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The Optimization of the Health Care System by M/M/S Queueing Model

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Abstract. The aim of the research is to optimize the health care system to maximize the use of the resources, and analyze the expected waiting cost and service cost of the multi queue multi-server queuing system to be optimized and also offer recommendations on the best policy to enhanced the performance of the organization so that can be capitalized the productivity of the resources. And the TORA software tool used to investigate the data. The result of the investigation demonstrates that the optimum server level at a lowest total cost.

Key words: Multi server model, queueing models, waiting cost, Waiting time, TORA

INTRODUCTION

The health care providers in India trying to provide good treatment and facilities for patients in the country like India where Government hospitals are one of the most popular and cheapest means of treatment, it is always difficult to get good treatment without waiting long time. Miller [1] in his study evaluated that health care has been an issue of rising importance for national government. Many national and regional health care plans have been developed in the past decades, in order to control the cost, quality and the availability of health care for all citizens. Manufacturing firms, hospitals, airline companies, banks, etc., trying to minimize the total waiting cost, and the service cost of the server. For the healthcare service sector customer satisfaction is a serious concern, a number of schemes has been established to develop customer satisfaction. The healthcare service sectors globally are experiencing pressure to reduce cost and the development of the quality. Queues, or waiting lines, are items in a list or line in the order that they will be processed. Queuing theory is the study of the statistics behind the formation of queues. Queuing models are representations of the statistical data that can be applied to major systems in order to increase the systems overall

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efficiency. Systems that can be improved through the use of a queuing model are almost limitless, but some examples include manufacturing plants, amusement parks, and hospitals [10]. With an ever-increasing population the formation of queues is inevitable. However, queues need to be managed so that society benefits most; especially in cases where there is imminent danger if queues are not managed successfully [1]. The most prevalent place where this particular situation occurs is in hospitals. All types of queues are formed in hospitals. Whether it is a simple treatment or an emergency surgery, the formation of queues can quite literally be life or death. Queues are ubiquitous, particularly in healthcare delivery systems. Especially in the hospital management queuing theory which is influential management tool has been under estimated and the appropriate use of this effective queuing management tool can yield remarkable results. The aim of this article is to offer a elementary understanding of queuing system and some of the precise queuing models that can be helpful in designing and managing healthcare delivery systems. If the number of doctors is increased in such a way that to reduce waiting time of patient and the treatment of patient can be done in time and can save the life of many patients. TORA software tool has been used to compute the performance measures of multi-server multi queue queuing model and the data was analyzed graphically.

QUEUING SYSTEM AND METHODOLOGY

$\{(M/M/s) : (\infty/FCFS)\}$ Queuing system performance measures

The probable number of patients waiting in the queue

$$L_q = \left[\frac{1}{(s-1)!}\left(\lambda/\mu\right)^s\left(\frac{\lambda\mu}{(s\mu-\lambda)^2}\right)\right]P_0$$

Where

$$P_0 = \left[\sum_{n=0}^{s-1}\frac{1}{n!}\left(\lambda/\mu\right)^n + \frac{1}{s!}\left(\lambda/\mu\right)^s\left(\frac{s\mu}{s\mu-\lambda}\right)\right]^{-1}$$

The probable number of patients in the system

$$L_s = L_q + \frac{\lambda}{\mu}$$

The probable waiting time of a patient in the queue

$$W_q = \frac{L_q}{\lambda}$$

The probable waiting time of a patient in the system

$$W_s = W_q + \frac{1}{\mu}$$

Expected service cost $ESC = S * C_s$

Where S is the number of systems and C_s is the cost of each server

The average waiting cost in the queue is $EWC = L_s * C_w$

Where L_s = the probable number of patients in the system and C_w = waiting cost of each patient.

Expected total cost multi server queuing model is $ETC = ESC + EWC = S * C_s + L_s * C_w$

RESULTS AND DISCUSSIONS

The data was analyzed in two cases that are seasonal period (May - November) and unseasonal period (December - April) and considering that the OPD (Outpatient Department) is working for six hours in a day and the arrival rate of outpatients 317 per hour in the seasonal period and the arrival rate of outpatients 150 per hour in the unseasonal period.

