UDC 658.519.8

MODELING THROUGHPUT AT WAREHOUSE SITES TO PREVENT CONGESTION AND DELIVERY DELAYS

Olena Kryvopyshyna
National Aviation University, Kyiv

Scientific supervisor - Klius I.S., Ph.D., Assoc.Prof.

Keywords: logistics; warehousing; throughput; discrete-event simulation; queuing theory.

The efficient management of warehouse operations is crucial for ensuring smooth supply chain operations and timely delivery of goods to customers. In recent years, the growth of e-commerce and global trade has intensified the need for optimizing throughput at warehouse sites to prevent congestion and minimize delivery delays. By accurately modeling throughput processes and identifying potential bottlenecks, businesses can proactively implement strategies to enhance operational efficiency and customer satisfaction.

In our work, we explore and analyze various modeling approaches for optimizing throughput at warehouse sites to mitigate congestion and prevent delivery delays, thereby contributing to the advancement of supply chain management practices. The assertions in our investigation are predicated on the research outcomes expounded in references [1, 2].

Consider the queue model of the warehouse receipt process with a single server. A model that includes arrivals, service times, a single server and an infinite queue is denoted by (M/M/1), which means (arrivals/time/a single server). In the proposed model, a single server operates on a first-come, first-served basis, reducing the number of customers in the system by one upon completing service.

Let's consider the fundamental performance indicators of the studied system:

1) Traffic intensity (ρ), which equals the arrival rate (λ) divided by the service rate (μ), or equivalently, $\rho = \lambda/\mu$.

2) The average number of customers in the system (L) is calculated by the formula: $L = \rho / (1 - \rho)$.

3) The average time a customer spends in the system (W) is equivalent to the average number of customers in the system divided by the arrival rate, thus $W = L / \lambda$.

When $\rho < 1$, additional performance measures can be derived:

- The average time that a customer spends in the queue $W_q = L_q / \lambda$.
- The average time that a customer spends in service $W_s = L_s / \lambda$.

Experimentally, we measured the time each customer spends in the system and compared the average with the theoretical prediction. The results indicate a close match between the observed and theoretical values, indicating the accuracy of the theoretical model.

Next, we consider a multi-server mass service model denoted by (M/M/c), which means (arrivals/time/ c servers). This model includes arrivals, service times, a multi-server and an infinite queue. This configuration extends the (M/M/1) queue model to accommodate multiple servers, where arrivals follow a Poisson process, jobs are served by c servers, and service times are exponentially distributed.

Service times follow with parameter μ, and when there are fewer than c jobs, some servers remain idle, while excess jobs queue in an infinite buffer. The server utilization, denoted by $\rho = \lambda/(c\mu)$, must be less than 1 for the queue to remain stable, indicating the average proportion of time each server is occupied.

These queuing models yield valuable insights into warehouse operations and their applicability benefits from augmentation for a comprehensive approach to enhancing throughput efficiency and alleviating congestion.

Conclusion

This research underscores the value of integrating queuing models, simulation techniques, and mathematical optimization algorithms to optimize warehouse throughput effectively. The practical application lies in the comprehensive integration of these modeling approaches, providing practical tools for businesses to enhance operational efficiency and customer satisfaction.

References:

1. Queueing Systems M/M/1 and M/M/c. Web Home | ECS | Victoria University of Wellington.URL: https://homepages.ecs.vuw.ac.nz/~schukova/SCIE201/Lecture9_final2018.html.

2. Samir Saci. Supply Chain Process Optimization Using Linear Programming. Medium. URL:https://towardsdatascience.com/supply-chain-process-optimization-using-linear-programming.