Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management
Kuala Lumpur, Malaysia, January 22 – 24, 2011

Using Simulation and Assignment Modeling for Optimization with Constraint in Ability of Servers

Mohsen. Baradari
Department of Industrial Engineering
Tafresh University, Tafresh, Iran

Ebrahim. Sharifi
Department of Industrial Engineering
Tafresh University, Tafresh, Iran

Majid. Sheikhmohammady
Department of Industrial Engineering
K. N. Toosi University of Technology, Tehran, Iran

Abstract

There may be limitation in using queuing system simulation results for optimization when servers are human because, we can't shift the servers from the current to new position easily due to their different capabilities. If simulation results are used without taking into consideration human resource ability, the optimal solution for resources assignment and maximum of productivity may not be obtained, even though the output number and productivity are increased. The research findings show that, the maximum of productivity is obtained by simultaneously using simulation and assignment modeling taking into account variation in human resource abilities.

Keywords
Simulation, productivity, assignment modeling, ability of servers

1. Introduction
Having correct information is necessary for managers to decide correctly. Therefore, a manager needs strong scientific methods such as simulation. Some papers have explained about using queuing system and statistical analysis for optimization [1, 2]. Other papers, have explained using simulation for bottleneck detection in manufactory that servers are machinery [3-5]. When we use queuing system simulation and decide to change the number of servers in each process, we suppose the abilities of old and new servers are the same, while in reality, when servers are human, we can't shift the servers from the current to new position easily due to their different capabilities. In this paper, we propose a new approach about using simulation and assignment modeling for optimization with constraint in ability of servers. It is important that, when we use assignment modeling for optimization without simulation, we neglect the queuing system parameters optimization as objective functions and if we use the simulation without assignment modeling, the maximum of productivity may not be obtained. Therefore, simultaneously using simulation and assignment modeling is very useful to increase productivity.

2. The Application Environment
The case study for this research is a production line of an automobile chair cover and production process model is shown in Figure 1.

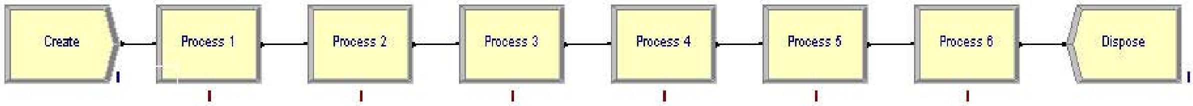

Figure 1: A production process model

3. Research Method

After gathering the required information, the model is simulated by Arena software. Then, with consideration of objective function and constraints, the required resources are determined by using assignment modeling taking into consideration the human resource ability.

4. Required Information

4.1 Sample Size

First, in process 1, the average and standard deviation of service time are calculated after sampling with initial sample size. Then, with 0.25 of precision and 95% of Confidence interval, the sample size is determined with Equation (1).

Samples : 0.22 , 0.95 , 0.21 , 0.19 , 1.5 , 0.46 , 1.22 , 0.23 , 0.48 , 0.12 $\bar{X}$= 0.558 , δ= 0.49

$$\mu = \bar{X} \pm t_{\frac{\alpha}{2}} \cdot \frac{\delta}{\sqrt{n-1}} \tag{1}$$

$$0.25 = 1.96 * \frac{0.49}{\sqrt{n-1}} \qquad n=15.75\approx 16$$

4.2 Sampling and Determining the Statistical Distribution

Based on the studied samples, the Statistical distribution for service time in process 1, is found Beta.

Samples : 0.19 , 0.98 , 0.55 , 0.88 , 1.42 , 0.16 , 0.18 , 0.47 , 0.21 , 1.07 , 0.43 , 1.6 , 1.23 , 0.32 , 0.85 , 0.45

Distribution: Beta , Expression: Beta (0 .886, 1.39) , Square Error: 0.002284

In order to validate the Statistical distribution, the kolmogorov-Smirnov Test is used.

