QUEUING FOR SUCCESS : A QUICK LOOK AT SERVICE OPTIMIZATION

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ABSTRACT

This comprehensive review explores the application of queuing theory in optimizing service systems across diverse sectors. The studies analyzed delve into the intricacies of minimizing customer wait times and maximizing server utilization. Spanning from Fair Price Shops, banks, and post offices to supermarkets, healthcare centers, and petrol stations, the research employs various queuing models such as M/M/C, GI/M/c, and GI/M/1/N. Methodologies encompass case studies, simulation modeling, and mathematical analysis, providing insights into factors influencing service efficiency and customer satisfaction. Findings underscore the versatility and effectiveness of queuing theory, suggesting avenues for future research, including advanced queuing models, real-time analytics, and the integration of emerging technologies. Practical implementation in real-world service environments remains crucial for continuous improvement.

Keywords: Queuing theory, service systems, queuing models, optimization, customer satisfaction, waiting times, server utilization, simulation modeling, communication networks, healthcare services, banking, customer service, queuing systems, queue management.

INTRODUCTION

Queuing theory, a fundamental paradigm in operations research, plays a crucial role in understanding and enhancing the performance of service systems across various sectors. This article presents a comprehensive review of studies applying queueing theory to optimize service systems, with a focus on minimizing customer wait times and maximizing server utilization. The diverse applications range from Fair Price Shops (FPS) and banks to supermarkets, healthcare centers, and petrol stations. Each study explores specific aspects, such as arrival rates, waiting times, and server configurations, contributing valuable insights to the field of service system management.

OBJECTIVE

To provide a comprehensive overview of the existing literature on queuing theory, focusing on its diverse applications in service systems, and to instill key insights contributing to optima

RESEARCH METHODOLOGY

The reviewed studies employ diverse research methodologies, including case studies, simulation modeling, mathematical modeling, and data analysis. Researchers utilize queuing models such as M/M/C, GI/M/c, and GI/M/1/N to analyze and optimize service systems. Simulation modeling is prevalent, particularly in studies assessing the optimal number of servers in specific contexts. The research also delves into factors influencing service efficiency, customer satisfaction, and the impact of various strategies on queue management zing service efficiency and customer satisfaction across different sectors

REVIEW OF LITERATURE

In a recent study conducted by Sasi, Subramanian, &Ravichandran , the research explores the application of queueing theory in Fair Price Shops (FPS), government buildings, banks, post offices, and other service sectors. The objective of this study is to achieve an optimal equilibrium between minimising wait times and maximising server utilisation by taking into account several aspects such as server utilisation, arrival rate, and service rate. The primary emphasis of this research is the implementation of the M/M/C queuing model in order to optimise queues at FPS (first-person shooter) venues. Simulation modelling is employed to ascertain the most favourable quantity of servers required to get a desired frame rate (FPS) in the region of Kerala, India. This study investigates the effects of many factors, including arrival rate, waiting time, and server utilisation.

The study conducted by Anand and Arora 1 aimed to assess the efficacy of customer service and waiting periods in Indian banks using a case study. The objective of their study was to ascertain the variables that influence the efficiency of customer service and to provide an estimation of the duration customers had to wait. The research conducted in this study was to

identify and analyse potential bottlenecks in service delivery inside Indian banks, with the ultimate goal of providing recommendations to improve customer service.

The study conducted by Bhardwaj et al. 2 examined a voice packetized statistical multiplexing system through the application of a fuzzy queuing model. The research conducted by the authors focused on the optimisation of communication networks, with particular emphasis on cases where voice traffic is predominant.

In their study, Kiataramkul and Neamprem 3 conducted an investigation of the effectiveness of a queuing model that incorporates many servers. The specific context of their analysis was centred around bank token systems and the impact on client waiting times. The research investigated several configurations of queueing theory in order to compute variables relevant to service.

In their study, Onoja et al. 4 proposed a mathematical model based on many servers and an exponentially distributed framework. This model aimed to analyse and predict various factors such as client waiting times, service rates, and arrival rates inside a banking environment. The objective of their study was to enhance the allocation of resources and minimise the duration customers spend waiting.

A study was undertaken by Jhala, Bhathawala, and Gujarat 5 with the objective of examining the utilisation of queueing theory within the context of supermarkets. The objective of their analysis was to maximise the efficiency of queue management for clients waiting outside the establishment. The study conducted a comparison between single queue and multiple queue multiserver systems, revealing the benefits of employing a single queue, multi-server method in terms of minimising client wait times and related expenses.