Case – I. Analysis of the data in unseasonal period

In the unseasonal period the average arrival rate is $\lambda = 150$ patients/hr and the average service rate $\mu = 6$ patients/hr. considering the cost of each server is Rs 200/- per hr., the cost of waiting per the patient is Rs 150/- per hr.

Minimum number of doctors can be calculated by using the formula

$$\rho < 1 \quad \text{i.e.} \quad \frac{\lambda}{S\mu} < 1, \quad \frac{150}{S(6)} < 1, \quad S > 25$$

Here the minimum number of required doctors is more than 25 ($S > 25$)

TABLE 1. Performance measures of the multi-server queuing model

Number of servers	Utilization factor	Ls	ESC	EWC	ETC
26	0.962	44.56	5200	6684	11884
27	0.926	32.54	5400	4881	10281
28	0.893	28.81	5600	4321.5	9921.5
29	0.862	27.13	5800	4069.5	9869.5
30	0.833	26.25	6000	3937.5	9937.5
31	0.806	25.75	6200	3862.5	10062.5
32	0.781	25.45	6400	3817.5	10217.5
33	0.758	25.27	6600	3790.5	10390.5
34	0.735	25.17	6800	3775.5	10575.5

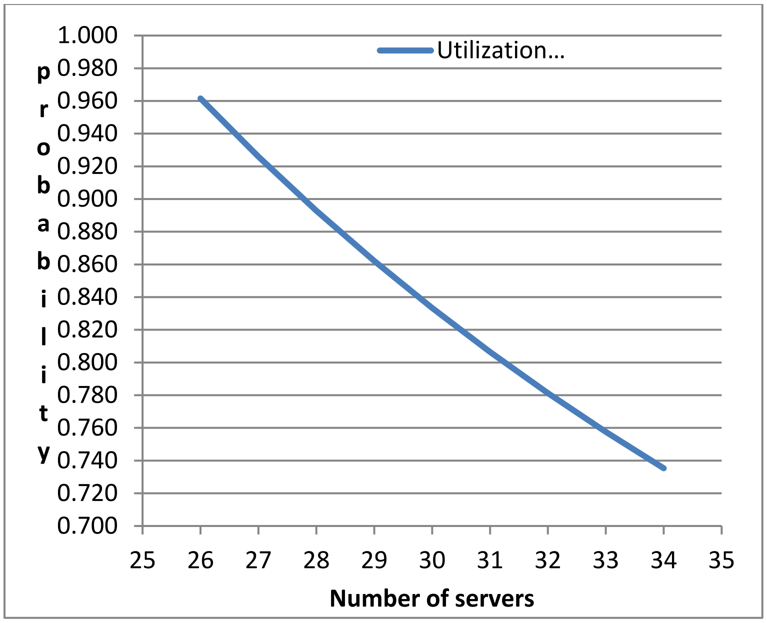

FIGURE 1. Scatter plot of utilization.

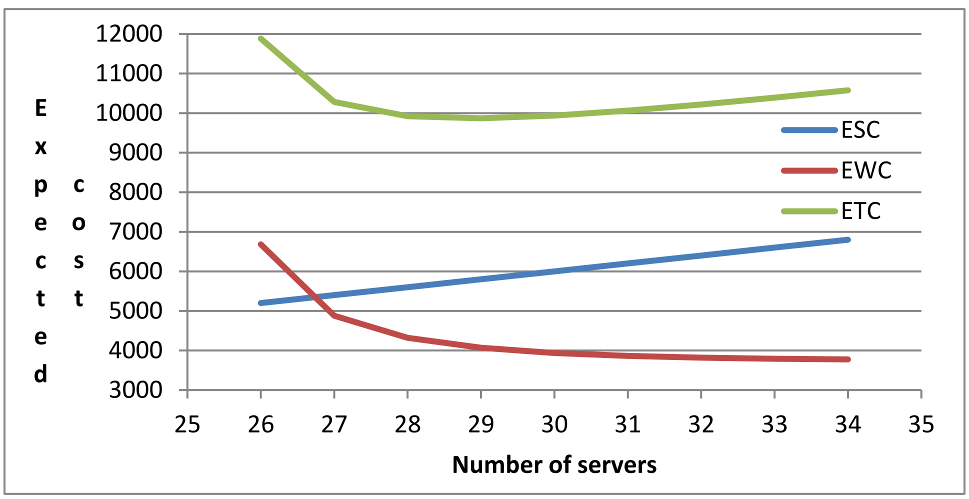

FIGURE 2. Number of servers versus expected Service, waiting total costs.

