Proceedings of the 2008 Winter Simulation Conference
S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler eds.

SIMULATION BASED DECISION-MAKING FOR HOSPITAL PHARMACY MANAGEMENT

Alkın Yurtkuran
Erdal Emel
Dept. of Industrial Engineering
Uludag University
16059 Bursa, TURKEY

ABSTRACT

Managing healthcare delivery systems plays an important role for healthcare providers in order to have high quality service performances. Inpatient pharmacy delivery systems are one of those that have a key role in hospital's service quality. Simulation is the best tool to analyze the hospital pharmacy operations due to their inherent complexity. In this article, a simulation model is developed based on data collected from a hospital in Turkey to analyze its pharmacy delivery system. In comparison to the baseline system, two different scenarios with varying factors are investigated, seeking to minimize drug delivery time to patients. The results presented here indicate the possibility for improved system performance.

1 INTRODUCTION

According to the Turkish Medical Association, state budget for health care services has doubled during 2002 to 2006 (Turkish Medical Association 2006). The Ministry of Health of Turkey stated that the ministry budget has tripled in last 3 years implying that the expenditures have been mainly on patient treatments and drugs. Moreover, in 2003, drug costs dominated 27 percent of the total health care costs in Turkey (Turkish Medical Association 2006). Therefore, while satisfying patients and quality standards; it is important to use the budget for health care services efficiently.

International heath care standards require a central pharmacy unit in hospitals that maintains and provides the inpatient pharmacy needs (Joint Commission International 2000). A central pharmacy unit provides a secure and proper stock area for the drugs and pharmacy material and is important for keeping the patient records. However, for hospitals that have high patient volumes and dispersed units, a central pharmacy service may result in high drug delivery time if the system is not managed efficiently. While call-based (orders that are received by phone calls from the clinics) or paper-based orders can be used in hospital pharmacy units only for low patient volumes, clinic-based pharmacy units may be setup to overcome the problem of high drug delivery times. Besides all these types of drug delivery systems, electronic order based systems are frequently used in hospitals via Healthcare Information Systems (HIS) recently. Patient records with past and ongoing treatments and pharmacy needs are stored and reached from different clinics using Healthcare Information Systems.

In service industry, simulation is considered to be one of the best tools to analyze real world systems (Law, 2000). In recent years, simulation based studies are conducted to answer "what if" questions in design of more efficient healthcare services (Jun et al., 1999). Due to their complex and stochastic nature, simulation is used as a tool to analyze critical parts of healthcare systems such as facility design (emergency departments, operating rooms, etc.), staff planning and scheduling and bed capacity management. On the other hand, pharmacy management studies are too few compared to those stated above. Wong et al. (2003) proposed a simulation study and investigated the drug delivery time for different scenarios. Another study by Spry et al. (2005), evaluated the turnaround time (time between order and delivery) for different pharmacy staff work schedules.

The simulation model, presented in this study, is for a tertiary level non-profit regional hospital pharmacy system. The hospital located in Bursa has over 40 in and outpatient clinics with 625 beds in total. The hospital units occupy space over 140,500 meter squares, on three blocks. It has recently been accredited by the Joint Commission International and therefore, the hospital management tries to increase the quality of healthcare provided in all areas, continuously.

The main objective of this study is to minimize the turnaround time of the medication orders using the available resources. Two alternative scenarios are studied compared to the current system. In each scenario, different factors and levels are evaluated in order to minimize the average time spent for delivery of orders.

The remainder of this paper is structured as follows; the details of the pharmacy unit and the proposed models are given in Section 2. Section 3 covers the current system simulation analysis. Section 4 and 5 cover the results

978-1-4244-2708-6/08/$25.00 ©2008 IEEE

of this study and conclusion. Finally, the future work is presented in Section 6.

2 THE PHARMACY UNIT

2.1 General Considerations

The hospital pharmacy unit is located in the base floor of the hospital and has three main tasks to be fulfilled;

- checking the orders,
- preparation of drugs according to orders,
- distribution of the prepared medications to the clinics.

The hospital uses an electronic order based system and the orders are given by nurses and doctors from the clinics. The pharmacy unit is responsible for the inpatients' pharmacy needs, except for the chemotherapy patients where chemotherapy drugs need a complex procedure to be prepared at another unit set within the hospital. Therefore, chemotherapy pharmacy unit is not included in this study.

