International Journal of Applied Operational Research
Vol. 4, No. 2, pp. 43-51, Spring 2014

Journal homepage: www.ijorlu.ir

Performance Evaluation and Improvement of Queuing System in Iran Khodro Agency, A Case Study

S. Gh. Jalali, M. S. Sabbagh, S. F. Hoseini*, M. Baghersad

Received: 17 September 2013 ; **Accepted:** 6 January 2014

Abstract Today, in a competitive market, service organizations and producers have a great attention to optimization and customer satisfaction in order to become competitive. Service organization must reduce the number of arrival, waiting time and service time in the queue to increase the customer satisfaction. In this paper by the aim of queuing theory we analyze the optimal amount of increment in a repair shop space and number of purchasing advanced equipment in one of the branches of Iran Khodro, automobile producer and assembler in Iran, in order to reduce customer waiting time; then we fine M/M/S ، M/M/S/S ، M/M/S/k models that fit to our analysis. Also we do the data sensitivity analysis in each part of the repair shop with respect to the cost of each situation and the effect of it on the whole system; then we specify the economic optimal service level in order to rearrange the stations in this branch.

Keywords Queuing System, Performance Evaluation, System Improvement, Iran Khodro Company.

1 Introduction

The final goal of all the service organizations and producers is achieving the customer satisfaction, this satisfaction can achieve by getting the customers what they want and satisfy their needs. One of the important needs of each customer is achieving the goods and services in the shortest time[1].

No one likes to stay in a queue, waiting time in a queue is not desired not for customers nor organizations, but the question is why queues exist? The answer is quite simple, if demand for goods or services in a special organization is more than its capability, at the same time, then the queue is made and makes a bad effect on both customers and organization.

Why the queue is made? There are lots of reasons behind it, for example time or space limitation, but usually by the correct investment, organizations can omit this kind of limitation, queuing theory is a tool to answer the questions like: how many customers and how long might stay in queue, By mathematical calculations[2],[3].

Corresponding Author. (✉)
E-mail: f_hoseini@ind.iust.ac.ir (S.F. Hoseini)

S. Gh. Jalali
Associate Professor, Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran

M. S. Sabbagh
Assistant Professor, Department of Industrial Engineering and Systems, Isfahan University of Technology, Isfahan, Iran

S. F. Hoseini
Ph.D. Student, Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran

M. Baghersad
Master Student, Department of Industrial Engineering and Systems, Isfahan University of Technology, Isfahan, Iran

Distributers have some specified ability, and restrictions reduce the customer waiting time, queuing theory is a powerful tool that managers can use it in order to optimize their decisions and define the optimize amount of investment and also to increase the customer satisfaction in after sale services [4].

There is a huge amount of literature in queuing theory that solve the practical problems, [5]do the performance evaluation of communicative cell by the view point of queuing theory, [6], [7]performance evaluation of queuing system in bank, [8], analysis of queuing system in freeway tax station, queuing systems in electricity distribution networks[9] queuing theory in electronic system and computers[10].

In this paper we define the optimal amount of service level with respect to current situation in one of the branches of Iran Khodre in order to increase customer satisfaction

2 Case Study

In this paper we analyze the queuing system specification of after sale service in one of the branches of Iran Khodro, automobile producer and assembler in Iran, in order to specify the optimal amount of increment in different parts of the branch.

service system in this branch works as follows, first of all a customer refers to the acceptance part, if there is any empty space in the parking, then he refers to the expert in then if there is any empty space in the mechanical and electrical parts, all the car's malfunctions are written in three copies for the owner, acceptance and accountant parts.

After a test, the car is transferred to the parking, and a blue number is assigned to it, and it goes through the service queue in order to refer to the different stations to get repaired, after that it is retransferred to the parking up to the customer release the car.

This branch involves different parts like acceptance, mechanical, electrical, painting, handling adoption, parking, spare parts warehouse, managerial parts etc.

Each station can do all the needed operations for each customer, in other words all the stations are the same, also the mechanical part involves one expert and eight repair men that work two by two and the expert has a guiding role. In each part of painting and electrical, one expert and three workmen work two by two, figure one shows the procedure.

