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Order batching in a pick-and-pass warehousing system with group genetic algorithm☆

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ABSTRACT

An order batching policy determines how orders are combined to form batches. Previous studies on order batching policy focused primarily on classic manual warehouses, and its effect on pick-and-pass systems has rarely been discussed. Pick-and-pass systems, a commonly used warehousing installation for small to medium-sized items, play a key role in managing a supply chain efficiently because the fast delivery of small and frequent inventory orders has become a crucial trading practice because of the rise of e-commerce and e-business. This paper proposes an order batching approach based on a group genetic algorithm to balance the workload of each picking zone and minimize the number of batches in a pick-and-pass system in an effort to improve system performance. A simulation model based on FlexSim is used to implement the proposed heuristic algorithm, and compare the throughput for different order batching policies. The results reveal that the proposed heuristic policy outperforms existing order batching policies in a pick-and-pass system.

1. Introduction

Warehousing management is a vital and logistical activity that can affect supply chain costs [29]. A pick-and-pass system, also called a progressive zoning system, divides a picking line into picking zones. Each zone is then typically assigned to a picker, and they are often connected by a conveyor in a warehouse [28]. This approach is commonly used for small to medium-sized items, such as household, health and beauty, office, and food products, which can be stored in relatively small and accessible pick locations along the picking line [27]. Since the emergence of e-commerce and e-business, global supply chain management has focused on the fast delivery of small and frequent inventory orders at a low total cost [3,33]. Thus, the operations of the pick-and-pass system play a key role in managing a supply chain efficiently.

The literature survey begins with a review on the warehouse management for pick-and-pass systems, followed by the developments of order batching policy. De Koster [6] approximated picking operations by applying the Jackson network model, and assumed that the service time at each pick station was exponentially distributed, and that customer orders arrived according to a Poisson process. Yu and De Koster [38] proposed an approximation method based on a $GI/G/m$ queuing network modeling technique by using Whitt's queuing network analyzer ([36]) to investigate the effects of order batching and picking area zoning on the mean order throughput time in a pick-and-pass system. Jewkes et al. [24] developed an efficient dynamic programming algorithm for determining the optimal item allocation and picker locations for an order picking line comprising multiple pickers. Jane and Laih [23] proposed several heuristic algorithms for balancing the workload among pickers in a picking line. Gagliardi et al. [11] proposed and analyzed different product location and replenishment strategies for a distribution center that uses a pick-and-pass system for fulfilling orders. Pan and Wu [31] developed an analytical model for a pick-and-pass system by describing the operation of a picker as a Markov chain to determine the expected travel distance of pickers in a picking line, and proposed three algorithms that optimally allocate items to storages. Parikh and Meller [32] proposed a cost model for estimating the cost of each type of picking strategy to mitigate the problem of selecting between batch picking and zone picking strategies. Melacini et al. [28] defined a framework for the pick-and-pass system design to minimize the overall picking costs and meet the required service level.

Order batching problem (OBP), a major decision problem in the design and control of warehousing systems [5] and a key factor for the success of an order picking system [19], determines how

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orders are combined into batches to be processed in a picking trip to reduce the travel distance of orders to be fulfilled [30]. Because obtaining precise solutions to the large-scale OBP by exerting reasonable computational efforts is impractical [9], researchers have developed heuristic methods to determine near-optimal solutions. De Koster et al. [4] combined well-known heuristics with new heuristics in an attempt to generate effective, fast, and robust order batching algorithms that are sufficiently simple to use in real-world situations. Gademann et al. [10] addressed batching in a wave picking operation, and presented an exact algorithm that assigns orders to batches to minimize the maximal lead time for each batch. Hwang and Chang [22] investigated order batch processing in which either a part of, or an entire single order or specific pair of orders may be grouped into a batch with a fixed capacity. Hsu et al. [20] developed a genetic-based algorithm for managing OBP with various types of batch structures and warehouse layouts to minimize the total travel distance. Won and Olafsson [37] addressed the typical warehousing problem of batching and order picking to improve the efficiency measured by the picking time and the effective use of vehicles. Hwang and Kim [21] presented an efficient order batching algorithm based on cluster analysis, and validated the performance of the proposed algorithm by comparing it with an existing algorithm regarding total travel time and the number of batches grouped. Tho and De Koster Rene [34] considered an OBP for a two-block rectangular warehouse by assuming that orders arrive according to a Poisson process, and adopted the well-known S-shape heuristic method for routing order pickers. Bozer and Kile [1] developed a new mixed-integer programming model to obtain near-exact solutions to the OBP. Ho et al. [16] developed several order batching methods for an order-picking warehouse with two cross aisles and an input/output point in one corner. Hsieh and Huang [19] developed K-means Batching and Self-organization Map batching polices, and investigated the overall performance of order picking systems by considering the storage assignment, order batching, and picker routing to determine the optimal policy combinations involving different order types. Henn [14] addressed an online order batching problem in which the maximal completion time of the customer orders arriving within a certain time to be minimized. Henn and Wäscher [13] presented two approaches based on the Tabu Search principle for deriving a solution to the OBP in a manual order picking system. Hong et al. [18] discussed an order batching formulation and a heuristic solution procedure suitable for parallel-aisle picking systems. Henn [15] applied variable neighborhood descent and variable neighborhood searches to minimize the total tardiness of a given set of customer orders. Henn and Schmid [12] discussed how metaheuristics can be used to minimize the total tardiness for a given set of customer orders. Lam et al. [25] proposed an order-picking system to manage an order-picking process as batches with common pick locations to minimize the travel distance, and determine the batch-picking sequence.

