Proceedings of the 2025 Winter Simulation Conference
E. Azar, A. Djanatliev, A. Harper, C. Kogler, V. Ramamohan, A. Anagnostou, and S. J. E. Taylor, eds.

SIMULATING INVENTORY SLOTTING STRATEGIES IN A ROBOTIC MOBILE FULFILLMENT CENTER

Justin Rist[1], and Paul Griffin[1]

[1]Dept. of Industrial and Manufacturing Eng., Pennsylvania State University, University Park, PA, USA

ABSTRACT

This case study presents a discrete event simulation model of a robotic mobile fulfillment center (RMFC) built in Simio. The model evaluates how different inventory slotting strategies affect operational performance at three facility scales: a small, medium, and large system. Inspired by a shoe fulfillment center, the model features standardized shelf sizes and a large number of SKUs due to variations in shoe models, sizes, and colors. A synthetic dataset was created to reflect realistic order volumes and SKU diversity without relying on proprietary data. Key performance metrics include order cycle time, pile-on, and AGV travel distance. The goal is to demonstrate how simulation enables robust evaluation of storage strategies in variable-rich RMFC environments. This work provides a foundation for comparing slotting methods and exploring how their effectiveness changes as facility size scales.

1 INTRODUCTION

Robotic mobile fulfillment centers (RMFCs) are increasingly prevalent in e-commerce and retail, offering flexible and efficient alternatives to traditional fixed-location warehousing. In RMFCs, mobile shelf units are moved to pick and stock stations by automated guided vehicles (AGVs), allowing orders to be assembled from dynamically located inventory (Benavides-Robles et al. 2024).

The shoe fulfillment center modeled in this study presents a challenging testbed due to its large number of SKUs, which are driven by variations in shoe size, color, and model, paired with standardized box sizes that simplify space planning. Although inspired by real operations, the model uses a representative synthetic dataset with realistic order structures and SKU frequency distributions. This allows the simulation to be generalizable while remaining operationally plausible.

Given the complex interactions between AGVs travel, shelf movements, replenishment cycles, and picker availability, traditional analytics alone are insufficient to evaluate design and policy options. Discrete event simulation (DES), implemented in Simio, provides a platform to explore how inventory slotting strategies influence key performance metrics across facility scales.

2 SYSTEM OVERVIEW

The fulfillment center layout is designed as a grid-based mobile storage zone serviced by AGVs, pickers, and stockers. Shelves are transported to pick or inbound stock stations on demand, and shelf locations are dynamically assigned, i.e. SKUs do not have fixed home positions. Three system configurations are developed:

- **Small-scale** – 36 shelf positions, 3 pickers, 2 stockers
- **Medium-scale** – 72 shelf positions, 6 pickers, 4 stockers
- **Large-scale** – 108 shelf positions, 9 pickers, 6 stockers

Orders are composed of 1 to 5 SKUs, and SKU popularity follows a long-tail distribution. Each simulation run represents a fixed time horizon with continuous order arrivals and stochastic item demand.

Standardized inventory sizes support physical realism without introducing unnecessary dimensional complexity.

3 SLOTTING STRATEGIES AND SIMULATION SETUP

The Simio model includes custom process logic to handle shelf assignment, AGV dispatch, replenishment coordination, and order picking. The focus is on comparing the operational performance of different slotting strategies under consistent demand conditions. The following strategies will be tested:

- **Random Slotting** – Items are placed on any available shelf space with no regard for frequency or class.
- **Class-Based Slotting** – SKUs are assigned to shelf zones based on frequency and volume, with high-demand items placed closer to pick stations. This method mirrors ABC classification approaches commonly used in traditional warehousing, adapted from the approach proposed by Muppani (Muppant) and Adil (2008).
- **Order Correlation-Based slotting** – SKUs are grouped based on likelihood of appearing together in the same customer order, adapted from the approach proposed by Chen and Li (2024).

Key performance metrics include:

- Average order cycle time
- Pile-on (the number of items a vehicle delivers per trip)
- AGV travel distance per delivery
- Picker utilization
- Percent of orders fulfilled within service level agreement

Each strategy will be evaluated for all system sizes to assess scalability and robustness under load.

4 RESULTS AND FUTURE WORK

Preliminary testing suggests that slotting strategies meaningfully influence order cycle time, pile-on, and AGV travel distance, particularly at the larger scale. As the number of shelves and SKUs grows, inefficient placement creates compounding travel delays and shelf congestion at pick stations.

Simulation-based evaluation using Simio enables rapid experimentation with different configurations, without needing access to proprietary systems or live operations. The model framework can be extended to support batching, dynamic re-slotting, and alternate AGV routing heuristics.

Future work will focus on integrating adaptive policies that respond to observed demand shifts over time and exploring trade-offs between shelf reassignment frequency and picker speed. The broader goal is to show how DES can be used as a flexible tool to test fulfillment design decisions in variable-rich RMFC environments.

REFERENCES

Benavides-Robles, M. T., Valencia-Rivera, G. H., Cruz-Duarte, J. M., Amaya, I., & Ortiz-Bayliss, J. C. (2024). Robotic Mobile Fulfillment System: A Systematic Review. *IEEE Access*, *12*, 16767–16782. https://doi.org/10.1109/ACCESS.2024.3359434

Chen, Y., & Li, Y. (2024). Storage Location Assignment for Improving Human–Robot Collaborative Order-Picking Efficiency in Robotic Mobile Fulfillment Systems. *Sustainability*, *16*(5), Article 5. https://doi.org/10.3390/su16051742

Muppani (Muppant), V. R., & Adil, G. K. (2008). Efficient formation of storage classes for warehouse storage location assignment: A simulated annealing approach. *Omega*, *36*(4), 609–618. https://doi.org/10.1016/j.omega.2007.01.006