Thangaraj and Rajendran 6 conducted a study that investigated a queueing system characterised by batch arrivals and two distinct service patterns. The model takes into account scenarios in which the server would offer bulk service if the queue length surpasses a specific threshold 'a' following a period of inactivity, while otherwise providing single service. The investigation computed the distributions of queue sizes and assessed multiple performance indicators while considering specific situations within the model.

The objective of the study conducted by Agyei, Asare-Darko, and Odilon 7 was to provide guidance to bank management in optimising the staffing of tellers by identifying the optimal balance between minimising total economic costs (comprising waiting cost and service cost)

and reducing customer waiting times. The researchers employed data collected from the Kumasi Main Branch of Ghana Commercial Bank Ltd in order to construct a queuing model with many servers operating in a single line. The findings of the analysis indicate that a five-teller system demonstrated superior performance compared to both four and six-teller systems in terms of average waiting times and overall economic expenses. These results suggest that implementing a five-teller system could be a cost-effective measure to improve customer satisfaction.

In their study, Harley et al. 8 examined the effects of several customer service components implemented by Nigerian banks on the financial performance of these institutions. A significant relationship was discovered between the mean duration of client waiting in queues and the financial viability of banks in Nigeria, so suggesting that proficient queue management and service provision play a crucial role in determining a bank's level of achievement.

Chandra and Madhu 9 conducted a study that investigated a Markovian queuing system characterised by the presence of multiple service counters and finite waiting times. In this particular concept, a pair of servers were employed at separate counters in order to deliver a comprehensive level of service to an individual customer. The primary objective of the analysis was to ascertain the distribution of queue sizes in a condition of equilibrium, while also examining the consequences of modifying specific factors. The research emphasised the possibility of achieving more accurate results by integrating state-dependent rates into the multi-counter system model. Moreover, it is underscored that the modelling of queueing systems with blocking is of utmost importance. However, it also highlights the necessity to shift focus towards the factors of bulk arrivals and service.

In a study conducted by Kamau 10, the focus was on examining the relationship between waiting queue management and customer satisfaction in commercial banks in Kenya. The objective of Kamau's study was to examine the efficacy of Kenyan banks in addressing customer grievances pertaining to extended waiting periods. This study investigated the strategies employed by commercial banks in the management of waiting lines, the obstacles they face in implementing these strategies, and the consequent effects on customer satisfaction. This research enhances the comprehension of queueing management in service systems, particularly in the setting of commercial banks in Kenya.

The study conducted by Ohaneme et al. 10 focuses on the evaluation of queuing systems at petrol stations. The present study employed petrol stations as a case study to assess the importance of queuing systems in service operations. The researchers noted that petrol stations exhibit a tendency to service consumers in a random manner, resulting in the formation of lengthy queues and prolonged waiting durations. The implementation of the M/M/6 queuing system has been demonstrated to yield substantial improvements in the efficiency of client services when rigorously applied. This study offers valuable insights into the optimisation of queueing systems within service sectors.

In their study titled "Single Working Vacation in GI/M/1/N and GI/M/1/∞," Banik, Gupta, and Pathak 12 investigate the use of single working vacation policies in the context of GI/M/1/N and GI/M/1/∞ systems. The topic of interest is queueing systems. They. conducted a study aimed at assessing the effects of a solitary working vacation on queueing systems. The authors employed embedded Markov chain and additional variable techniques to estimate queue length distributions and other essential performance metrics. This study aims to enhance comprehension of the impact of server vacations on the performance of queueing systems.

The study conducted by Rao et al. 13 focuses on the use of queuing theory in the context of communication networks. The present study has made substantial progress in the utilisation of queuing theory within the realm of communication networks. The research examined the arrival and broadcasting procedures occurring at various network nodes, constructing a comprehensive model for an interdependent communication network. The results of this study have significant significance for the enhancement of network architecture and administration, specifically in relation to optimising data flow inside communication networks.

The field of queueing theory is of paramount importance in comprehending and enhancing the performance of service systems. The research undertaken by Jacob and Szyszkowski 14 centred on the analysis of call centre data. The researchers noted that the duration of desertion in call centres adheres to a universally applicable and autonomous probability distribution. Based on their empirical findings, the researchers determined that the Poisson distribution exhibited the highest level of suitability as a model for call centres, specifically in relation to service times.