From the Fig.1and Fig.2, the graphical analysis of the data as follows as the number of servers increased the utilization factor and waiting cost of the patient is decreased but service cost is increased and the total cost is decreased to certain level then again increased, at the minimum total the number of servers are twenty nine this can treat as the optimal total cost and optimal number of doctors are required.

Case – II. Analysis of the data in seasonal period

In the seasonal period the average arrival rate is $\lambda = 317$ patients/hr and the average service rate $\mu = 6$ patients/hr. considering the cost of each server is Rs 200/- per hr., the average cost of waiting per the patient is Rs 150/- per hour. Minimum number of doctors can be calculated by using the formula

$\rho < 1$ i.e. $\frac{\lambda}{S\mu} < 1$, $\frac{317}{S(6)} < 1$, $S > 52.83$

Here the minimum number of required doctors is more than 52.83 ($S > 52.83$)

TABLE 2. Performance measures of the multi-server queuing model

Number of servers	Utilization factor	Ls	ESC	EWC	ETC
53	0.997	361.13	10600	54169.5	64769.5
54	0.978	89.95	10800	13492.5	24292.5
55	0.961	69.55	11000	10432.5	21432.5
56	0.943	62.32	11200	9348	20548
57	0.927	58.77	11400	8815.5	20215.5
58	0.911	56.74	11600	8511	20111
59	0.895	55.48	11800	8322	20122
60	0.881	54.66	12000	8199	20199
61	0.866	54.1	12200	8115	20315
62	0.852	53.72	12400	8058	20458

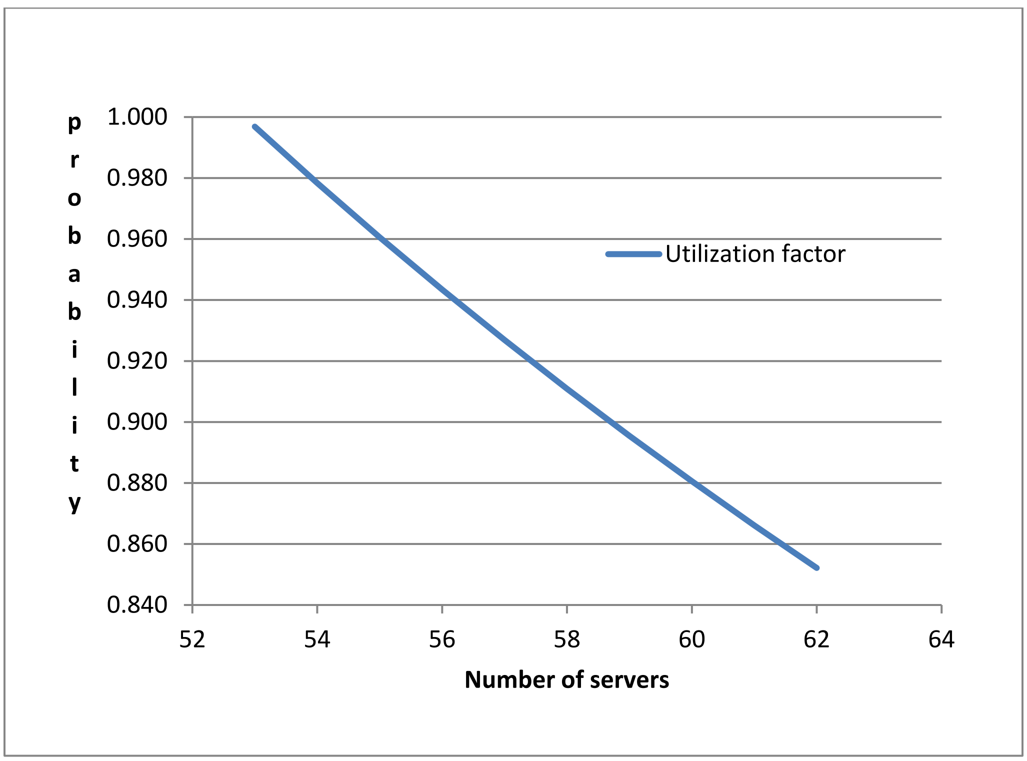

FIGURE 3. Scatter plot of utilization.