Previous studies on order batching policy have focused primarily on classic manual warehouses, also known as picker-to-part systems; whereas its effect on pick-and-pass systems has rarely been discussed. In a classic manual warehouse, the travel time of vehicles or pickers is often the dominant component of the operation cost; thus, a decrease in travel time or travel distance is used as the criteria of order batching. In contrast to classic manual warehouses, a pick-and-pass system contains a picking line or a conveyor of a fixed length, and the minimization of the travel distance may not be suitable under such conditions; instead, a reduction in the number of batches formed may serve as a more appropriate goal.

In practice, congestion may occur between two adjacent picking zones in a line since a picker must wait for the preceding picker to finish picking and transfer the container containing the picked items. Therefore, an optimal batching policy must consider both the number of batches and the balance of the picking line concurrently. This paper develops an order batching heuristic algorithm based on the group genetic algorithm (GGA) in a pick-and-pass system by considering the line balancing and the least number of batches formed to minimize the total operation time. The performance of the algorithm is compared and validated with the results generated by simulation models.

The remainder of the paper is organized as follows. Section 2 describes the framework and the order batching problem for a pick-and-pass system under consideration. Section 3 presents the proposed order batching heuristic, followed by an experimental design and a simulation model implemented to investigate the performances of the order batching heuristic in Section 4. Conclusions are highlighted in Section 5.

2. Description of picking operations and order batching problem

2.1. Picking operation for a pick-and-pass system

The pick-and-pass system considered in this study consists of a roller conveyor connecting all pick stations (zones) located along the conveyor line, as shown in Fig. 1. The picking line in the system has n pickers who pick the order items located in the vertical shelves in the respective zones. These vertical shelves are assumed to have precisely the same number of racks as the item types. Dummy items with no demand may be created to ensure that this relationship holds if less item types than racks are present.

A computer-aided picking system (CAPS) can be implemented in practice in a pick-and-pass system. In a CAPS, light indicator modules are mounted to all racks, and these modules automatically guide order pickers toward the pick locations, and show the amount of each item to be retrieved. The advantages of a CAPS include effectively improving the picking productivity by 50% or more and reducing the picking task error [23]. In addition, a CAPS simplifies training for pickers, thus lowering operational costs.

In such an information support system, the light indicator modules can show only the data of items to be picked in one order in a picker's assigned zone at a time in order to avoid pickers picking the wrong items. The picker picks the item quantity

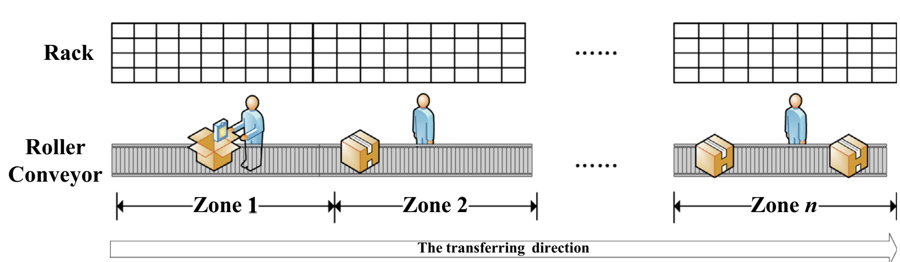

Fig. 1. A pick-and-pass system.