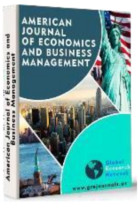

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Article

Queuing Analysis of Service Operations in Retail Business

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Abstract: This study examines service operations in retail business using queuing analysis, with a focus on a retail store in Mumbai, India. The research applies Little's Law and the G/G/1 queuing model to analyze customer flow, waiting times, and queue dynamics. Data collected on March 30, 2023, includes 561 observations of arrival times, service start times, finish times, and queue lengths. The results highlight patterns in customer arrivals, queue sizes, and cycle times. The study finds that peak congestion occurs at specific intervals, particularly early in the morning and late in the evening, leading to prolonged wait times and inefficiencies in service operations. The findings suggest that the store's current service capacity is insufficient to handle peak demand, resulting in an average customer wait time of 3.31 hours. To address these challenges, strategic interventions such as increasing checkout counters and opening additional stores in high-traffic areas are recommended. These insights provide valuable guidance for improving efficiency and customer satisfaction in retail service operations.

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Introduction. Retail trade is the closest economic sector to final consumers and serves as the main tool for regulating the volume and assortment of products, which are key components of the production process. It also allows for monitoring consumer preferences and the dynamics of product quality.

In the research of Veloso and Montelar, methods for evaluating customer perceptions of service quality, brand image, customer satisfaction, and loyalty in traditional retail stores in Portugal are proposed[1].

Kermanshachi, Nipa, and Nadiri assessed the efficiency of retail stores by using the Kano model based on a survey focused on store characteristics that influence customer satisfaction[2].

Briggs, Deretti, and Kato proposed methods for evaluating service levels in order to establish customer-oriented management principles in retail enterprises[3].

Chien and Chi examined the key factors shaping service quality and corporate image using PLS-SEM (Partial Least Squares Structural Equation Modeling) analysis[4]. Their research found that customers prioritize service quality and the image of the service provider when choosing a retail organization.

C. Nguyen, T. Doan, and D. Nguyen investigated factors determining customer satisfaction in Vietnamese supermarkets[5]. The SERVQUAL model was used in their study, and the results confirmed that accuracy, empathy, responsiveness, and reliability positively impact customer satisfaction.

One of the key tasks in developing a comprehensive set of measures to manage the effectiveness of retail network services is fostering customer loyalty by identifying the main factors influencing it and making strategic decisions accordingly.

According to Karimov it is appropriate to distinguish between different levels of managing customer loyalty in the retail sector[6]:

1. Management at the retail network level
2. Management at the store level

When evaluating performance, stores should be considered as primary business units, with a focus on efficient customer service and the sources of revenue and costs related to services. However, customer impressions and experiences from interacting with a company are not always directly linked to a specific store.

Therefore, customer loyalty may be shaped and influenced by factors at both the store level and higher levels of management. These factors include strategic and operational management of the distribution network and brand positioning, which play a crucial role in shaping consumer trust and long-term engagement.

Customer's trust is also influenced by queuing time in the store, therefore it is of utmost importance for any business to reduce waiting time in the queue. This study aims to analyze one day dynamics of queue length, processing and arrival times and suggest solutions for bottlenecks.

Methodology.

The study aims to highlights the queuing analysis method based on Little' law in retail business in Mumbai, India. As the data consists of arrival time, starting time, finish time and queue lengths at a given moment, the analysis highlighted in this article can be used for similar business. The article analyzes service operations in a retail business in Mumbai, India. The analysis was carried out on 30th March in 2023. The dataset includes 561 observations.

So, we used G/G/1 system to evaluate expected waiting time because the distribution of arrival rate belong to normal distribution for a customer using following formula[7]:

$$W_q = (\frac{c_a^2 + c_e^2}{2}) \times (\frac{u}{1-u}) \times t_e$$

Where, c_a −coefficient variation of customer arrivals;

c_c − coefficient variation of processing time;

u − average processing time;

t_e −average process time at the station.

We can make use of Little's law to help understand queuing behavior. Work in progress can be expressed in the below formula:

$$Work - in - progress = the\ arrival\ rate\ at\ the\ queue\ (cycle\ time) \times waiting\ time\ in\ the\ queue\ (throughput\ time)$$

Results and analysis.