There are three types of staff working in the pharmacy; technicians, pharmacists and deliverymen. Technicians are responsible for printing the orders, taking the drugs from the shelves, and preparing the drug packages for delivery. Pharmacists check the suitability of the order for the patient diagnosis and finally deliveryman are tasked with the distribution of the drugs to the clinics. In emergency cases, a dedicated staff from the clinics or the emergency department come and fetch the drugs. Therefore, while the emergency order preparation is included, the deliveries are excluded from this study.

The pharmacy is working on a two-shift basis; day and night shifts. Day shift starts at 08:00 in the morning and ends at 16:00. On the other hand, night shift is between 16:00 - 08:00. The staff, working within these shifts is summarized in Table 1.

Table 1: Current number of staff working

	Day Shift	Night Shift
Technician [T]	12	6
Pharmacist [P]	4	2
Deliveryman [D]	6	3

2.2 Current Pharmacy Processes

Orders for patients are given by nurses or doctors from clinics or emergency department. Since, the hospital has an electronic order system; orders arrive at computers in the pharmacy as the first step. Technicians print the orders on order cards. Order cards have the patient name, the diagnosis, drugs needed, the clinic that the patient is treated and the other information such as, age, sex, etc. of the patient. In the current system, there are two computers connected to the hospital HIS.

The second step is to check the orders, and verify whether the order is suitable for the patient or not. Pharmacists review the orders before administration. If any question arises at this step, the pharmacist can contact the nurse or doctor who ordered the medication and change the orders by filling a modification form. After the verification step, drugs are prepared by technicians accordingly and packaged for delivery. Figure 1 summarizes the order process flow inside the pharmacy unit.

- Orders arrive at pharmacy via HIS
- Orders are printed on Order Cards by Technicians
- Orders wait for verification
- Orders are verified and checked by Pharmacists
- If necessary a Change Form is filled by Pharmacists
- Orders wait for collection and preparation
- Drugs are collected from shelves and packaged by Technicians
- Packages queue for delivery by Deliverymen

Figure 1: Order process flow inside pharmacy

After the medications are prepared for delivery, the deliverymen distribute the packages to the clinics. During the day shift, the hospital is divided into six main delivery zones and one deliveryman is assigned for each zone for the delivery and pickup processes. On the other hand, for the night shift, three deliverymen are assigned for the delivery and pickup processes. There are two criteria to be satisfied to initiate the delivery of the drug packages to the clinics, i.e. delivery capacity or delivery time. The deliverymen watch for these two indicators; if the delivery boxes become full, delivery takes place immediately. On the other hand, if the capacity cannot be filled within a time period, delivery takes place with the current packages. However, the delivery time goal is not precise and varies from 30 to 60 minutes.

The pharmacy unit operates on a daily basis; in other words, no matter what the treatment time or the type is, for every patient, the drugs are ordered daily. The software used in the hospital does not permit the orders to be given for the day after. Therefore, every day the orders are reviewed and re-ordered to the pharmacy unit by nurses or doctors. During the night shift, pharmacy staff begins to prepare the medication packages for the same day. In order to reduce the heavy workload in the mornings, night shift staff tries to prepare the medications between 04:00 - 08:00 hours ordered for the day time.

Sometimes some of the delivered medications are sent back to the pharmacy with re-orders. These returned drugs have a different procedure compared to the initial orders. First, technicians modify the patient records using the computers. Then, a cancellation form is filled and drugs are placed back to the shelves. There are three main causes of these returned drugs;

- HIS software problems,

- Discharge of patient,
- Modification of the patient treatment after morning visit of doctors.

Firstly, the HIS software lacks the proper handling of solution or suspension based drugs. Since they are not suitable for daily dosages like other drugs (i.e. to be used in a time period more than a day), when the nurses repeat the order for the following day, the solution or suspension based drugs are prepared and delivered again to the clinics. Secondly, if the pharmacy is not notified on time for an impromptu discharged patient, the patient's previously given daily order for the discharge day will be delivered. Thirdly, the main cause of the returned drugs is the morning visits of doctors. Since the clinics want the drugs to be delivered early in the morning, nurses or assistant doctors give the following day's order before the morning visits. If the patient's treatment is changed after the morning visit, a re-order is given and the delivered drugs are sent back. Figure 2 shows the process flow of the returned drugs inside the pharmacy unit.

