Emirati Journal of Business, Economics and Social Studies
Vol 1 Issue 1 (2022) 36 - 41
DOI: 10.54878
Emirates Scholar

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Service Quality Control using Queuing Theory

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Abstract

Customers are compelled to queue when a service system is at its busiest. This issue not only reduces customer pleasure, but it also causes the company to lose money. For consumer losses, this study proposes a queue model of customer queuing behavior. The goal is to reduce customer losses, hence researchers are looking at queue setup and optimization in random service systems. We developed three queuing models: MG1, GM1, and GG1 for estimating service quality control. We investigate queuing systems for predicting replies for service quality control based on queue models of customer behavior. The study found that the MG1 queue model yields the best service quality, however the GM1 and GG1 results are relatively close behind.

Keywords:
Service quality control, MG1 queue model, GM1 queue model, GG1 queue model.

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1. Introduction

Delays abound in the service business. Delays occur when there is a mismatch between the demand for a service and the capacity available to supply it. Typically, this mismatch is caused by natural variations in demand timing and the amount of time required to offer service. The dynamics of service systems are extremely complicated because to this unpredictability and the interplay between the arrival and service operations. According to a new Statista analysis on customer interactions with service providers, 62 percent of customers in the US discontinued doing business with companies that had poor service quality in 2018. (Statista, 2022). (Williams, 2021) collected answers from 12700 company executives, agents, and customers to determine how the poor service quality is effecting the businesses in New Zealand for a research on detecting the effect of poor service quality. According to the findings of the survey, 77% of clients would transfer their business elsewhere if they experienced poor service quality. According to a report published in commbox, the United States lost $1.6 trillion in 2020 owing to poor service quality. This number is frightening not just because of its enormous scope, but also because it might have been avoided totally (CommBox, 2020).

As a result, companies have begun to employ queuing models in order to enhance service quality. It is also noted that without the use of a queueing model, estimating degrees of congestion or determining how much time is required to perform the service is impossible. One of the early study on improving the service quality was conducted in 1987 by Larson (Larson, 1987) and the study stated the importance of queue models for quality control. The purpose of this study is thus to implement queuing theory for studying the service quality control. Three different queue models, MG1, GM1, and GG1 are used to determine the performance. The performance is calculated using three alternative queue models: MG1, GM1, and GG1. The arrival process in the MG1 queue is markovian, and the service response is general. General arrival and markovian service response is in the GM1 queue, whereas general arrival and service response are in the GG1 queue. A single server circumstance is defined by the 1 in all queue models.

The mathematical formulation of the equations for the three queue models using the Gauss elimination method is done in the research. Extrapolation of the results is carried out for the three queue models, and the result is determined. The outcomes of the results will help the service providers to improve the service quality by selecting the best queue model.

The following are the sections of the research: The literature evaluation and identification of the research gap and aim were completed in Section 2. The third section of the study examines queue models mathematically in order to improve service quality control. The results of the three queuing models are discussed in Section 4 of the study. The conclusion is discussed in Section 5.

2. Literature Review

Several attempts have been made to apply queuing theory to estimate service quality control using various queue models. (Hsu & Tapiero, 1989) used the MG1 queue model was used to perform a

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study of a manufacturing facility, and it was discovered that quality and quantity difficulties in the design of production systems are interconnected. (Xu et al., 2007) studied about the service quality for ticketing company and stated that implementation of queue management have improved the overall performance of the system. (Bae & Kim, 2010) did a comparative study between MG1 and GM1 queue models to identify the service quality for impatient customers. (Satanaryana et al., 2015) used the UCL (Upper Control Limit) and LCL (Lower Control Limit) parameters were used to estimate the performance of the MM1 queue model, which was used to determine the range of services available at the airport. According to the authors, using queue models to optimize the servers can increase the system's quality and efficiency. (Kuzu, 2015) performed a comparison of conventional and queue approaches for implementing queue management in ticketing systems. According to the authors, implementing queue management improves service quality significantly. (Yadav & Sohani, 2019) utilized the MM1 queue model to estimate the performance of the food chain's services, and described how as the number of servers grows, so does the system's service quality. The authors compared the performance of the MM1, MM2, and MM3 queue systems and concluded that the MM3 system outperforms the other two. (Afolalu et al., 2019) did the comparative study of MM1 and MG1 queue model for a bank in Nigeria. According to the authors, the usage of queue models has been proven to be quite successful, with a minor drawback, in terms of improving the productivity performance of the systems. (Avilés-González & Avilés-Sacoto, 2021) studied the behavior of service quality in cafeteria in Mexico. The authors studied the system's performance in three phases: current process analysis, arrival analysis, and improvement analysis, using the lean system with the MM1 queue model. According to the authors, using the queuing model in the right way can improve service quality.

Using queue models to improve service quality control is crucial, according to the research. However, the majority of the research focused on MM1, MG1, and GM1 queue models. None of the studies conducted a comparison analysis before recommending the best queuing model for increasing service quality control. As a result, the goal of this research is to conduct a comparison analysis of three queue models and determine the results.

Table 1 gives the detail listing of the research gap, question and objective that is carried out in the study.