We carried out the analysis of the distribution of arrival times, queue dynamics, and distribution of cycle time. Also, we calculated expected waiting time for a customer and the average number of people in the queue.

This histogram shows how frequently arrivals occur over time. If the distribution is uniform, arrivals are evenly spread; if it is skewed, it indicates peak periods. A bimodal shape shows distinct arrival patterns, such as rush hours.

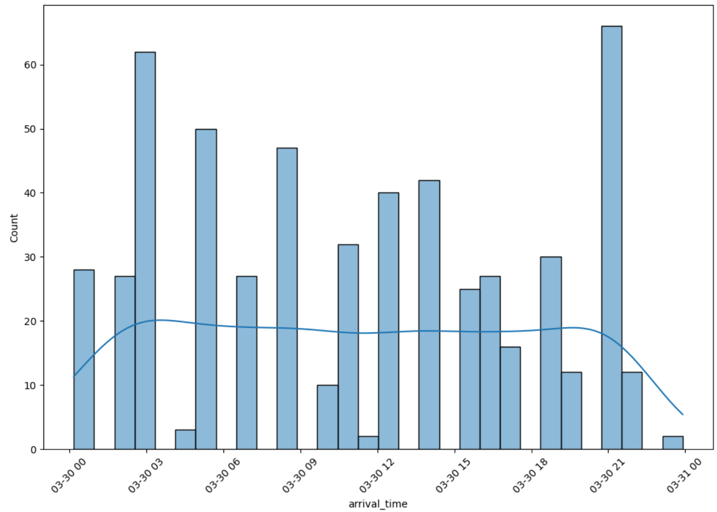

Figure 1. Distribution of arrival time

According to figure 1, from 3 am to 6 am the number of people was very high, also it was high at 9 pm. In the daytime the number of people coming to retail store was lower. The lower rate of arrivals during daytime was from 3 pm to 6 pm, while the minimum was reached at 12 am.

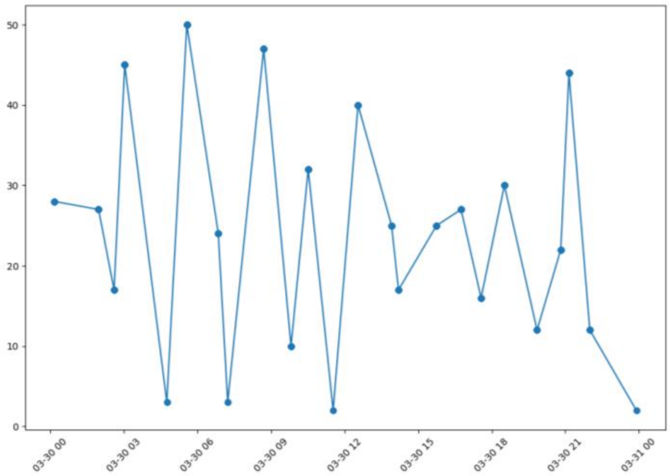

Figure 2. Queue size dynamics

Figure 2 line plot tracks how the queue size changes with time. Spikes indicate periods of high congestion, while steady or decreasing trends suggest smooth processing. If the queue remains high for long durations, it may indicate bottlenecks or slow service. As we observe the figure 2 we can see spikes every three hour. The biggest spikes accounted for 6 am and 9 am. Also at 9 pm queue size increased significantly.