- Returned drugs are brought back to the pharmacy by Deliveryman
- Returned drugs are deleted from the patient's record by a Technician
- A cancellation form is filled by the Technician
- Returned drugs queue for shelving
- Returned drugs are shelved by Technician

Figure 2: Process flow for returned drugs

The pharmacy unit is also responsible for emergency orders. Emergency orders should be prepared and delivered as quickly as possible. When an emergency order arrives, it is immediately processed and prepared. Emergency orders are first printed by technicians and verified by pharmacists and then the prepared drugs are delivered. When an emergency order is given by a clinic or the emergency department, a staff from these departments is assigned for picking the prepared medications.

2.3 Proposed Scenarios

The basic question to be answered by this study is how to improve the system with minimum resources. The improvement means to decrease the average turnaround times of the orders. In order to improve the current system, meetings are held both with the pharmacy and the hospital administration. As a result of these meetings, it is found that the current turnaround times are not short enough to give a high quality service. Using only the currently available human resources in the system, apparently, the basic option is to change the number of the staff between the day and night-shifts. As described previously, the current night-shift staff begins to prepare the daily medication packages every morning starting at 04:00 for the orders given starting at 00:00 midnight.

Therefore, the first option to be considered is to begin the preparation of drugs after the morning visit of doctors. This will prevent the drug returns and consequently decrease the turnaround times of the orders but, on the other hand, will create an additional workload to the day shift in the mornings.

As a result of further discussions with hospital management, HIS order module modification is decided to be considered as a second option. The option is to modify the order module of the HIS software such that the doctors and nurses may order the medications without waiting for the 00:00 of the day that they are needed. After such a modification, the night shift can prepare the medications from 16:00 to 08:00 hours. It is important to note that the delivery time of the prepared drugs is not changed in both of the options.

3 SIMULATION MODEL OF THE PHARMACY

The simulation model is created using ProModel 6.0. ProModel is a discrete event system simulation software, which enables users to do simulation for evaluating, designing and planning of manufacturing or service systems.

3.1 Data Collection

First, collecting the HIS data for emergency orders over a two-week time period, the probability distribution of emergency order inter-arrival times was determined. Table 2 summarizes the day and night shifts' emergency order inter-arrival times. Triangular distributions fit well to the measured min, mode and max values for the corresponding shifts.

Table 2: Inter-arrival times for emergency orders (min)

Hours	Min	Mode	Max
08:00 – 16:00	4	15	21
16:00 – 08:00	5	19	25

Then, inter arrival time distributions are determined for clinical orders. In order to understand the nature of the order times, the statistical sampling is divided into two parts. Since the assistant doctors or nurses are mainly asked to give orders before 08:00 to secure the delivery of routine doses in the morning hours, inter arrival times for clinical orders are collected separately before and after 08:00. Table 3 shows the corresponding distributions. In Table 2 and 3, distributions of the emergency and clinical orders address the number of orders made in given time periods. Clinical and emergency orders can be made more than once for the same patient and also they include re-orders.

Table 3: Inter-arrival times for clinical orders (min)

Hours	Min	Mode	Max
00:00 - 08:00	0.5	1.5	3
08:00 - 23:59	2	2.5	3

Table 4 shows the percentage of causes that result in drug returns and re-orders. Since the total percentage of the first two are very low compared to the change after morning visits, drug returns because of software problems and discharge of patients are not included in the model. The drug returns correspond to 21% of the drugs delivered before 08:00. Another set of data is collected for the delivery processes. Table 5 presents the distribution of orders according to the pre-determined zones.

Finally, the processing and delivery time data are also collected. After discussing with the pharmacy staff, processing times determined for order and drug returns are summarized in Table 6. Triangular distributions are fitted for the processing times in the simulation model as given in Table 6.