H_0: X ~ F

kolmogorov- Smirnov Test : Test Statistic = 0.156 < Critical value = 0.328

The critical value is greater than Test Statistic. Therefore, the Statistical distribution Beta, is validated. The statistical distributions of other processes are identified by the same way (see Table 1 below).

Table 1: Statistical distributions

	Statistical distribution	Number of resources
Create (enter the entity)	Constant(0.22)	-
Process 1	Beta(0.886,1.39)	2
Process 2	Expo(0.17)	1
Process 3	Norm(0.36, 0.011)	3
Process 4	Norm(0.29, 0.008)	2
Process 5	Expo(0.22)	1
Process 6	Triangular(0.6, 0.76, 0.97)	3

5. Model Replication Parameters

5.1 Reduction of the Initial Condition Bias

There is difference between terminating and non-terminating simulation. In a non-terminating simulation, at initial condition, system is not idle. Therefore, we should reduce the initial condition bias [6]. In order to reduce the bias, the model replicates ten times and output number per hour is shown in Table 2.

Table 2: Average of production per hour when the simulation is started in idle condition

Group	Replication Length (hour)	Replication										Group Mean
		1	2	3	4	5	6	7	8	9	10	
1	1	224	222	220	224	217	219	222	220	218	220	220.6
2	1	234	234	232	233	230	233	230	236	229	231	232.2
3	1	228	242	230	236	238	230	231	232	234	231	233.2
4	1	236	221	233	230	235	232	232	234	232	234	231.9
5	1	228	232	237	235	236	235	232	231	234	232	233.2
6	1	233	235	230	232	232	234	232	235	233	230	232.6
7	1	237	234	229	231	232	233	237	233	230	233	232.6
8	1	225	228	234	235	234	233	230	233	235	230	231.7

As it is shown in Figure 2, the warm-up period to start the stable condition of system is considered one hour.

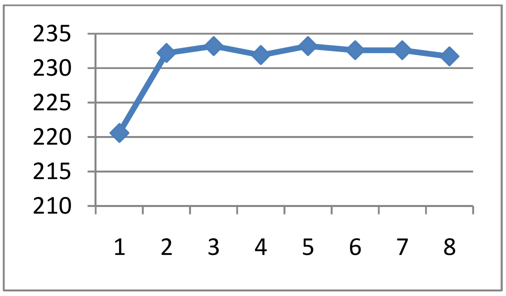

Figure 2: Average of number out per hour

5.2 Determining the Number of Replications

First, the model runs ten times and output number of production is recorded as below:

1618, 1620, 1622, 1622, 1624, 1624, 1625, 1631, 1624, 1618 $\bar{X}$= 1622.8 & δ= 3.82

Then for 95% of confidence interval, the number of replications is determined as below:

$\mu = \bar{X} \pm t_{\frac{\alpha}{2}} . \frac{\delta}{\sqrt{n-1}}$ $2 = \pm 1.96 * \frac{3.82}{\sqrt{n-1}}$ n= Number of Replications =13

6. The Model Verification and Validating

Our objective is to compare the average of sample and population. The sample size is not very large and the variances are not determined. Therefore the t-Test is used.

$H_0 : \bar{X}_1 = \bar{X}_2$ $n_1 =$ Simulation sample size

$H_1 : \bar{X}_1 \neq \bar{X}_2$ $n_2 =$ Actual production sample size

The test statistic is determined with Equation (2).

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(n_1-1){s_1}^2 + (n_2-1){s_2}^2}} . \frac{\sqrt{n_2.n_1(n_2+n_1-2)}}{n_2+n_1} \quad (2)$$

$$t = \frac{1622-1610}{\sqrt{(13-1)(3.82)^2+(13-1)(5.75)^2}} . \frac{\sqrt{13*13(13+13-2)}}{13+13} = 1.23 \longrightarrow$$ Test Statistic = 1.23 < Critical Value = 2.06

Critical value is greater than test statistic. Therefore, the model is validated in 5% level of significance.

7. Finding an Optimal Solution with Arena Simulation Model

The required resources are found considering the objective functions and constraints with Arena OptQuest optimization tool and algorithm based on Tabu search. For optimal solution, see Table 3.

