducing/increasing an output depending on a few parameters. Some potential applications could be for a bank or a department store, where the objective is to reduce the time in system of the customers.

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