Table 4: Causes of drug returns

	Percentage (%)
Deficiency of HIS Software	7
Discharge of patients	4
Change of treatment after morning visits	89

Table 5: Distribution of orders with respect to zones

	Percentage (%)
Zone 1	15
Zone 2	25
Zone 3	10
Zone 4	10
Zone 5	20
Zone 6	30

Table 6: Processing times for drug orders and returns (min)

	Min	Mode	Max
Orders			
Order print-outs	0.5	1	1.2
Verification and checking	0.8	1	1.5
Filling in the modification form	0.5	1	1.5
Collection and preparation of drugs	3	5	7
Returns			
Deletion from patient record	1	2	3
Filling in the cancellation form	0.5	1.5	2
Shelving the returns	3	5	7
Delivery or pickup	28	32	36

3.2 Performance Measures

Since the aim of this study is to minimize the average time spent in the system or equivalently the turnaround time of orders, the performance measure is defined as the time between the order given and its delivery to the clinics. Here it is important to note that, even though the doctors and nurses can give orders starting at 00:00 hours for the following day, these orders that are processed after midnight can only be delivered starting at 07:00 hours. Therefore, the average time spent in the system actually starts after 07:00.

3.3 Simulation Parameters

In order to simulate the actual system accurately, two important simulation parameters are to be determined. The first one is the warm-up time, but since this simulation model is a terminating one, meaning that the system runs for a particular time period, there is no need to determine the warm-up period time.

The second important parameter is the replication number. The replication number or the sample size should be determined for a particular confidence level. The simulation model is first put through 15 replications, each with a run length of one day. The average time spent in the system is found to be 115.91 minutes with a standard deviation of 12.49 minutes. Thus, for a 95% confidence interval (α=0.95), the half-width is (Banks 2005)

$$hw = t_{n-1,1-\alpha/2}\frac{s}{\sqrt{n}} = 2.145\frac{12.49}{\sqrt{15}} = 6.92$$

The target hw(ε) is set to 8 and in order to reach to 8, the approximate number of replication will be at least;

$$n' = \left[\frac{z_{1-\alpha/2}.s}{hw}\right]^2 = \left[\frac{(1.96)(12.49)}{8}\right]^2 = 9.36$$

Other candidates which are around the approximate replication number should be tested. Table 7 summarizes the iterative solution procedure.

Table 7: Final sample size for the current model

R	10	11	12	13
$t_{0.025,R-1}$	2.26	2.23	2.20	2.18
$\left(\frac{(t_{0.025,R-1})(S)}{\varepsilon}\right)^2$	13.15	12,82	12,09	11.71

Since R = 13 is the smallest integer satisfying the predefined hw(ε), the replication number for the baseline pharmacy model simulation is set to 13 for a %95 confidence level (Banks 2005).

3.4 Verification and Validation

One of the most important parts of a simulation study is the verification and validation step. Validation is the process of determining whether the model is a meaningful and accurate representation of the real system (Harrell 2000). In this study the model is validated in two ways. Firstly, upon development of the model, it is validated through communicating it with the pharmacy staff and hospital administration. Secondly, the real data collected as the time interval between the order and the delivery on a daily basis is collected and its average is compared with the output of the simulation model. The comparison done by using the Welch's t-test is shown in Table 8. Since the %95 confidence interval includes zero, there is no significant difference between the two systems.

Verification is the process of determining whether the model operates as intended (Harrell 2000). Verification is done to see that the simulation model works without errors. In this study, verification step is conducted via sensitivity analysis. The inter-arrival times is changed to check that the simulation model reacts as expected. Two different systems are analyzed to see if the simulation model is accurate. The arrival rates of the orders are doubled and also reduced to half. The sensitivity analysis is summarized in Table 9. When the arrival rate of the orders are doubled, the average time spent in the system for the orders is also doubled. On the other hand, when the input reduced to half, the average time spent in the system is reduced to half. As a result, the simulation model is verified.

3.5 Experimental Design

In this study, in addition to the baseline scenario, two more scenarios are investigated. Each scenario including the baseline has variants with three factors at three levels. Therefore, three separate designs of experiments are conducted to determine the optimal conditions of each scenario. Since the resources are restricted by the pharmacy and hospital budget, scenarios are constructed without any need for additional human resources. Moreover, the number of deliverymen is not included as a factor in the scenarios since the pharmacy management stated that the number of deliverymen should be kept constant. As a result of meetings that are held both with the pharmacy managers and the hospital administration, the following scenarios are analyzed. In all these scenarios, number of computers, number of pharmacists and number of technicians are all considered as factors. However factor levels are different in each scenario.

The first scenario to be studied is the current system named as baseline scenario. While the second scenario cancels the orders given after midnight for morning delivery and it requires orders to be given after the morning visits of doctors. When such after visit orders are given, medication packages will be prepared and delivered to the clinics immediately. Since the resource need in the mornings will be high within this scenario, factor levels are selected accordingly. This scenario aims to reduce the order returns.