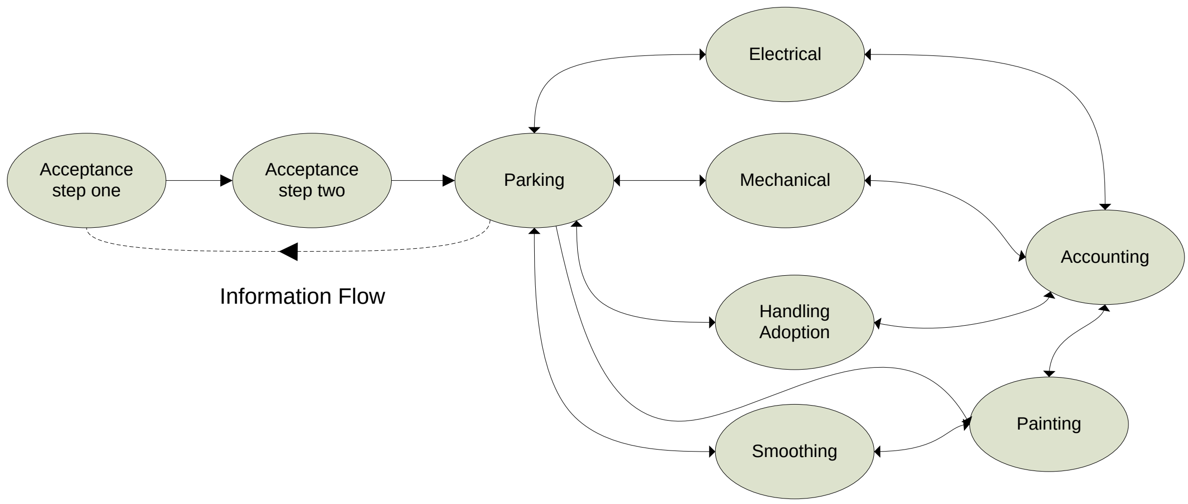

Fig. 1 an Overview of different steps of activities

2.1 Data collection procedure

All the data are real, and they have been achieved by counting the incoming interval of customers to the acceptance and incoming interval to the repair shop in order to compute incoming rate λ, arrival rate $\bar{\lambda}$, and service time μ [11]. By the aim of SPSS we fit suitable distribution to the data that will be explained in details in section three [12].

Table 1 and table 2 are some sample of service time and arrival time. Figure 2 shows that how an exponential distribution can fit the data correctly.

Table 1 The part of service time data

Data Number	Acceptance Step One	Acceptance Step Two	Acceptance Step three	Electrical	Mechanical	Parking
1	4.85	12.35	13.94	1.7	1.85	0.31
2	5.49	13.1	2.16	1.7	0.68	0.63
3	3.76	8.32	9.18	0.75	3.79	0.4
...						
108	1.02	9.6	0.36	1.85	0.75	0.11
110	3.57	8.9	1.59	1.75	1.92	0.46
110	4.67	9.8	0.2	1.21	1.44	0.62
Mean of data	**4.24**	**9.53**	**4.71**	**1.21**	**1.42**	**0.35**

Table 2 The part of incoming time data

Data Number	Acceptance Step One	Acceptance Step Two	Acceptance Step three	Electrical	Mechanical	Parking
1	10.17	14.44	10.45	4.22	5.56	5.3
2	13.42	0.52	5.6	1.02	4.24	10.72
3	6.48	3.01	10.51	4.66	5.93	8.91
...						
89	5.39	0.04	8.7	2.23	8.99	10.3
90	6.32	16.67	9.2	0.51	3.15	11
91	9.51	8.84	5.2	2.55	5.74	12.1
Mean of Data	**9.49**	**8.86**	**7.33**	**3.42**	**5.84**	**8.6**

