Measuring Company Performance by Simulation

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Abstract: Simulation is the most widely used management science and operations research technique employed by industry and government. In its broadest sense, computer simulation is the process of designing a mathematical-logical model of a real system and experimenting with this model on a computer. This paper is based on the system simulation of a company in which several kinds of electronic instruments are repaired. Working system of the company is modeled and simulated by the ARENA software for academic purposes. Simulations for alternative models are run several times in order to improve system performance. Impressive improvements in system operations have been obtained by employing the simulation model for planning purposes.

Key-Words: Simulation, System Performance, ARENA, System Cost.

1 Introduction

Simulation is a technique that has been employed extensively to solve problems. Simulation models are abstractions of systems. They should be built quickly, explained to all project personnel, and changed when necessary. The implementation of recommendations to improve system performance is an integral part of the simulation methodology [1]. Simulation has been used to study such wide ranging topics as urban systems, social systems, transportation systems, health care delivery systems, and many more. Simulation is the most widely-used management science and operation research technique employed by industry and government. Some references to papers by areas of application can be given below.

The relation between capacity of deterministic models and the original stochastic models from which they are derived was first examined by Rybko and Stolyar and Dai [2, 3]. The use of continuous model techniques has been an active area of research over the past several years; see, for example, the work of Avram et. al. [4], Bramson [5], Chen [6], and Maglaras [7]. An extensive list of references may be found in Dai [8] and Pritsker.

There is a significant and growing literature for problem of server assignment to queues (both static and dynamic). Mandelbaum and Stolyar [9] examine a queuing system with flexible servers operating in parallel and show that for a strictly convex cost function (of the queue lengths), a generalized cμ rule is asymptotically optimal. Squillante et al. [10] use simulation to study threshold policies for systems that consist of parallel queues. Laws [11] appears to be the genesis of most of the heavy-traffic related activity in this area, and study a dynamic routing problem.

As the use of modeling and simulation has increased, the need for languages oriented to specific problem types and industries has increased. Many special purpose simulation languages have been developed to meet these needs. It is known that there are distinct advantages to using simulation language. In addition to the savings in programming time, a simulation language also assists in model formulation by providing a set of concepts for articulating the system description. Pritsker and Happ [12] developed GERT, Harry Markowitz [13] developed SIMSCRIPT then SIMSCRIPT II.5, Pritsker and Pedgen [14] developed SLAM, then SLAMSYSTEM and TESS, Pedgen [15] developed SIMAN, then XCELL+ and WITNESS and so on.

In this paper, simulation model of a real company in which sort of defective instruments are repaired in seven departments is built, and then obtained system is analyzed by using ARENA software.

2 Methodology

In this paper, working system of a company where electronic instruments are repaired at seven departments is modeled and simulated in order to see the improvement conditions and solve bottleneck problems of the system. For modeling the system, methodology of simulation software, ARENA, produced by Rockwell Company, for academic purposes is used.

3 System

The interested system is a multi-server queuing system. In this system, any kind of defective instruments as medical instruments, textile machines, and computers and soon are repaired at seven departments of the company. At each of these departments, different instruments are repaired according to the specialization of technicians. The company income in different departments is given in Table 1.

Table 1. Company income in different departments

Departments	Income per hour ($)
P_1(Serdar)	130
P_2(Ertan)	22
P_3(Fikret)	94
P_4 (Recai)	56
P_5(Vedat)	13.6
P_6(Levent)	28.8
P_7(Bortek)	100

In this system, after entering the company, defective instruments are registered first then sent to depot for waiting the price proposal to be accepted by their firms. If the firm accepts the proposed price, defective instrument will send one of the seven departments to be repaired. If the proposed price is not accepted, instrument will send back to firm. Before modeling the system, model assumptions are given in the following order.

Model Assumptions:

1. Daily working time is assumed to be 8 hours.
2. There are 20 working days (160 hours) in one month.
3. Resting time of technicians is undervalued.
4. Mean value of different measures is taken as repairing time of each department
5. Approximately 1.1 defective instruments are assumed to enter the system in 1 hour.
6. The number of workers who transfer the defective instruments is assumed to be infinity.

System data has been collected during four months (640 hours). Although 576 defective instruments have entered the system, only 367 defective instruments have approved to be repaired, so 63.75% of defective instruments have approved and stay in the system to be repaired, and 36.25% have unapproved and sent back without being repaired. If a defective instrument stays in the system, it will send to related department with certain probabilities which are illustrated in Table 2. It is clear that $P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 = 1$.