The third scenario includes an electronic order HIS software modification. This modification basically permits the day after orders. As stated previously, in the current system, orders are given on a daily basis and in order to get the medications early in the morning, clinical units give the orders after midnight. Moreover the preparation of these orders begins at 04:00 a.m. However, in the third scenario, nurses or doctors can give the orders for the day after starting from 17:00. Therefore, the pharmacy staff can begin to prepare the required medication in the night shift after 17:00. In Table 10 where all the scenarios and related factors are summarized, factor code A corresponds to number of technicians and B and C correspond to number of pharmacist and number of computer respectively. In the other three columns, the corresponding factor levels (level 1 to 3) are summarized.

Since the arrival logic is different in each scenario, replication numbers and interval estimates are calculated separately. The replication numbers for the second and third scenario are calculated similarly to be 18 and 14 respectively. Taguchi's design of experiments is used to mainly to determine the possible nonlinear effects of the scenarios and factors. Three separate experimental studies are conducted for each of the scenarios since factor levels are not comparable in each scenario. Then the best options from each scenario are compared by Welch t-test to determine the statistical difference within these options.

Taguchi's design of experiments is generally used for quality improvement studies. The main aim of the design is to maximize the signal to noise ratio (S/N). Signals can be thought of as high quality products or services, and noises are those factors that are not under the control of the designer. The main idea behind this design is to maximize the signal to noise ratio. Since the aim of this study is to minimize the turnaround time of the orders, "smaller the better" S/N ratios are calculated and analyzed for every factor and level. There are 3 factors with 3 levels in all of the scenarios, thus an L-9 design is used.

4 RESULTS AND DISCUSSION

Figure 3 shows the resultant S/N ratios (Eta) for the baseline scenario (scenario_1). Since the night shift staff begins to prepare the morning orders after 04:00 in the baseline scenario, as expected, transferring a technician to the night shift from the day shift reduces the average time spent in the system. Moreover, adding a pharmacist from day to night shift has also a positive effect on reducing the turnaround time.

Figure 4 shows the experimental results for the scenario_2 which includes canceling the orders given after midnight but forces the orders to be given after the morning visits of the doctors. As expected, transferring a technician and a pharmacist from night to day shift reduces the turnaround times of the orders.

Figure 5 shows the results of the experiments for the scenario_3. Since the orders can be given the day before and prepared at the night shift, transferring one technician and one pharmacist from night shift to day shift minimizes the turnaround time of the orders.

In all of the experiments, computer numbers significantly affects the results. As expected, computer numbers should be increased in order to reduce the average time spent in the system. After evaluating the scenarios, the best options are compared with each other. This part of the study can be thought of as a minimax objective functions(William 2005). The options that give the maximum S/N ratios from each of the scenarios are compared in order to find the minimum turnaround times of orders. Table 11 shows the model output (turnaround times of orders) interval estimates for the best options from each of the scenarios.

Since the factors levels of the proposed scenarios are different, 3 individual Taguchi designs are applied and best options of these scenarios are compared. Table 12 shows the comparison of the best options found from each of the scenarios. A Welch-t test with a 95% confidence is used to compare each of the average turnaround times of options. Since, there are two intervals for each of the comparisons, 97.5% confidence levels are used for each of the options (Banks 2005). The aim of the comparison is to find intervals for $\mu_1- \mu_2$, $\mu_1- \mu_3$ and $\mu_2- \mu_3$ and then evaluate these intervals for significance. Since the interval for the best options of scenario_1 and scenario_2($\mu_1- \mu_2$), includes zero it is concluded that, there is no statistical difference between these two scenarios. On the other hand, since the average turnaround time intervals for the difference between scenario 1 and 3 as well as 2 and 3 exclude zero, it can be concluded that there are significant differences between these options. Therefore, one can say that the best option from scenario 3 is statistically better than the best of other two scenarios. The proposed system as scenario 3 which includes, HIS software modification and transferring one technician and one pharmacist to the day shift, improves the system performance and decrease the turnaround time of the orders resulting in a higher quality service.