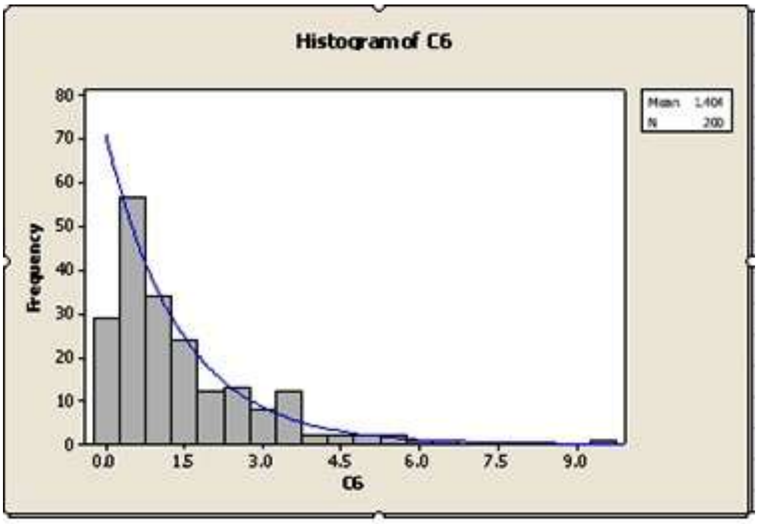

Fig. 2 the fitness function service time in mechanical part

2.2 Relaxing assumption

Some special cars like ambulances get the service as soon as possible without any waiting time in the queue but it does not happen frequently (one time per 22 days), so we ignore it and use the FIFO discipline.

3 Specifying the model of queuing system

3.1 Specifying the model of acceptance queue

Acceptance part has three steps, at first the car's number is recorded then the test and repairs are done, and in the final step the customer must pay the bill according to guaranty and warranty specifications; also some services are out of guaranty.

Service time in each step by the aim of SPSS software and use of fitness function is exponential by the means of 4.31, 9.27, 4.63 minutes.

In the mechanical and electrical parts, the service time and incoming rate are different, and also the queue capacity is limited so for those reasons we cannot use Erlang distribution, and also incoming rates are 9.81, 8.51, 7.83 minutes, so we analyze each step separately and the models of them are $M/M/1,\ \lambda = 7.83$ $M/M/2,\ \lambda = 8.51$ $M/M/2,\ \lambda = 9.81$ [3],[13].

3.2 Specify the queue model in other parts

3.2.1 Electrical parts

Two electrical stations exist, and two workmen in each station are available so by recording the incoming time in this part and by the aim of SPSS car incoming and service time distributions are exponential by the $\mu = 1.26,\ \ \lambda = 3.03$ [13].

$$\rho = \frac{\lambda}{S\mu} = \frac{3.03}{2\times 1.26} = 1.2 > 1 \qquad \mu, \lambda$$

So if there is not any empty space in the queue, stable situation is never achieved and the

length of queue increases non stopping by the rate of 0.51 per hour.
So to handle this situation, in this branch, managers do not allow any incoming car at the number of 20, forced balking, and the queue model is M/M/2/20.

3.2.2 Parking part

Parking part has 29 parking spaces so the model of this part is $M/M/29/29$, $by\ \lambda = 9.81\ and\ \mu = 0.34$

3.2.3 Mechanical part

This part is completely like the electrical part and this model is M/M/4/25 by $\lambda = 6.21,\ \mu = 1.41$

4 Computation and analysis of the branch's queue system

In this section we first compute the L_q after that by the aim of Little relations we compute other parameters [2], [3], [14].

L_q : *mean of the customers in the waiting line.*

$$M/M/S \Rightarrow Lq = \frac{\pi_0}{S!}\left(\frac{\lambda}{\mu}\right)^S \frac{\rho}{(1-\rho)^2}, \qquad \rho = \frac{\lambda}{S\mu} \tag{1}$$

Special form $M/M/2 \Rightarrow \pi_0 = \frac{1-\rho}{1+\rho} \qquad , Lq = \frac{2\rho^3}{1-\rho^2}$ (2)

And we compute $L_q, L, W\ and\ W_q$ by the Little relations[2], [3], [13].