Research Gap	Research Objective
RG1: There appears to be a dearth of research comparing the MG1, GM1, and GG1 queue models for service quality control.	RO1: Determine which of the MG1, GM1, and GG1 queuing models is best for increasing service quality control.

Table 1: Research Gap and objective for the study

3. Service Quality Control using Queue Models

Quality control is an imperative ingredient of design of an efficient service system. For λ service requests arriving at the system and μ responses generated.

3.1 Derivation of Quality Control other models for improving service quality

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It was observed during study that other three queue models follow second order polynomial equation to identify the service quality as mentioned in eq. (1) below

$$Q_C = y_i = a_0 x_i^2 + a_1 x_i + a_2 \quad (1)$$

where a_0, a_1 and a_2 are coefficients of polynomials. Eq. (7) gives the service quality parameter for larger values of requests arriving in the system.

3.1.1 Values of a_0, a_1 and a_2

To calculate the coefficient values, "S" represents the error in computation and can be mathematically represented as

$$S = \sum(y_i - \hat{y}_i^2) = \sum(y_i - a_o x_i^2 - a_1 x_i - a_2)^2 \quad (2)$$

If be differentiate S w.r.t a_0, a_1, a_2 and setting each of these coefficients equal to zero, we get

$$\left.\begin{aligned} na_0 + a_1\sum x_i + a_2\sum x_i^2 &= \sum y_i \\ a_0\sum x_i + a_1\sum x_i^2 + a_2\sum x_i^3 &= \sum x_i y_i \\ a_0\sum x_i^2 + a_1\sum x_i^3 + a_2\sum x_i^4 &= \sum x_i^2 y_i \end{aligned}\right\} \quad (3)$$

where "n" is the degree of polynomials, which can be solved using Gauss Elimination method. Table 2 gives the computation values of a_0, a_1 and a_2 respectively.

MG1 Model	GM1 Model	GG1 Model
$\boldsymbol{a_0 = 1484.0}$	$a_0 = 1484.5$	$a_0 = 1483.5$
$\boldsymbol{a_1 = 0.873200}$	$a_1 = 0.873201$	$a_1 = 0.873377$
$\boldsymbol{a_2 = 0.000005}$	$a_2 = 0.0000051$	$a_2 = 0.000006$

Table 2: Computation of a_0, a_1 and a_2

Thus, the service quality control parameters for the three queue models for MG1, GM1 and GG1 for providing the services with great efficiency are mentioned in equations 4, 5 and 6 respectively.

$$y(MG1) = 1484.0 + 0.873200 * \lambda + 0.000005 * \lambda^2 \ (4)$$
$$y(GM1) = 1484.5 + 0.873201 * \lambda + 0.0000051 * \lambda^2 \ (5)$$
$$y(GG1) = 1483.0 + 0.873377 * \lambda + 0.000006 * \lambda^2 \ (6)$$

Table 3 mentions the comparative study of the service quality control for all the four queues adopted for the analysis. The outcomes determine the processing time of responses in seconds.

	Responses in Seconds		
Requests	MG1	GM1	GG1
1000	2362.2	2362.8	2362.4
1500	2805.1	2805.8	2806.6
2000	3250.4	3251.3	3253.8
2500	3698.3	3699.4	3703.9
3000	4148.6	4150.0	4157.1
3500	4601.5	4603.2	4613.3
4000	5056.8	5058.9	5072.5
4500	5514.7	5517.2	5534.7
5000	5975.0	5978.0	5999.9
5500	6437.9	6441.4	6468.1
6000	6903.2	6907.3	6939.3
6500	7371.1	7375.8	7413.5
7000	7841.4	7846.8	7890.6
7500	8314.3	8320.4	8370.8
8000	8789.6	8796.5	8854.0
8500	9267.5	9275.2	9340.2
9000	9747.8	9756.4	9829.4
9500	10230.7	10240.2	10321.6
10000	10716.0	10726.5	10816.8

Table 3: Analysis of Service Quality Control for the four queue models

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4. Outcomes

The results of the research, as shown in Table 3, clearly show that for a given number of requests for service, the best system should use the MG1 queue architecture. However, additional investigation revealed that the GM1 queue model substantially resembles the MG1 queue model in terms of enhancing service quality. However, the following conditions were followed to observe the outcomes:

1. Arrival should be less than a threshold value (predecided < μ).
2. It was discovered that the GG1 queue model provides great service quality control for a small number of requests, but as the number of requests grows, the MG1 queue model provides the highest service quality.
3. For larger numbers of requests, the service quality control for the MG1 and GM1 queue models is nearly identical.

5. Conclusion

The response result performance was investigated utilizing queuing theory for service quality control in this study. The research found that using queuing theory, we can analyse quality control in the service business. This research uses three queuing systems: GM1, MG1, and GG1 with a single independent server. The necessity to illustrate a methodical approach for creating effective queueing systems led to the selection of such a model. More realistic assumptions about processing speeds and arrival rates are necessary for practical applications. The results of the three queuing models were compared to determine which model produced the best results. In terms of future research, one may look at the effects of cost, quality, and time in a queuing system to see how quality control affects total response.

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