Table 8: 95% Confidence interval for the difference between simulation model and current system

	Simulation Model		Actual System		Welch-t test		
	Mean (Std. Dev.)	n	Mean (Std. Dev.)	n	Half-width	Interval	df
Average time spent in the system	114.22 (9.84)	13	117.83 (48.74)	7	45.66	[-49.17, 41.96]	6

Table 9: Sensitivity Analysis

	Current Model		Double Arrival Rate		Half Arrival rate	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Average time spent in the system	114.22	9.84	301.44	44.59	66.81	11.23

Table 11: 95% Confidence intervals of the best options of the scenarios

Scenario	Factor(Level)	# of Replication(n)	Mean(X)	Std. Dev.(s)	Half-width	Interval
1	A(3)B(3)C(3)	13	91.17	11.41	7.39	[84.28, 98.06]
2	A(3)B(3)C(3)	18	95.08	19.79	10.07	[85.01, 105.15]
3	A(2)B(2)C(3)	14	74.12	18.93	10.67	[63.45, 84.79]

Table 10: Experimental design factors and factor levels

Scenario	Code	Level 1	Level 2	Level 3
Scenario_1	A	Current	Night -1 Day +1	Night +1 Day -1
	B	Current	Night -1 Day +1	Night +1 Day -1
	C	1	Current	3
Scenario_2	A	Current	Night -1 Day +1	Night -2 Day +2
	B	Current	Night -1 Day +1	Night -2 Day +2
	C	1	Current	3
Scenario_3	A	Current	Night -1 Day +1	Night +1 Day -1
	B	Current	Night -1 Day +1	Night +1 Day -1
	C	1	Current	3

Table 12: Comparison of alternative scenarios

i	j	X_i-X_j	Welch t-test		
			Half width	Interval	df
1	2	-3.91	11.57	[-15.48,7.66]	27
1	3	17.05	12.41	[4.64,29.46]*	21
2	3	20.96	14.10	[6.92,34.99]*	28