L : *Average number of the customers in the system.*
W : *Mean of waiting time for each customer from arrival up to end.*
W_q : *Mean of waiting time for each customer from arrival up to start serving.*

$$L = L_q + \frac{\lambda}{\mu} \tag{3}$$

$$W_q = \frac{L_q}{\lambda} \tag{4}$$

$$W = Wq + \frac{1}{\lambda} \tag{5}$$

4.1 Computation and analysis the first step in acceptance part

By the aim of above equations we have

$\lambda = 9.81, \quad \mu = 13.921, \quad S = 2$

$L = 0.8046 \qquad L_q = 0.0999 \qquad W = 0.0820h \qquad W_q = 0.0102$

$$p = \frac{\lambda}{S\mu} = \frac{9.81}{2 \times 13.921} = 0.35234$$

4.2 Computation and analysis the second step in acceptance part

According to previous equations we have

$\lambda = 8.5165, \quad \mu = 6.472, \quad S = 2$

$L = 2.3204 \qquad L_q = 1.0045 \qquad w = 0.2725h \qquad w_q = 0.1179h$

$$\rho = \frac{\lambda}{S\mu} = \frac{8.5165}{2 \times 6.472} = 0.658$$

4.3 Computation and analysis the parking part

According to the section 2, the parking queue model is M/M/S/S, a special form of M/M/S/K that K=S, and there is no queue in this form so $L_q = 0$ [2], [14].

$\lambda = 9/81, \quad \mu = 0/34, \quad S = 29$

$$\rho = \frac{\bar{\lambda}}{S\mu} = \frac{8.5165}{29 \times 0.34} = 8.8637 \qquad \pi_S = 0.1318$$

$L = 25.0486 \qquad L_2 = 0 \qquad \bar{\lambda} = 8.5165 \qquad \rho = 0.863 \qquad w = 2.9412h \qquad w_q = 0 \qquad \pi_S = 0.1318$

4.4 Computation and analysis the electrical part

Queue model of this part is M/M/S/K and we compute L, L_q according to the Little relations [2], [14].

$$L_q = \frac{\pi_0}{S!}\left(\frac{\lambda}{\mu}\right)^S \frac{r}{(1-r)^2}\left[1 - r^{k+S+1} - (1-r)(k-S+1)r^{k-S}\right] \qquad (6)$$

$$L = L_q + S - \pi_0 \sum_{n=0}^{S-1}\left(\frac{\lambda}{\mu}\right)^n \frac{S-n}{x!} \qquad (7)$$

$\lambda = 3.03, \quad \mu = 1.26, \quad S = 2, \quad k = 2$

$L = 15.5395 \qquad L_q = 13.5490 \qquad \bar{\lambda} = 2.508 \qquad \rho = 0.995 \qquad w = 6.1959h \qquad w_q = 5.4023h$

4.5 Computation and analysis the mechanical part

$\lambda = 6.21, \quad \mu = 1.41, \quad S = 4, \quad k = 25$

$L = 17.7133 \quad L_q = 13.7550 \quad \bar{\lambda} = 5.5784 \quad \rho = 0.989 \quad w = 3.1753h \quad w_q = 5.4023h$

5 Analysis different plans and parameters reduction method:

5.1 Computing the total waiting time:

Total waiting time of each customer is sum of waiting time in three steps [3], [13].

$W_{total} = W_{step1} + W_{step2} + W_{step3} = 0.082h + 0.27251h + 0.19h = 0.5495h = 32.97\,\text{min}$

21.27 minutes of W_{total} is for acceptance ,11.7 minutes is for test and 11.7 is for paying the bill that is desired from the manager point of view and there is no need to increase the station numbers.

5.2 Sensitivity analysis of parking part

Arrival rate is $\lambda = 9.81$, but there is no enough space for all the customers, so it reduce to $\bar{\lambda} = 8/5165$ and the branch loses 0.1318 number of customers, in this part only S can increase that we show the impact of it in table 3.

Table 3 Increment impact analysis

S	λ - $\bar{\lambda}$	$\bar{\lambda}$	S	λ - $\bar{\lambda}$	$\bar{\lambda}$	S	λ - $\bar{\lambda}$	$\bar{\lambda}$
30	1.104	8.7060	**35**	0.4020	9.4080	**40**	0.0923	9.7177
31	0.9301	8.8799	**36**	0.3120	9.4980	**41**	0.0645	9.7455
32	0.7726	9.03374	**37**	0.2374	9.5726	**42**	0.0441	9.7659
33	0.632	9.1780	**38**	0.1770	9.6330	**43**	0.0295	9.7805
34	9.3015	0.5085	**39**	0.1292	9.6808	**44**	0.0193	9.7907

Economic analysis shows that optimal amount of increment is equal to 15, this extension is computed according to constraint and creates a two floor parking space, and by this increment, according to table 1, only 0.0193 numbers of customers will be lost.