Table 2. Sending probabilities of an instrument to departments

Departments	Probabilities
P_1	0.21
P_2	0.1
P_3	0.2
P_4	0.08
P_5	0.11
P_6	0.1
P_7	0.2

At each department, the defective instruments are repaired or not. The instruments repairing probabilities and repairing time of seven departments are given on Table 3.

Table 3. Instrument repairing probabilities and repairing time of departments

Departments	Repairing probability	Repairing time (hour)
P_1	0.97	8.31
P_2	0.79	16.4
P_3	0.86	8.42
P_4	0.83	21.3
P_5	0.85	15.6
P_6	0.57	16
P_7	0.75	10

Using activities and their service time, simulation model of the actual manufacturing system is built on ARENA. The ARENA network model of clothes manufacturer is depicted in Fig. 1.

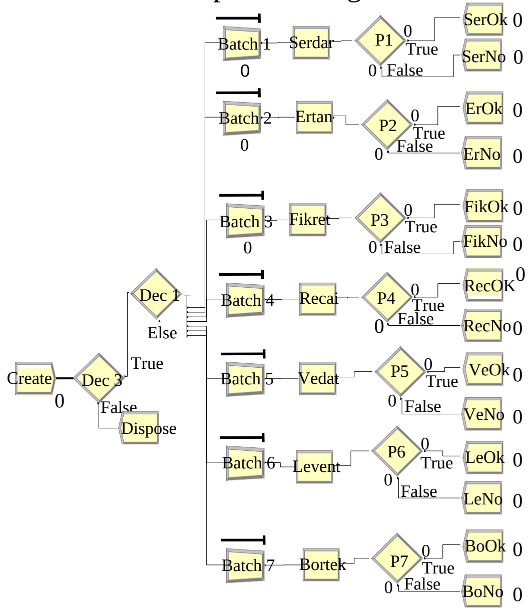

Fig. 1. Network model of the system

In this model, entities representing instruments are created at Create node. The time between entity arrivals is exponentially distributed with a mean of 1.1. Entities are routed to decide node, then routed whether to dispose node if the proposed price does not accepted or to decide node to be repaired if the proposed price is accepted. 36.25% of the entities send back to their firms without being repaired and the rest, 63.75 % of them, are routed to seven queue nodes of departments where the entities wait for service with certain probabilities, given in Table 2. When an entity arrives at a queue, its disposition depends on the status of the server that follows queue. If the servers are idle, the entity passes through the queue and goes immediately into the service activity. If no server is available, the entity waits at the queue until a server can process it. When a server does become available, the entity will automatically be taken out of the queue and service will be initiated. First in first out is the default priority for files. All entities start with attribute values equal to zero. Capacities of all queues in the system are assumed to be unlimited (infinity), in another saying, no limit on number of entities in queues. After taking services at related departments, entities are routed to decide nodes of departments P_1, P_2, P_3, P_4, P_5, P_6 and P_7. From P_1, P_2, P_3, P_4, P_5, P_6 and P_7 they are routed to dispose nodes according to their repairing conditions. Repairing probabilities and repairing time of each department are given in Table 3 above. System is completed when all activities are completed.

4 Results

After running the current simulation model, the simulation results are summarized by ARENA. The current simulation model runs several times for one year period (2080 hours). Yearly system performance is increased from 1332 to 1884 units in one year by reducing the bottlenecks problems at queues. Simulation results of process detail summary are given on Table 4. In Table 4, stabile time per entity with maximum and minimum values and accumulated time are shown. According to the results, yearly average working time of the first department P_1, named Serdar, is 2040.85 hours, the second department P_2, named Ertan, is 2223.73 hours and the third department P_3, named Fikret, is 2034.79 hours, the forth department P_4, named Recai, is 2337.20 hours, the fifth department P_5, named Vedat, is 1969.26 hours, the sixth department P_6, named Levent, is 1916.90 hours and the seventh department P_7, named Ertan, is 2539.47 hours. It is clearly seen that accumulated time of P_7 is more than the others, however in the same department an entity is repaired in approximately 10 hours which is smaller than the other four departments.