*Denotes a significant difference

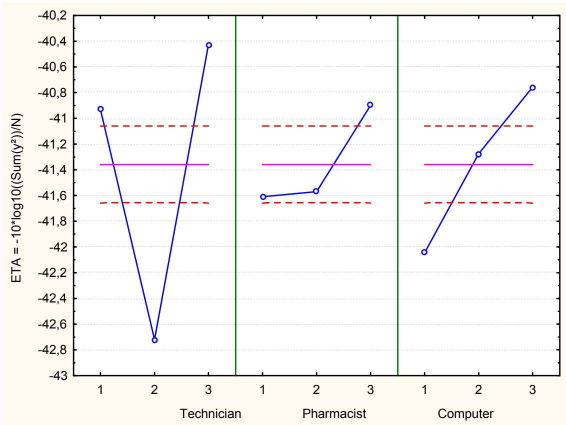

Figure 3: Average Eta by factor levels for Scenario_1

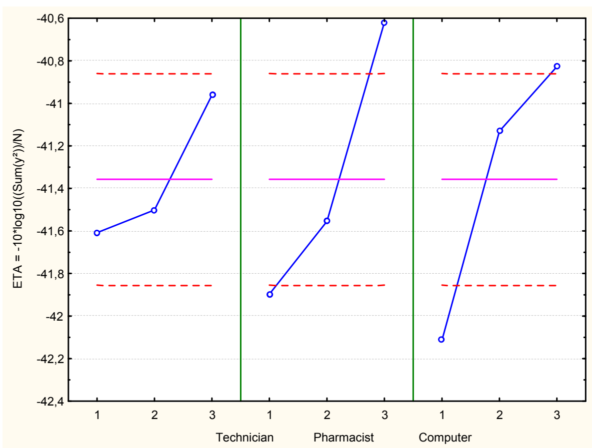

Figure 4: Average Eta by factor levels for Scenario_2

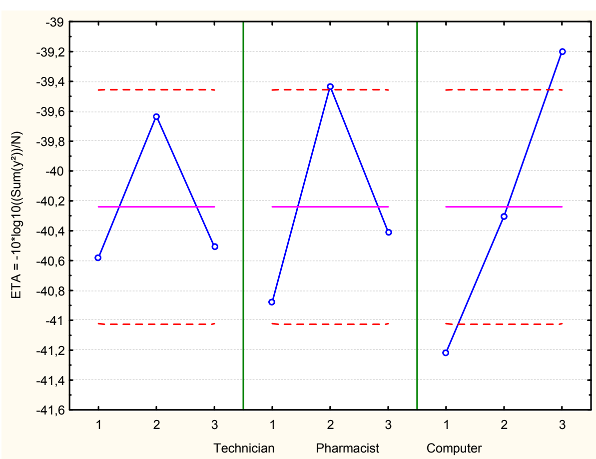

Figure 5: Average Eta by factor levels for Scenario_3

5 CONCLUSION

This study proposed a pharmacy simulation model for a hospital in Turkey which uses an electronic-order based system. The goal of the study is to find the best option that minimizes the turnaround times of the orders while evaluating different scenarios. Since the resources are restricted by the pharmacy budget, only changing the staff number between shifts are considered.

The computational results of the comparative study of the current model and the best option from proposed scenarios indicate that, by a software update which will allow the nurses or doctors to give orders for the following day reduces the turnaround time of the orders by 36 percent. Also, it is to be noted that, the service quality of the pharmacy is improved even without increasing the number of staff.

It is also shown that, the results of such simulation studies provide help and guidance to the hospital and pharmacy administrations to improve their healthcare services for inpatients.

6 FUTURE WORK

Since this simulation study is proposed for a particular hospital pharmacy system, the next phase of the study will be to expand the scope and construct a model for general hospital pharmacy delivery systems that can be implemented in any hospital pharmacy system.

Instead of using Taguchi design methods for analyzing the experiments, traditional factorial design methods can also be used and a detailed analysis can be conducted over the factors and their interactions. Additionally, instead of doing the optimization by experimental design, integration of a heuristic algorithm i.e. genetic algorithm, into the simulation model to determine the optimal day and night shift schedules can be investigated in the future. Since the model includes the delivery of the drugs, optimization of the routes of the deliverymen would likely be included in such extensions.

Finally, more alternatives scenarios can be studied and the inter arrival times of orders can be collected in more detail i.e. on an hourly-basis, in order to see the reaction of the system during the day and night-shifts separately.

ACKNOWLEDGMENTS

The authors are grateful to the pharmacy staff and hospital vice-director Assoc. Prof. Sinan Cavun and Funda Coskun, M.D. for their support and help in supplying the information that is needed for the model and proposed scenarios.

REFERENCES

Banks, J., J. S. Carson, B. L. Nelson, and D. M. Nicol. 2005. *Discrete-event system simulation*. 3rd ed. Upper Saddle River, New Jersey: Prentice-Hall, Inc.

Harrell, C., Ghosh, B.K., Bowden, R. 2000. *Simulation Using ProModel*. New York: McGraw-Hill.

JB Jun, SH Jacobson, JR Swisher 1999. Application of discrete-event simulation in healthcare clinics: A survey. *Journal of Operational Research Society*, 50, 109-123.

Joint Commission International. 2002. International Standards for Hospitals, Joint Commission on Accreditation of Healthcare Organizations. JCI. IL, USA.

Law, A.M., and W.D. Kelton. 2000. *Simulation modeling and analysis*. 3rd ed. New York: McGraw-Hill.

Spry, C.W., Lawley, M.A. 2005. Evaluating hospital pharmacy staffing and work scheduling using simulation. *In Proceedings of the 2005 Winter Simulation Conference*, ed. M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines (eds), 2256-2263.

Turkish Medical Association, 2006. Turkey's statistics on health service. Available via <http://www.ttb.org.tr/kutuphane/istatistik2006.pdf>. [accessed March 04, 2008](In Turkish).

Williams, H.P. 2005. *Model Building in Mathematical Programming*. John Wiley & Sons.

Wong, C., G. Geiger, Y. Derman, C. Busby, and M. Carter 2003. Redesigning the medication ordering, dispensing, and administration process in an acute care academic health sciences centre. *In Proceedings of the 2003 Winter Simulation Conference*, ed. S. Chick, P. J. Sanchez, D. Ferrin, and D. J. Morrice (eds), 1894-1902.

AUTHOR BIOGRAPHIES

ALKIN YURTKURAN is teaching assistant and M.S. student in Industrial Engineering Department at Uludag University, Bursa. His research interests include simulation and analysis of service systems performances.

ERDAL EMEL is a professor in Industrial Engineering Department at Uludag University, Bursa, Turkey. His research interests include production and operations planning and simulation.