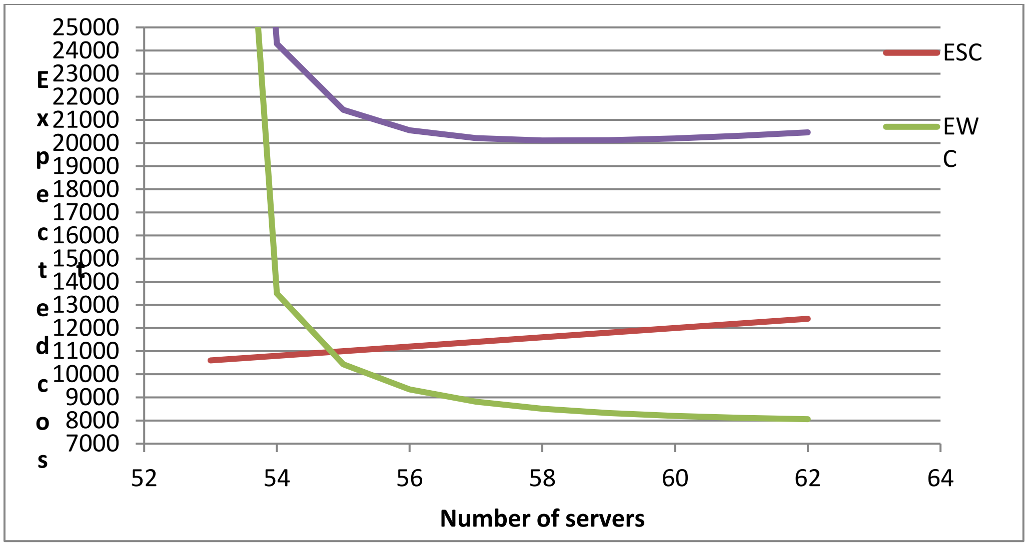

FIGURE 4. Number of servers versus expected Service, waiting total costs.

From the Fig.3 and Fig.4, the graphical analysis of the data as follows as the number of servers increased the utilization factor and waiting cost of the patient is decreased but service cost is increased and the total cost is decreased to certain level then again increased, at the minimum total the number of servers is fifty-nine this can treat as the optimal total cost and optimal number of doctors are required.

CONCLUSION

The application of multi-server queuing model plays a key role in hospital performance. In case –I (unseasonal period) the optimal required number doctors are twenty-nine to balance service cost and waiting cost but in case – II (seasonal period) the optimal required number of doctors are fifty-five to balance service cost and waiting cost. After studying the advantages and disadvantages of the system this paper recommends that to increase the number of doctors in seasonal period to decrease the waiting time and waiting cost of the patients, and this paper gave the optimal number of required doctors in the seasonal period and optimal cost for proper treatment of patients in time to save many lives.

REFERENCES

1. Asabe S. A., Oye N. D., Monday Goji, hospital patient database management system A Case Study of General Hospital north-bank Makurdi- Nigeria, An international journal of advanced computer technology, (Vol. II, Issue III), pp 65 – 72, 2013
2. Brahma P K, Queuing theory and customer satisfaction: a review of terminology, trends, and applications to hospital practice, Asia Pacific Journal of Marketing & Management Review, Vol.2 (6), pp 83 – 89, June (2013)
3. Gupta. D, Denton B.T (ed.), Handbook of Healthcare Operations Management: Methods and Applications, International Series in Operations Research & Management Science, pp 19 -44
4. Gupta P.K, Hira D.S, Operations research, revised edition, S. Chand, pp 903-910, 2008
5. Hamdy A.Taha, Operations research: an introduction, 8th edition, Pearson Education, Inc., pp 557-558, 2007