Objective Function 1: Max [[System Number out]*2.2]-[System Total Cost]

Objective Function 2: Min $\sum$ Number of entity in Queue

Subject to : $\sum$ Number of Resource ≤ 12

System Number Out ≥ 1600

Table 3: Current assignment and optimal solution for assignment

	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6	Total resources
Current assignment	2	1	3	2	1	3	12
Optimal solution for assignment	2	1	2	2	1	4	12

The result of simulation indicates that, there is one extra resource in process 3, while there is the bottleneck in process 6. Now, resources number 4, 5, and 6 serve in process 3 and their ability factors in process 6, are 0.5. So, we can't shift these servers to process 6, easily.

8. Assignment Modeling with Consideration of Human Resource Ability

We suppose that the ability of each human resource for each process which has been known by expert persons in operations ranges from 0 to 1. The ability factors of resources are shown in Table 4.

Table 4: Ability factors of resources

	Process 1	Process 2	Process 3	Process 4	Process 5	Process 6	Available capacity	Available resource-hour
Resource 1	1	0	1	0.5	1	1	1	7
Resource 2	1	0	1	0.5	1	1	1	7
Resource 3	0	1	0	0.5	1	0	1	7
Resource 4	1	0	1	0.5	0	0.5	1	7
Resource 5	1	0	1	0.5	0	0.5	1	7
Resource 6	1	0	1	0.5	0	0.5	1	7
Resource 7	0	1	0.5	1	0	1	1	7
Resource 8	0	1	0.5	1	0	1	1	7
Resource 9	0	0	0.5	0.5	1	0	1	7
Resource 10	0.5	1	0	1	1	1	1	7
Resource 11	0.5	1	0	1	1	1	1	7
Resource 12	0.5	1	0	1	1	1	1	7
Required resources	2	1	2	2	1	4	$\sum = 12$	
Required resource-hour	14	7	14	14	7	28		$\sum = 84$

X_{ij} = Binary Variable(0,1) = Allocation from resource i to process j
C_{ij} = Allocation Cost
Objective function: Min $\sum\sum C_{ij}X_{ij}$ i = 1, 2,…, 12 , j = 1, 2, 3, 4, 5, 6
Subject to
$\sum X_{1j} \le 1, \sum X_{2j} \le 1 \; , \; \sum X_{3j} \le 1 \; , \; \sum X_{4j} \le 1 \; , \; \sum X_{5j} \le 1 \; , \; \sum X_{6j} \le 1$
$\sum X_{7j} \le 1, \sum X_{8j} \le 1 \; , \; \sum X_{9j} \le 1 \; , \; \sum X_{10j} \le 1 \; , \; \sum X_{11j} \le 1 \; , \; \sum X_{12j} \le 1$
$X_{11} + X_{21}+X_{41}+X_{51}+X_{61}+0.5X_{10\,1}+0.5X_{11\,1}+0.5X_{12\,1} \ge 2$
$X_{32} + X_{72}+X_{82}+X_{10\,2}+X_{11\,2}+X_{12\,2} \ge 1$
$X_{13} + X_{23}+X_{53}+X_{63}+0.5X_{73}+0.5X_{83}+0.5X_{93} \ge 2$
$0.5X_{14} + 0.5X_{24}+0.5X_{34}+0.5X_{44}+0.5X_{54}+0.5X_{64}+X_{74}+X_{84}+0.5X_{94} + X_{10\,4}+X_{11\,4}+ X_{12\,4} \ge 2$
$X_{15} + X_{25}+X_{35}+X_{95} + X_{10\,5}+X_{11\,5}+X_{12\,5} \ge 1$
$X_{16} + X_{26}+0.5X_{46}+0.5X_{56}+0.5X_{66}+X_{76}+X_{86} + X_{10\,6}+X_{11\,6}+X_{12\,6} \ge 4$
The best assignment is determined by solving the problem.
New assignment: $X_{16} = X_{23} = X_{32} = X_{43} = X_{51} = X_{61} = X_{76} = X_{86} = X_{95} = X_{10\,6} = X_{11\,4} = X_{12\,4} = 1$
Current assignment: $X_{11} = X_{21} = X_{32} = X_{43} = X_{53} = X_{63} = X_{74} = X_{84} = X_{95} = X_{10\,6} = X_{11\,6} = X_{12\,6} = 1$
The daily profit is determined with Equation (5).

