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SIMULATION-BASED OPTIMZATION FOR OPERATIONAL EXCELLENCE OF A DIGITAL PICKING SYSTEM IN A WAREHOUSE

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ABSTRACT

This study aims at introducing a simulation-based optimization for operational excellence of a Digital Picking System (DPS) in a warehouse in terms of productivity. The DPS is a well-known system used for picking multiple items based on given inventory information (i.e. quantity, type, and picking order of items) without using a paper. Since its performance is heavily dependent on item locations (or DPS segmentation) and a labor schedule associated with dynamic interactions, this study adopts simulation-based optimization to identify the optimal design of a DPS regarding its labor schedule under realistic conditions of a retailer-driven commodity chain. The proposed approach is implemented in AnyLogic® 8.7.11 simulation software with inventory data of a warehouse in South Korea. In addition, OptQuest® is used as the optimizer to resolve the optimization problem via Metaheuristic for operational excellence of the subject facility.

1 INTRODUCTION

Inventory management is one of the most significant issues for reduction of operational cost in a supply chain. According to Lee and Billington (1992), poor inventory management can annually increase additional holding cost from 24% to 40%. Particularly, operational excellence of companies (e.g., Walmart and JD.com) in retail and wholesale business is heavily dependent on successful inventory management. For example, Walmart in U.S. claimed that approximately 87% of products went through its distribution center (Yuan et al. 2021) for reduction of delivery time. In China, JD.com has established approximately 7,000 distribution centers so that it can achieve the inventory turnover days of 40. Similarly, in South Korea, multiple big retailers (e.g., Shinsegae and Market Kurly) has adopted new technologies based on artificial intelligence and big data analysis in their inventory management for short delivery time of items to consumers with personalized consumption patterns (Kim 2021).

In fact, adoption of new technologies in inventory management is necessary for reduction of operational cost as well as sales cost (Aro-Gordon and Gupte 2016). This study aims at introducing a simulation-based optimization approach for inventory management with a Digital Picking System (DPS) which is used for picking multiple items based on given inventory information such as quantity, type, and picking order of items (Park et al. 2009). For the minimum operational cost for the maximum productivity, the DPS is segmented via OptQuest® regarding its labor schedule under AnyLogic® 8.7.11 simulation software. Actual inventory data of a warehouse in South Korea is applied.

2 METHODOLOGY

This study considers spatial segmentation of a DPS used in a warehouse in retail and wholesale business. The multi-facility model with the Euclidean distance (Tompkins et al. 2010) is extended to solve the devised problem for the facility consisting of multiple commodities (365 types), pallet racks (105 cells per pallet rack), single conveyor, and six picking and packing workers. Note that each worker picks up an item from a pallet rack and make a package at a workspace on a conveyor (with speed of 50cm/s).

$$Min\ f(S,A) = \sum_{i\in N}\sum_{j\in M}\sum_{k\in P} s_{ijk} d\left(X_i, L_j\right) c_{ijk} a_{ik} \quad (1)$$

Subject to

$$\sum_{i\in N}\sum_{j\in M} s_{ijk} a_{ik} = S_k \text{ for } \forall k \in P \quad (2)$$

$$\sum_{i\in N} a_{ik} = 1 \text{ for } \forall k \in P \quad (3)$$

$$0 \le s_{ijk} \le S_k \text{ for } \forall i \in N, \forall j \in M, \forall k \in P \quad (4)$$

$$a_{ik} \in \{0,1\} \text{ for } \forall i \in N, \forall k \in P \quad (5)$$

where s_{ijk} is a weight of item k associated with travel between cell location $X_i = (x_i, y_i, z_i)$ and packing location $L_j = \left(\alpha_j, \beta_j, \gamma_j\right)$; c_{ijk} is a unit travel cost of item k between X_i and L_j; $d\left(X_i, L_j\right)$ is the Euclidean distance between X_i and L_j; a_{ik} is a binary assignment indicator for item *k* (1: assigned, and 0: not assigned); N is a set of cells; M is a set of packing locations; P is a set of items; S_k is the total quantity of item *k*. Note that each flow represents one unit of item k. Equation (1) represents the minimization of total transportation cost of items between cells and packing locations in a facility. The decision variables (i.e., s_{ijk} and a_{ik}) are regulated by Equations (2) – (5). Particularly, Equation (2) is a constraint to assign the whole quantity of item k to cell i. The devised optimization formula is applied to OptQuest®, and physical activities in the subject facility are modelled in AnyLogic® 8.7.11 with the actual inventory data collected from a warehouse in South Korea. one when item k is assigned to cell *i*.

3 CONCLUSION

The simulation-based optimization approach for inventory management via a DPS in a warehouse is proposed. Particularly, item locations (or DPS segmentation) and relevant labor activities have been considered. To identify the optimal design of a DPS under realistic conditions of a retailer-driven commodity chain, real data of the local delivery company in South Korea is used. AnyLogic® 8.7.11 with OptQuest® is used for the implementation. As a result, the proposed approach enables to enhance performance of the subject facility in terms of productivity.

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