6. Mardiah F. P, Mursyid H. B., The Analysis of Appointment System to Reduce Outpatient Waiting Time at Indonesia's Public Hospital, Human Resource Management Research, pp 27-33, 2013
7. Mohammad karim B, et al, Using Queuing Theory and Simulation Model to Optimize Hospital Pharmacy Performance, Iran Red Crescent Med J., pp 1 – 7, 2014
8. Obamiro J K, Queuing Theory and Patient Satisfaction: An Overview of Terminology and Application in Ante-Natal Care Unit, Economic Sciences Series, Petroleum-Gas University of Ploiesti Bulletin, Vol. LXII, pp 1 – 11, 2010
9. Prasad S.V, Badshah V.H., Porwal P, Decision Making by M/M/S Queuing Model: A Case Study-I, International Journal of Pure and Applied Mathematical Sciences, Vol.7, pp 137-143, 2014
10. Ryan Orlando, Stephen T, optimizing hospital performance using queuing models, University of Pittsburgh, Swanson School of Engineering, pp 1 - 7
11. 11. Samuel F, Jeffrey H, A survey of queuing theory applications in healthcare, ISR Technical Report 2007, The Institute for Systems Research, pp 1 – 24
12.
13. Sharma.J.K, Operations research theory and applications, third edition, Macmillan India Ltd. New Delhi, pp 725-750, 2007
14. Vasanta Kumar, V., Srinivasa Rao, T., & Srinivasa Kumar, B. (2018). Queuing system with customer reneging during vacation and breakdown times. Journal of Advanced Research in Dynamical and Control Systems, 10(2), 381-385.
15. Rao, H., Kumar, V., Srinivasa Rao, T., & Srinivasa Kumar, B. (2018). Optimal control of M/M/1 two-phase queueing system with state-dependent arrival rate, server breakdowns, delayed repair, and N-policy. Paper presented at the Journal of Physics: Conference Series, 1000(1) doi:10.1088/1742-6596/1000/1/012031
16. Hanumantha Rao, S., Vasanta Kumar, V., Srinivasa Rao, T., & Srinivasa Kumar, B. (2016). A two-phase unreliable M/Ek/1 queueing system with server startup, N-policy, delayed repair and state dependent arrival rates. Global Journal of Pure and Applied Mathematics, 12(6), 5387-5399.
17. Rao, S. H., Kumar, V. V., Rao, T. S., & Kumar, B. S. (2016). M/M/1 two-phase gated queueing system with unreliable server and state dependent arrivals. International Journal of Chemical Sciences, 14(3), 1742-1754.
18. Srinivasa Rao, B., Srinivasa Kumar, C., & Rosaiah, K. (2016). Variable limits and control charts based on the half normal distribution http://compass.astm.org/download/JTE20140429.33793.pdf. Journal of Testing and Evaluation, 44(5), 1878-1884. doi:10.1520/JTE20140429
19. Nagaraju, V., Kumar, V. V., & Rao, K. V. (2017). Pattern of life expectancy at birth in india, significant changes over the past years. International Journal of Economic Research, 14(20), 493-499
20. Asadi, S. S., Kumar, M., Kumar, N., & Rajyalakshmi, K. (2017). Estimation of runoff for agricultural utilization using geoinformatics: A model study from telangana state. International Journal of Civil Engineering and Technology, 8(10), 472-483.