In their study, Adeleke 15 focused on university health centres and utilised a single-server queuing model to estimate waiting times. The researchers' model, which made the assumption of Poisson arrival with exponential service rates and implemented the First-In-First-Out (FIFO) queue discipline, facilitated the estimation of patient arrivals and waiting durations in emergency departments. These models possess significant value in augmenting the efficiency of healthcare systems.

In their study, Cochran and Roche 16 conducted an investigation of a range of modelling strategies aimed at mitigating the issues of hospital bed shortages and congestion. The scope of their study included the utilisation of empirical equations, including linear and nonlinear equations, as well as the application of time series forecasting and queuing theory-based models. It is worth noting that models based on queuing theory demonstrated superior performance compared to techniques based on formulas. These queuing theory-based models provided more effective strategies for optimising the distribution of beds and enhancing the quality of healthcare services.

Queueing theory is a fundamental paradigm that provides insights into the dynamics of waiting lines and service systems. The efficiency of queuing in traditional and modern banks in Nigeria was assessed by a comparative analysis undertaken by Kasum et al. in 2006. The collection of primary data was conducted by utilising an inverted-funnel questionnaire that was administered by the bank clients themselves. The results of the study revealed that consumers of contemporary banks encountered notably reduced waiting durations in comparison to customers of conventional banks, thereby emphasising the significance of effective service provision within the banking industry.

In their study, Pei-Chun et al. 17 utilised queueing theory as a framework to assess the efficacy of different Taiwanese banking institutions, including postal banking services. The research conducted by the authors centred on the examination of several operations of automated teller machines (ATMs), including cash withdrawal, fund transfer, password reset, and balance inquiry. The effectiveness of ATM services was evaluated through the utilisation of a queueing model, which revealed the necessity of augmenting the number of ATMs in certain financial institutions in order to mitigate consumer wait times.

The researchers Green et al. 17 employed the M/M/s queuing model in their study to investigate the interplay between service delays, patient utilisation, and the optimal number of servers necessary for the functioning of healthcare systems. The aforementioned findings

make a valuable contribution to the existing body of knowledge about the optimisation of healthcare services.

The study conducted by Tian and Zhang 20 examined a queueing system that incorporated several servers and a vacation policy with a (d, N)-threshold. This policy permitted a designated quantity of inactive servers to concurrently engage in vacation periods. The primary aim of their study was to determine the ideal values for the variables d and N. The research conducted by Ke et al. (2009) expanded upon previous studies by investigating the optimal vacation approach (d, c) for an M/M/c/N queue with servers that are prone to failures and require repair processes. This study contributed to the advancement of knowledge in the field of server management inside queueing systems.

. Tian and Zhang conducted a study that examined a queueing system of the GI/M/c type, incorporating the concept of vacations, wherein all servers collectively cease operation when the system is devoid of customers. The authors proposed the notion of synchronous vacations, wherein servers resume operation if there are clients in a waiting state. The length of vacations is determined by a random variable that follows a distribution characterised by its phase. The research was centred on the computation of stable probability distributions pertaining to wait durations and queue lengths during arrivals. The work aimed to provide explicit formulas for both measurements.

In their 2002 work, Tian and Zhang examined a GI/Geo/1 queuing model in discrete time, specifically focusing on the presence of server downtime and vacations. The researchers employed a matrix-geometric technique to explicitly compute stationary distributions for both queue length and waiting time.

In their study, Nosek et al. 21 examined queuing-based methodologies in the field of healthcare administration. The authors placed particular emphasis on the evaluation of hospital practises and the enhancement of pharmaceutical services as means to augment consumer satisfaction.

In the study conducted by Katayama 22 the primary focus was on a tandem queue system that incorporated cyclic services. The investigation took into account the presence of servers on vacation as well as a whole service load. The objective of the study was to determine the mean durations of stays, accounting for breaks, as well as the mean waiting times, which are relevant for the examination of performance in packet switching systems.

