On fast storing and/or retrieving multiple loads in an e-commerce warehouse

YU Hu[a], YU Yugang[a], René de Koster[b]

[a] *School of Management, University of Science and Technology of China, Hefei 230026, China*

[b] *Rotterdam School of Management, Erasmus University, The Netherlands*

Abstract

E-commerce has received a lot of attention and lead to many changes in product distribution systems. In the circumstance of e-commerce, enormous small orders, tight delivery schedules and high volatility of the amount of orders are three of the most important challenges encountered by central warehouses. Customers order only small quantities of products, and these orders contain only one or two items, as well as require next day delivery services, or even the same day delivery. These vast number of small orders now have to be consolidated, sorted and delivered directly by a single central warehouse, but they were handled by a multi-tier product distribution systems with many warehouses to cooperate each other. In order to achieve ambitious delivery target, more and more new generation of warehouses for e-commerce distribution are developed for efficient storing and/or retrieving. This paper studies a new e-commerce warehouse for fast storage and order-picking. Different from traditional warehouse operation, the new e-commerce warehouse, a puzzle-based compact storage system, can handle the multiple requests simultaneously. However in a traditional warehouse, a storage request and a retrieval request are commonly combined and handled sequentially in a cycle, so called dual command operation, to improve the operation efficiency of a warehouse. This traditional sequential dual command mode is just a feasible solution, only applicable for handling two combined heterogeneous requests, i.e. a storage and a retrieval request, in puzzle-based storage systems, and be less efficient in e-commerce environment that prioritizes fast retrieval time. We propose an optimal dual command mode for moving two requested loads to the I/O point of the puzzle-based storage system with the objective to minimize total travel time. Two requested loads are not limited to two heterogeneous requests but can be any two combined requests, i.e. two storage requests, two retrieval requests or mix of storage and retrieval requests. We formulate this problem with dynamic programming models for systems. In case of one empty cell used to move requested loads out, we develop the property that feasible states of the empty cell at each stage can be represented by at most three states of them and we can reduce the computational complexity of the model from $O(l^2m^2n^2)$ to $O(m^2n^2)$, where m and n represent the number of row and column of the system, respectively, and $l = max(m, n)$. In case of multiple empty cells, we develop heuristics based on several rules observed from optimal solution of dynamic programming models. We find that a significant reduction in average travel time under the optimal dual-command modes can be achieved up to 30% compared with the sequential dual command mode and single command mode (request is finished one by one) in a traditional warehouse. This new policy in the new

system are able to take advantage of dual command operation to improve the productivity of the system but also the rate of retrieval even if all requests are homogeneous. Experiment results show that our algorithm performs well; the average gap between our heuristic and the optimal solution for a system with one empty cell are less than 1.5%. Besides, we find the average travel time per request decreases dramatically with an increase of the number of empty cells if the number of empty cells is few, but about four empty cells are almost sufficient enough for a system to perform best. This implies the throughput rate of the new system can be close to the optimal, while the number of empty cells can be flexibly adjusted in the system without changing much storage capacity, to match the amount of orders processed. Furthermore, for any given number of requests to be handled in dual command mode, the average travel time per request is independent of the proportion of the number of storage requests and retrieval requests in the request set, which is highly volatile in e-commerce delivery, for all four different sequencing polices. In addition, we find that the simple first-come-first-serve (FCFS) policy can give a well performed solution compared to the optimal sequencing policy. This finding may incur that sequencing is not that much beneficial in our puzzle-based compact storage system, and make good adaptability of the system in dynamic changing e-commerce era.

Keywords: e-commerce, warehouse, dual-command mode, puzzle-based compact storage systems, dynamic programming