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Service Quality Control using Queuing Theory

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ABSTRACT
When a service system is extremely busy, customers are forced to wait in line. In addition to decreasing consumer satisfaction, this issue results in financial losses for the organization. This research suggests a queue model of consumers' queuing behavior in order to account for consumer losses. Researchers are examining the best practices for queue formation and optimization in random service systems with the aim of reducing customer losses. The MG1, GM1, and GG1 queuing models were created to estimate the quality control of the service. We look into queueing systems that use customer behavior models to predict responses for service quality control. Although GM1 and GG1 findings are quite close to MG1 results, the investigation concluded that MG1 produces the highest quality service.

1. Introduction

Life in the service industry is full with setbacks. There will be delays if the supply of a service is inadequate in comparison to its demand[1-5]. This discrepancy usually arises as a result of inherent differences between the timing of demand and the time needed to provide service[6-10]. Due to the unpredictable nature of both arrivals and service activities, the dynamics of service systems are notoriously complex. New data from Statista on consumer-provider interactions shows that 62% of American consumers cut ties with businesses in 2018 due to subpar service. Statistics Canada (2022). Research on identifying the effect of bad service quality was conducted by Williams (2021) with the goal of determining how low service quality is affecting businesses in New Zealand. The study surveyed 12,700 firm executives, agents, and customers. When asked what they would do in the event of subpar service, 77% of respondents said they would go elsewhere[[10-15]. The US wasted $1.6 trillion in 2020 because of subpar service, says an article in commbox. Both the sheer magnitude of the problem and the fact that it might have been entirely prevented make this figure very unsettling. According to CommBox in 2020.

Therefore, queuing models have become popular among businesses as a means to improve service quality. It should be mentioned that in order to estimate congestion levels or service completion times, a queueing model is necessary. In a seminal work from 1987, Larson (Larson, 1987) highlighted the use of queue models for quality control in an effort to enhance service quality. So, applying queuing theory to the study of service quality control is the goal of this research. The performance is determined using three distinct queue models: MG1, GM1, and GG1. Three different queuing models—MG1, GM1, and GG1—are used to determine the performance. The MG1 queue uses a markovian arrival procedure and a general service response. Markovian service response and general arrival are in the GM1 queue, while service response and general arrival are on the GG1 queue. The 1 in every queue model defines a single server scenario.

The study uses the Gauss elimination method to formulate the equations for the three queue models mathematically. We determine the result by extrapolating the findings for the three queue models. Service providers will be able to use the results to choose the optimum queuing model, which will improve service quality.

The research is organized into the following sections: Section 2 comprehensively reviewed the literature, identified the study gap, and set the research aim. The study's mathematical examination of queuing models for better service quality control is the subject of the third section. Section 4 delves into the study's discussion of the three queuing models' outcomes. In Section 5, we talk about the final verdict.

2. Literature Review

Using different queue models, there have been multiple attempts to estimate service quality control by applying queuing theory. Using the MG1 queue model, researchers Hsu and Tapiero (1989) examined a factory and found that problems with quantity and quality in production system design are related. According to research on ticketing firm service quality (Xu et al., 2007), queue management has increased system performance. A study comparing the MG1 and GM1 queuing models was conducted by Bae and Kim (2010) to determine the quality of service for clients who are impatient. In order to identify the variety of services offered by the airport, the MM1 queuing model was estimated using the UCL (Upper Control Limit) and LCL (Lower Control Limit) parameters (Satanaryana et al., 2015). The authors state that the system's efficiency and quality can be enhanced by optimizing the servers with queue models. In order to integrate queue management in ticketing systems, (Kuzu, 2015) compared traditional methods with queue approaches. The authors state that service quality is greatly enhanced after queue management is implemented. Using the MM1 queue model, Yadav and Sohani (2019) estimated the food chain's service performance and detailed how the system's service quality improves with an increase in the number of servers. In their analysis, the scientists found that the MM3 queue system performed better than the MM1 and MM2 systems. A Nigerian bank had the MM1 and MG1 queuing models compared (Afolalu et al., 2019). When it comes to enhancing the systems' productivity performance, the authors claim that using queue models has been largely successful, with one little downside. The behavior of service quality in Mexican cafeterias was investigated (Avilés-González & Avilés-Sacoto, 2021). In order to study the system's performance, the authors used the lean system with the MM1 queue model and went through three phases: arrival analysis, improvement analysis, and current process analysis. When applied correctly, the queuing model can enhance service quality, say the authors.