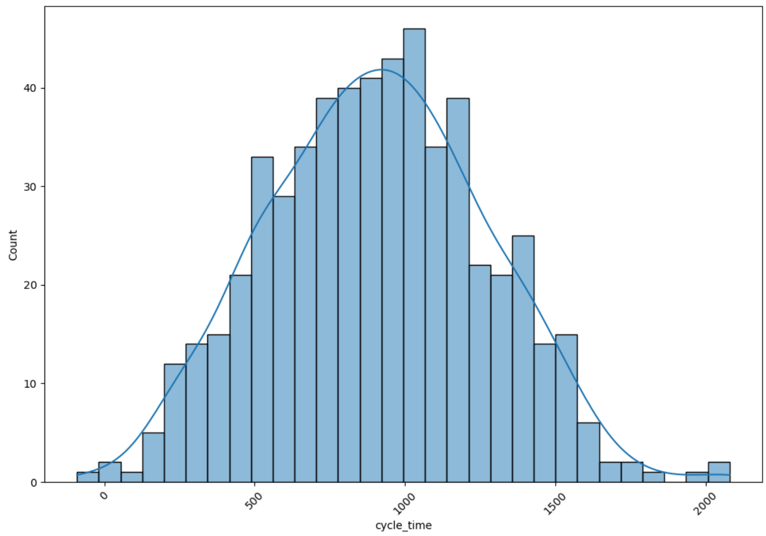

Figure 3. The distribution of cycle time

This histogram represents how long customers spend in the system from arrival to completion. A wide spread means high variability, while a narrow distribution suggests a more consistent process. It is clear that on average customers spent 1000 seconds or approximately 17 minutes in the queue[8]. A long right tail indicates that some customers experience significantly longer cycle times, possibly due to service inefficiencies.

Table 1. Given performance metrics

Metric	Value
Coefficient of Variation (CV) of Arrivals c_a	5.3006
Coefficient of Variation (CV) of Processing Time c_e	0.4766
Arrival Rate (arrivals per second) r_a	0.0065
Average Interarrival Time (seconds) t_a	152.8444
Average Processing Rate (jobs per second) r_e	0.0016
Average Processing Time (seconds) t_e	634.3238

Based on the above given distribution of arrivals, we use G/G/1 system to evaluate expected waiting time for a customer[7].

The utilization of single server will account for $u = \frac{0.0065}{0.0016} \approx 4.06$.

If we calculate waiting time $W_q = \left(\frac{5.3^2 + 0.48^2}{2}\right) \times \left(\frac{4.06}{4.06-1}\right) \times 634.32 \approx 11946.02$

According to Little's law $WIP_q = arrival\ rate\ \times waiting\ time\ in\ the\ queue.$

$$WIP_q = 0.0065 \times 11946.02 = 77.64$$

So, average wait a customer could expect in the queue is 11946.02 seconds or 3.31 hours, and there would be an average of 78 people in the queue. This shows huge challenge in the work of retail store because it cannot cope with so many arrivals at the same time. Therefore, it is recommended to open up an additional store near the shop to meet the demand, as well as increase number of checkouts during peak times[9].

Conclusion.

The findings of this study provide significant insights into the queuing dynamics of retail service operations, highlighting key inefficiencies and potential solutions. The analysis of customer arrivals, queue size dynamics, and cycle time distribution reveals that service operations in the studied retail store experience substantial congestion during peak hours, particularly between 3 AM to 6 AM and around 9 PM. The long average waiting time of 3.31 hours and the large queue sizes during these peak times indicate serious operational challenges that can negatively impact customer satisfaction and business performance.

Using Little's Law and the G/G/1 queuing model, the study has identified key performance metrics such as the coefficient of variation of arrivals (5.3006) and processing time (0.4766), the average interarrival time (152.84 seconds), and the average processing time (634.32 seconds). These metrics demonstrate a high variability in customer flow, leading to bottlenecks in service delivery. The prolonged waiting times and excessive queue lengths indicate that the current operational model is insufficient to manage customer demand effectively, necessitating strategic interventions.

One of the most critical findings is that the store's existing infrastructure and service capacity cannot accommodate the influx of customers during peak hours. As a result, there is a clear need for operational improvements to enhance efficiency and customer experience. Potential strategies include increasing the number of checkout counters during peak times, optimizing employee schedules to ensure adequate staffing, and potentially opening additional stores in high-traffic areas to distribute customer flow more evenly. Implementing an advanced queuing system, such as appointment-based or self-checkout options, may also help mitigate long waiting times.

Furthermore, the study highlights the importance of continuous monitoring and data-driven decision-making in retail operations. By leveraging queuing theory and predictive analytics, businesses can better anticipate customer demand patterns and allocate resources more efficiently. Regular analysis of service performance metrics will enable managers to implement timely interventions that improve service efficiency and customer satisfaction.

In conclusion, this study underscores the necessity of optimizing queuing management in retail businesses to enhance customer experiences and operational efficiency. By adopting data-driven strategies and proactive management techniques, retail stores can minimize customer wait times, reduce congestion, and improve overall service quality. Future research could explore the application of machine learning algorithms to predict peak traffic times more accurately and develop dynamic staffing models that further enhance service efficiency. By addressing these operational inefficiencies, retail businesses can achieve a competitive advantage and sustain long-term customer loyalty.

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