5.3 Sensitivity analysis in electrical part

With respect to 14.96% increasing in parking $\bar{\lambda}$, incoming rate in electrical part increases up to 3.4833 , so we must define the optimal amount of it according to $\lambda = 3/4833$, and we have the following result:

$\bar{\lambda} = 2/5187 \quad L = 17/4112 \quad Lq = 15/4122 \quad W = 6/9127h \quad Wq = 6/1191h$

With respect to our calculation waiting time in the queue in this part is 6.1191 hours, and mean of waiting time for each customer is 6.9127 hours, which is a long time.

For improvement in waiting time we increase the station up to two stations in this part

5.4 Sensitivity analysis in mechanical part

With respect to increment in parking spaces, incoming rate λ in this part increase to 7.139 and other parameters are as follows:

$\bar{\lambda} = 5.6349 \quad L = 21/3194 \quad Lq = 17.3230 \quad W = 3.7835h \quad Wq = 3.0742h$

We proposed the follow solution to improve this situation:

5.4.1 Transforming the M/M/4/25 to M/M/8/27

For improve the service level of mechanical part, we can create two extra stations and use eight stations instead of six and one workman in each station so we have

$\mu = 0.78 \quad \bar{\lambda} = 6.1980 \quad L = 21.1318 \quad Lq = 13.1857 \quad W = 3/4095h \quad Wq = 2.1274h$

6 Conclusions

By the aim of queuing theory we can define the optimal amount of parameters like number of service stations, rate of service according to financial or space constraint in order to achieve customer satisfaction in a competitive market.

In this paper; we analyze the queue system in one of the branches of Iran Khodro, automobile producer and assembler in Iran, and with respect to objective function and cost and benefit analysis we had found the optimal increment. There are 15 empty spaces in parking, two stations in each electrical part and mechanical part. In the current situation system, the branch loses 18.20% numbers of customers, but in our proposed model it reduce to less than 0.002%, that leads to more than 20%benefit , also W reduces from 8.549 to 5.3124.

References

1. Newell, G. F., (1982). Applications of queueing theory.
2. Bregni, S., Brandt, H., Hapke, C., Lau, V. K., Kwok, Y. K. R., Verma, D. C., et al., (1998). Queueing networks and Markov Chains: Modeling and performance evaluation with computer science applications, p. 896.
3. Gross, D., Shortle, J. F., Thompson, J. M., Harris, C. M., (2013). Fundamentals of queueing theory: Wiley. com, p. 528.
4. Horovitz, J., (2000). The seven secrets of service strategy: Prentice Hall, p. 140.
5. Qiu, T., Xia, F., Feng, L., Wu, G., Jin, B., (2011). Queueing theory-based path delay analysis of wireless sensor networks, Advances in Electrical and Computer Engineering, 11, 3-8.
6. Kolesar, P., (1984). Stalking the endangered CAT: A queueing analysis of congestion at automatic teller machines, Interfaces, 14, 16-26.
7. Kostecki, M., (1996) Waiting lines as a marketing issue, European Management Journal, 14, 295-303.
8. Jiang, Y. S., Hu, L., Lu, G., (2010). Determined method of subway footway width based on queuing theory, Journal of Traffic and Transportation Engineering, 3, p. 015.

9. Xiufan, C. F. D. L. M., Zheng, K. J. C. Y. Q., (2002). Application of queue method in power distribution marketing scheme [J], in Proceedings of The Csu-epsa, p. 014.
10. Harrison, P. G., Zertal, S., (2005). Calibration of a queueing model of raid systems, Electronic Notes in Theoretical Computer Science, 128, 145-164.
11. Freund, J. E., Miller, I., Miller, M., (2011). John E. Freund's Mathematical Statistics with Applications, 7/e: Pearson Education India, p. 624.
12. Cronk, B. C., (2008). How to use SPSS: A step-by-step guide to analysis and interpretation: Pyrczak Pub, p. 130.
13. Nelson, R., (1995). Probability, stochastic processes, and queueing theory: the mathematics of computer performance modeling: Springer, p. 583.
14. Trivedi, K. S., (2008). Probability & statistics with reliability, queuing and computer science applications: John Wiley & Sons, p. 848.