The research emphasizes the importance of using queuing models to enhance service quality control. Nevertheless, queuing models MM1, MG1, and GM1 were the primary subjects of the investigation. Before suggesting a queuing model to improve service quality control, no study compared any of the available options. The purpose of this study is, thus, to compare and contrast three queuing models and draw conclusions.

All of the study's research questions, objectives, and gaps in knowledge are laid forth in Table 1.

Table 1. Research Gap and objective for 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.

3. Service Quality Control using Queue Models

When planning a reliable service system, quality control must be a top priority. The system receives service requests and generates replies for each of them.

3.1 Derivation of Quality Control other models for improving service quality

According to the research, the other three queuing models use a second-order polynomial equation (eq. (1) below) to determine the quality of the service.

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

where a0, a1 and a2 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.

Table 2. Computation of a_0, a_1 and a_2

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

Therefore, equations 4, 5, and 6 indicate the service quality control parameters for the three queuing models for MG1, GM1, and GG1, respectively, in order to provide the services with great efficiency.

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

Table 3 shows the results of a comparison study of the four queues used for service quality control. The results dictate, in seconds, how long it takes to process the replies.

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

	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

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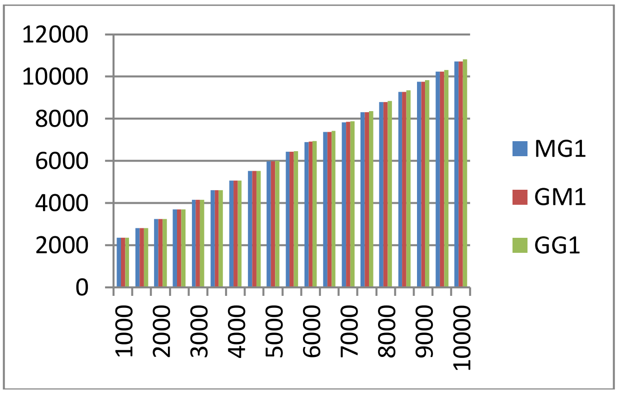

Fig 1. Analysis of Service Quality Control for the four queue models

4. Outcomes

The research findings, as displayed in Table 3, make it quite evident that the MG1 queue architecture is the optimal choice for a given amount of service requests. If we look at how the GM1 queue model improves service quality, we see that it is very similar to the MG1 queue model. Nevertheless, in order to see the results, the following conditions had to be met

(1) It is expected that the arrival will be below a predetermined threshold value (< μ).
(2) With a low volume of requests, the GG1 queue model offers excellent service quality control; but, with an increase in the volume of requests, the MG1 queue model outperforms the others.
(3) When dealing with higher request volumes, the MG1 and GM1 queue models' service quality management mechanisms are very similar.

5. Conclusions

This study used queuing theory to examine the performance of response results in terms of service quality control. According to the study's findings, queuing theory can be used to examine service quality control. Three distinct queuing systems—GM1, MG1, and GG1—and a single server are utilized in this study. The selection of this model was driven by the need to demonstrate a systematic approach to developing efficient queueing systems. For real-world applications, we need more accurate assumptions regarding processing speeds and arrival rates. We compared the three queuing models' outputs to find the one that worked best. Looking at the implications of time, cost, and quality in a queuing system might help researchers understand the role of quality control in total response.

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