Table 4. Process detail summary

Replication:10 **Stop Time: 2080**		**Start Time:0.00** **Time Units: Hours**	
Process			
Time per Entity			
VA Time Per Entity	**Average**	**Minimum**	**Maximum**
P1_Serdar	8.4333	8.0174	8.9455
P2_Ertan	16.4720	16.0298	16.9504
P3_Fikret	8.4783	8.0500	8.9604
P4_Recai	21.4422	21.1258	21.9266
P5_Vedat	15.5060	15.0676	15.9080
P6_Levent	15.9741	15.5648	16.4591
P7_Bortek	9.9979	9.5207	10.4494
Time per Entity			
Total Time Per Entity	**Average**	**Minimum**	**Maximum**
P1_Serdar	8.4333	8.0174	8.9455
P2_Ertan	16.4720	16.0298	16.9504
P3_Fikret	8.4783	8.0500	8.9604
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P6_Levent	15.9741	15.5648	16.4591
P7_Bortek	9.9979	9.5207	10.4494
Accumulated Time			
Accum VA Time	**Average**	**Minimum**	**Maximum**
P1_Serdar	2,040.85		
P2_Ertan	2,223.73		
P3_Fikret	2,034.79		
P4_Recai	2,337.20		
P5_Vedat	1,969.26		
P6_Levent	1,916.90		
P7_Bortek	2,539.472		

Multiplying these average working times by hourly income given in Table 1, total income of each department will be obtained easily. As it is seen in Table 5, the highest total income is the income of P_1, while the lowest income is the income of P_5 department.

Table 5. Annual income of each department.

Department	**Total income**
P1_Serdar	$265310.5
P2_Ertan	$48922.06
P3_Fikret	$191270.2
P4_Recai	$130883.2
P5_Vedat	$26781.936
P6_Levent	$55206.72
P7_Bortek	$253947

While total time and accumulated time per entity are given in Table 6 and line graphs of average, maximum and minimum accumulated times of 10^{th} run are given in Fig. 2, the number of input and output values of each department is shown in Table 7 and the line graph of input values is given in Fig. 3.

Table 6. Average time of departments in the 10th run.

Replication: 10	Time Units: Hours			
Process				
Time per Entity				
VA Time Per Entity	**Average**	**Half Width**	**Minimum Average**	**Maximum Average**
P1_Serdar	8.4347	0.01	8.187	8.4409
P2_Ertan	16.4651	0.02	16.4216	16.5000
P3_Fikret	8.4737	0.01	8.4532	8.4814
P4_Recai	21.4420	0.01	21.4171	21.4500
P5_Vedat	15.5311	0.01	15.4953	15.5531
P6_Levent	15.9946	0.01	15.9741	16.0157
P7_Bortek	10.0031	0.01	9.9765	10.0251
Time per Entity				
Total Time Per Entity	**Average**	**Half Width**	**Minimum Average**	**Maximum Average**
P1_Serdar	8.4347	0.01	8.187	8.4409
P2_Ertan	16.4651	0.02	16.4216	16.5000
P3_Fikret	8.4737	0.01	8.4532	8.4814
P4_Recai	21.4420	0.01	21.4171	21.4500
P5_Vedat	15.5311	0.01	15.4953	15.5531
P6_Levent	15.9946	0.01	15.9741	16.0157
P7_Bortek	10.0031	0.01	9.9765	10.0251
Accumulated Time				
Accum VA Time	**Average**	**Half Width**	**Minimum Average**	**Maximum Average**
P1_Serdar	2,121.35	87.15	1925.63	2260.02
P2_Ertan	2,058.11	94.81	1879.64	2223.73
P3_Fikret	1,984.51	85.90	1788.72	2132.61
P4_Recai	2,195.64	172.19	1692.25	2548.63
P5_Vedat	2.023.66	142.08	1616.94	2315.68
P6_Levent	1,850.55	184.66	1392.19	2287.11
P7_Bortek	2,368.74	76.20	2183.44	2539.47

From Table 6 and Fig. 2, unbalanced distributions in the range of maximum and minimum values of accumulated times are seen at the departments P_4, P_5 and P_6 .

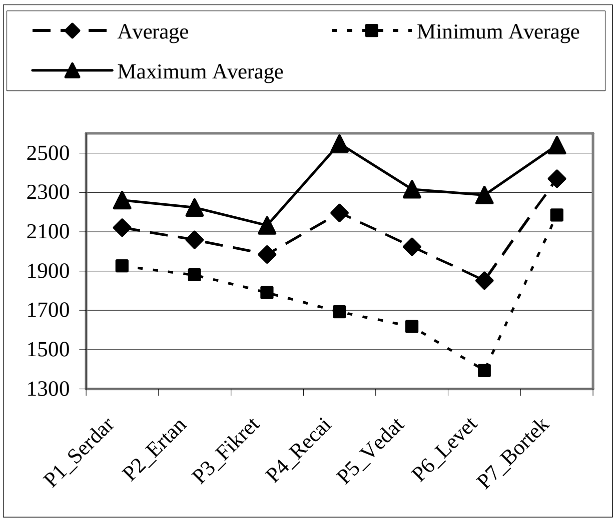

Fig. 2 Accumulated time of each department.