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Table 1: Summary of Reviews

Study	Sector	Queuing Model	Objective	Methodology	Key Findings
Sasi et al. (2023)	Various (FPS, banks, post offices)	M/M/C	Optimal equilibrium between wait times and server utilization	Simulation modeling	FPS optimization using M/M/C model in Kerala, India
Anand and Arora (2019)	Indian banks	Article	Assess customer service and waiting periods	Case study	Identify and analyze bottlenecks for improving customer service
Bhardwaj et al. (2019)	Communication networks	Fuzzy queuing model	Optimize communication networks, focus on voice traffic	Article	Voice packetized statistical multiplexing system
Kiataramkul and Neamprem (2019)	Banks (token systems)	Article	Effectiveness of queuing model with multiple servers	Article	Analyze variables relevant to service in different configurations
Onoja et al. (2018)	Banking	Exponentially distributed model	Analyze waiting times, service rates, and arrival rates	Mathematical model	Enhance resource allocation and minimize customer waiting times
Jhala et al. (2017)	Supermarkets	Single vs. multiple queues	Maximize efficiency of queue management	Article	Single queue, multi-server method minimizes client wait times
Thangaraj and Rajendran (2017)	Queueing system with batch arrivals	Article	Investigate scenarios with bulk service	Article	Assess queue size distributions and performance indicators
Agyei et al. (2015)	Banks	Many servers in a single line	Optimize teller staffing for cost-effectiveness	Queuing model	Five-teller system demonstrated superior performance
Harley et al. (2014)	Nigerian banks	Article	Effects of customer service components on financial performance	Article	Relationship between client waiting durations and financial viability

Chandra and Madhu (2013)	Markovian queuing system	Multiple service counters	Analyze distribution of queue sizes	Article	Emphasize state-dependent rates in multi-counter system models
Kamau (2012)	Commercial banks in Kenya	Article	Relationship between waiting queue management and customer satisfaction	Article	Examine strategies, obstacles, and effects on customer satisfaction
Ohaneme et al. (2012)	Petrol stations	M/M/6 queuing system	Evaluate queuing systems at petrol stations	Article	M/M/6 queuing system improves client services
Banik et al. (2011)	Queuing systems (GI/M/1/N and GI/M/1/∞)	Single working vacation policies	Assess effects of server vacations on queuing systems	Markov chain	Evaluate queue length distributions and performance metrics
Rao et al. (2011)	Communication networks	Article	Queuing theory in communication networks	Article	Construct a comprehensive model for an interdependent communication network
Jacob and Szyszkowski (2009)	Call centers	Poisson distribution	Analysis of call center data	Empirical findings	Poisson distribution suitable model for call centers
Adeleke (2009)	University health centers	Single-server queuing model	Estimate waiting times in emergency departments	Article	Significant value in augmenting efficiency of healthcare systems
Cochran and Roche (2009)	Hospital bed shortages	Queuing theory-based models	Mitigate hospital bed shortages	Article	Queuing theory-based models more effective than formula-based techniques
Kasum et al. (2006)	Banks in Nigeria	Article	Comparative analysis of queuing efficiency	Inverted-funnel questionnaire	Consumers of contemporary banks experience reduced waiting durations
Pei-Chun et al. (2006)	Taiwanese banking institutions	Queuing model	Efficacy of different banking institutions	Article	Augmenting the number of ATMs can mitigate consumer wait times

Green et al. (2006)	Healthcare systems	M/M/s queuing model	Interplay between service delays, patient utilization, and servers	Article	Valuable contribution to optimizing healthcare services
Tian and Zhang (2006)	Queuing system with vacation policy	(d, N)-threshold policy	Determine ideal values for variables d and N	Article	Enhance knowledge in server management in queuing systems
Tian and Zhang (2003)	GI/M/c queuing system	Synchronous vacations	Computation of stable probability distributions	Article	Provide explicit formulas for wait durations and queue lengths
Tian and Zhang (2002)	GI/Geo/1 queuing model	Discrete time	Explicitly compute stationary distributions	Matrix-geometric technique	Examining server downtime and vacations
Nosek et al. (2001)	Healthcare administration	Article	Evaluate hospital practices and enhance pharmaceutical services	Article	Augment consumer satisfaction
Katayama (1995)	Tandem queue system	Cyclic services	Determine mean durations of stays, accounting for breaks	Article	Relevant for examining performance in packet switching systems

CONCLUSION

The findings from these studies underscore the versatility and effectiveness of queueing theory in optimizing service systems. From banking to healthcare and beyond, the application of queuing models provides actionable insights for improving customer satisfaction and operational efficiency. The studies reviewed reveal the importance of tailored queuing strategies, considering factors like server configurations, arrival rates, and waiting times in specific service contexts.

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