21. Asadi, S. S., Kumar, N. V., Rajyalakshmi, K., & Kumar, M. S. (2017). Designee of water harvesting structures for water resources management: A model study from chelila watershed, Bhutan. International Journal of Mechanical Engineering and Technology, 8(10), 666-679.
22. Asadi, S. S., Raju, M. V., Sujatha, M., & Rajyalakshmi, K. (2017). Geospatial based analysis of topographical features for resources management: A model study from Bhutan. International Journal of Mechanical Engineering and Technology, 8(10), 812-822.
23. Asadi, S. S., Rajyalakshmi, K., Kumar, M. S., & Kumar, N. V. (2017). Evaluation of surface water characteristics using remote sensing and GIS - A model study. International Journal of Civil Engineering and Technology, 8(9), 1002-1012.
24. Kumar, D., Rajyalakshmi, K., & Asadi, S. S. (2017). Digital marketing strategical role to promote technical education in Andhra and telangana: An exploratory study. International Journal of Civil Engineering and Technology, 8(10), 197-206.
25. Kumar, D. P., Rajyalakshmi, K., & Asadi, S. S. (2017). A model analysis for the promotional techniques of cell phone subscriber identity module (SIM) cards. International Journal of Civil Engineering and Technology, 8(9), 889-897.
26. Kumar, D. P., Rajyalakshmi, K., & Asadi, S. S. (2017). Analysis of mobile technology switching behavior of consumer using chi-square technique: A model study from Hyderabad. International Journal of Civil Engineering and Technology, 8(9), 99-109.
27. Rao, I. V. R., Anusha, S., Mohammad, A. B., & Satish Kumar, D. (2018). Object tracking and object behavior recognition system in high dense crowd videos for video supervision: A review. Journal of Advanced Research in Dynamical and Control Systems, 10(2 Special Issue), 377-380. Retrieved from www.scopus.com
28. Satish Kumar, D., Anusha, S., Rao, D. S., & Niranjan, H. (2018). A study on consumer behavior at corporate retail stores in vijayawada city. Paper presented at the Journal of Physics: Conference Series, , 1139(1) doi:10.1088/1742-6596/1139/1/012039 Retrieved from www.scopus.com
29. Sateesh Kumar, D., Shaik, M. S., Narayana, B., & Appa Rao, B. V. (2021). Perceptions of users of UDAN scheme in indian civil aviation sector. Paper presented at the AIP Conference Proceedings, , 2375 doi:10.1063/5.0066377 Retrieved from www.scopus.com
30. Satish Kumar, D., Siri, Z. B., Rao, D. S., & Anusha, S. (2019). Predicting student's campus placement probability using binary logistic regression. International Journal of Innovative Technology and Exploring Engineering, 8(9), 2633-2635. doi:10.35940/ijitee.i8984.078919
31. Prasad, C. M. V. S., Rao, K. R., Satish Kumar, D., & Prabhu, A. V. (2018). Performance evaluation of power optimization in wireless sensor networks using particle swarm optimization. International Journal of Engineering and Technology(UAE), 7, 404-408. Retrieved from www.scopus.com
32. Rajyalakshmi, K., Kumar, D. P., & Asadi, S. S. (2017). An analitical study for evaluation of factors influencing the customers to utilization of e-commerce sites. International Journal of Mechanical Engineering and Technology, 8(12), 184-196.

33. Vasam, N., Vasanta Kumar, V., & Rao, V. (2018). Joint and net effect on life expectancy at birth through the literacy rate and infant mortality rate of India and state-Wise by path analysis. ARPN Journal of Engineering and Applied Sciences, 13(7), 2588-2593.
34. Krishna, K. M., Sharma, M. R., & Reddy, N. K. (2018). Forecasting of silver prices using artificial neural networks. Journal of Advanced Research in Dynamical and Control Systems, 10(6 Special Issue), 480-485.
35. Srinivasa Rao, T., Srinivasa Kumar, B., & Hanumanth Rao, S. (2018). A study on Γ-neutrosophic soft set in decision making problem. ARPN Journal of Engineering and Applied Sciences, 13(7), 2500-2504.
36. Srinivasa Rao, T., Srinivasa Kumar, B., & Hanumanth Rao, S. (2018). Use of Γ(gamma)- soft set in application of decision making problem. Journal of Advanced Research in Dynamical and Control Systems, 10(2), 284-290.
37. Kumar, P., & Keerthika, P. S. (2018). An inventory model with variable holding cost and partial backlogging under interval uncertainty: Global criteria method. International Journal of Mechanical Engineering and Technology, 9(11), 1567-1578.
38. Phani Bhaskar, P., Prasanna Kumar, D., & Rajya Lakshmi, K. (2018). The impact of customers trust, value, satisfaction and loyalty towards E-commerce websites. Journal of Advanced Research in Dynamical and Control Systems, 10(4), 73-77.
39. Vijay Prasad, S., Peter Praveen, J., Tiwari, A., Prasad, K., Bindu, P., Donthi, R., & Mahaboob, B. (2018). An application of LPP - graphical method for solving multi server queuing model. International Journal of Mechanical Engineering and Technology, 9(1066-1069), 1066-1069.