Table 7. Average number of input and output values of each department

Replication: 10	Time Units: Hours			
Process				
Number In	**Average**	**Half Width**	**Minimum Average**	**Maximum Average**
P1_Serdar	252.70	10.13	230.00	269.00
P2_Ertan	125.90	5.76	115.00	135.00
P3_Fikret	235.00	10.19	212.00	252.00
P4_Recai	103.20	8.15	79.0000	120.00
P5_Vedat	131.20	9.28	104.00	150.00
P6_Levent	116.60	11.40	88.0000	143.00
P7_Bortek	238.40	7.67	218.00	255.00
Number out	**Average**	**Half Width**	**Minimum Average**	**Maximum Average**
P1_Serdar	251.50	10.31	228.00	268.00
P2_Ertan	125.00	5.77	114.00	135.00
P3_Fikret	234.20	10.19	211.00	252.00
P4_Recai	102.40	8.04	79.0000	119.00
P5_Vedat	130.30	9.16	104.00	149.00
P6_Levent	115.70	11.55	87.0000	143.00
P7_Bortek	236.80	7.59	218.00	254.00

From Table 7 and Fig. 3, while the department P_1 repairs approximately 252 defective instruments which is the highest number, the department P_4 repairs approximately 102 defective instruments which is the lowest number.

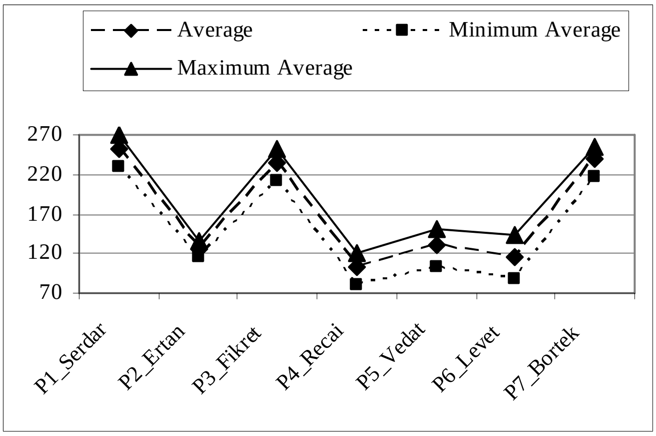

Fig. 3 Line graph of average input numbers of each department

When yearly working time and number of entities are considered, it is easily seen that the departments P_2 and P_5 show low performance, low wages and low repairing percentages. When the queues are considered, the queues which have higher waiting time and higher number of waiting entities are at P_2 and P_5. By increasing the number of technicians one by one, waiting time and number of waiting entities are decreased at P_2 and P_5. After running the alternative models several times, it is seen that system performance and company income increase. By improving the system conditions, total income increase from $473067.768 to $972321.676. Comparison of old and new incomes of the company can be seen in Table 8.

Table 8. Company income

	Average income hr	**Old average time yearly**	**New average time yearly**	**Old average income yearly**	**New average income yearly**
P1Serdar	130	1062.85	2040.85	138170.5	265310.5
P2Ertan	22	1002.04	2223.73	22044.88	48922.06
P3Fikret	94	1006.19	2034.79	94581.86	191270.26
P4Recai	56	1060.74	2337.2	59401.44	130883.2
P5Vedat	13,6	1034.28	1969.26	14066.208	26781.93
P6Levent	28,8	937.6	1916.9	27002.88	55206.72
P7Bortek	100	1178	2539.47	117800	253947
			Total	473067.76	972321.67

5 Conclusion

In this paper, a real system is observed and necessary data is collected for one year. After that, the working system of a company where electronic instruments are repaired at seven departments is modeled and simulated by the student version of ARENA software in order to see the improvement conditions and solve bottleneck problems of the system. According to the reports, simulations for alternative models are run several times in order to improve system performance. Impressive improvements in system operations have been obtained by employing the simulation model for planning purposes. Using the estimated performances from simulation outputs, it is found that yearly production capacity of the system is increased from 1332 units to 1884 units and the repairing rate of instruments is increased approximately 40% by increasing the number of technicians at some workstations. As a result, this work is concerned with building graphical model of a real system, simulating and analyzing of this system by ARENA, measuring performance of the system by its effectiveness and efficiency in achieving system objections. While modeling and simulating the system, only thing that is evaluated manually is the calculation of annual income of each department. In the future studies, modeling, simulation and cost of system should be evaluated all together.

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