$$Resources\ Total\ Cost = Resources\ Value\ Added\ Cost + Resources\ Idle\ Cost \quad (3)$$
$$Total\ Cost = Variable\ Cost + Fixed\ Cost \quad (4)$$
$$Profit = (Output\ Number * Sale\ Price) - Total\ Cost \quad (5)$$

To compare the results, see Table 5 and Figure 3.

Table 5: Comparison of methods

	Resources Value Added Cost	Resources Idle Cost	Resources Total Cost	Variable Cost	Fixed Cost	Sale Price per Unit	Output Number	Profit (per Day)
Current Situation	77	28	105	2433	305	2.2	1622	830
After Simulation without Assignment Modeling	87	18	105	2587	305	2.2	1725	903
After Simulation and Assignment Modeling	88	17	105	2835	305	2.2	1890	1018

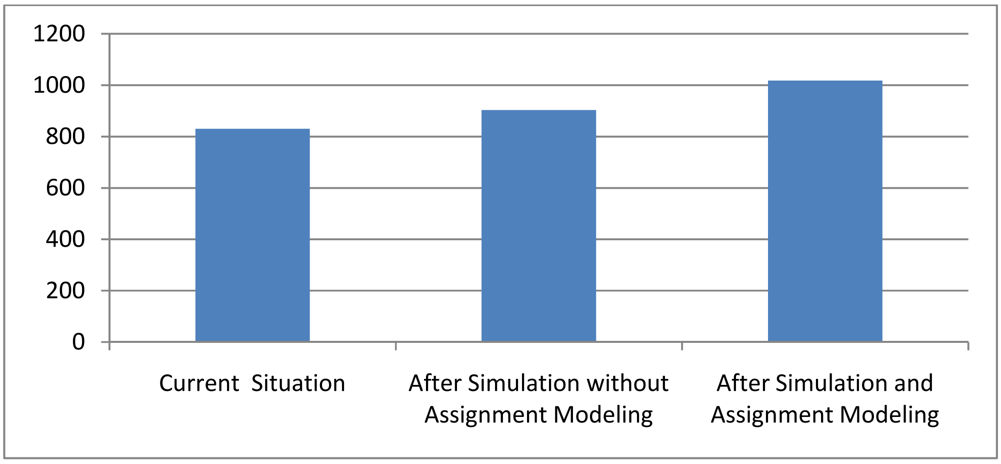

Figure 3**:** Daily profit

Observing the results obtained from simulation and assignment modeling shown in Table 5 and Figure 3, the output number of production in current situation is 1622 and the daily profit is $830. By using simulation results and shifting one human resource from process 3 to process 6 without assignment modeling, the resources idle time is reduced. Therefore, the output number of production and daily profit are increased to 1725 and $903, respectively. However, it is not the maximum of output number and profit that we can obtain without employment the new human resources. The maximum profit is $1018 and it is obtained with using simulation and assignment modeling at the same time taking into consideration human resource ability.

9. Conclusion

In complex queuing systems, mathematical analyzing of the system is difficult. Simulation is one of the best tools to solve this problem. Finding an optimal solution within Simulation model needs to shift all resources from current to new position. However, when the servers are human, we can't shift the human resources to new position easily, because of their different abilities. If we use the simulation without taking into consideration ability of servers, the optimum assignment and maximum productivity may not be obtained. Therefore, simultaneously using simulation and assignment modeling taking into consideration human resource ability is very important to increase productivity. This paper is a sample for statistical analysis and contribution of the paper is developing a modeling process considering the constraint of human resource ability. Considering that we range ability factor from 0 to 1, for future research, the integrating of fuzzy logic and simulation may be useful for optimization with constraint in ability of servers.

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