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Aggregation of orders in distribution centers using data mining

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Abstract

This paper considers the problem of constructing order batches for distribution centers using a data mining technique. With the advent of supply chain management, distribution centers fulfill a strategic role of achieving the logistics objectives of shorter cycle times, lower inventories, lower costs and better customer service. Many companies consider both their cost effectiveness and market proficiency to depend primarily on efficient logistics management. Warehouse management system (WMS) presently is considered a key to strengthening company logistics. Order picking is routine in distribution centers. Before picking a large set of orders, effectively grouping orders into batches can accelerate product movement within the storage zone. The order batching procedure has to be implemented in WMS and may be run online many times daily. The literature has proposed numerous batching heuristics for minimizing travel distance or travel time. This paper presents a clustering procedure for an order batching problem in a distribution center with a parallel-aisle layout. A data mining technique of association rule mining is adopted to develop the order clustering approach. Performance comparisons between the developed approach and existing heuristics are given for various problems.

Keywords: Distribution centers; Order batching; Data mining; Association rules

1. Introduction

With the arrival of supply chain management, distribution centers serve a strategic role of achieving the logistics objectives of reduced cycle times, inventories and costs, and increased customer service levels (Coyle et al., 1996). Many companies consider both their cost effectiveness and market proficiency to depend primarily on efficient logistics management. Warehouse management system (WMS) currently is considered a key to strengthening company logistics. Logistics activities mainly consist of transportation, inventory management, order fulfillment and warehousing. These activities establish an essential connection among suppliers, distributors and customers in supply chains. Distribution centers occupy an important position in the supply chain; such centers store products, and retrieve products from storage to fulfill customer orders. Warehousing is the essence of the businesses of companies such as wholesale distributors. Since warehousing activities are frequent, even the small improvement can achieve significant savings. One costly way of increasing the warehousing productivity is through novel distribution center design. It is also possible to increase the productivity by less radical methods including changing the warehousing activities, such as receiving, order picking and shipping.

Order picking is a routine and time-consuming process, and generally contributes considerably to logistics costs (Tompkins et al., 1996). Order picking efficiency depends on factors such as storage racks, warehouse layout and control mechanisms. To attain better order picking efficiency, several approaches are generally used to reduce travel times or distances by establishing more effective control mechanisms in warehouses (Roodbergen & de Koster, 2001). The first method involves identifying good picking routes in which products are retrieved from storage such that the travel distances are minimized. The second

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method is zoning, namely, an order picker collects only the product items of an order located in their assigned zone. The storage assignment method also can increase the productivity by assigning products to the correct storage locations. Finally, the order batching procedure can be taken as an important method for reducing travel distances. Order batching employs packing a number of orders in a single tour. The present paper concentrates on order batching.

During an order picking operation, order pickers may pick one order at a time (single order picking). Picking a number of orders simultaneously (batch picking) may achieve higher productivity (Van den Berg, 1999). A batch is a set of orders that are grouped together for picking in a single tour. For batch picking, orders must be consolidated before commencing the picking operation. Distribution center managers are interested in finding the most economical way of picking customer orders, minimizing costs by reducing distance traveled. Moreover, order batching can reduce time spent on reading information and other warehousing activities (Brynzer & Johansson, 1996).

The computation of travel distance and time of assigning a particular order to a particular batch is extremely complicated because travel distance and time are dependent on the other orders assigned to the batch (Rosenwein, 1996). Therefore, obtaining the exact solutions of the order batching problems is very difficult and time-consuming. The optimization based approaches seem impractical for order batching problems since the mathematical models are highly complex. The previous results obtained using optimization methods in the literature are generally limited to small problems involving few orders.

Vinod (1969) formulated two integer programming models for order batching. The objective function coefficients were taken from assigning a value to each order. This value was arbitrarily defined, and is not discussed in Vinod. One illustrative example was given in which seven batches are grouped from only 14 orders. Kusiak, Vanelli, and Kumar (1986) reported the batching results of eight orders by using an integer quadratic program that minimizes distances between orders. The method of determining the distances between orders was not discussed. Finally, Armstrong, Cook, and Saipe (1979) investigated the batching problem for a conveyorized order picking system. A mixed-integer program was formulated under the criterion of minimum order processing time, and was solved by the Bender's decomposition method. Recently, Chen and Wu (in press) have developed an order batching approach based on association rule mining and 0–1 integer programming, namely ARIP. Association rule mining is used to discover the correlations between orders. A 0–1 integer program is then formulated to maximize the associations between orders within each batch. From the experimental results, the order batching approach developed by Chen and Wu can locate quality solutions for large problems. However, the huge amount of execution time may restrict the application of ARIP in practice to meet the requirement of quick response to customers' orders.

As mentioned above, obtaining the optimal solutions for order batching problems is extremely difficult and time-consuming. Research on the development of optimization based batching procedures is limited. The literature thus has introduced several batching heuristics for minimizing the distance traveled or time spent on picking by operators and/or S/R (storage/retrieval) machines (Elsayed, 1981; Elsayed & Stern, 1983; Elsayed & Unal, 1989; Gibson & Sharp, 1992; Hwang et al., 1988; Hwang & Lee, 1988; Rosenwein, 1996). Van den Berg (1999) surveyed these batching heuristics. Moreover, Elsayed and Unal (1989) developed batching heuristics for saving travel time. Elsayed and Stern (1988) considered various order proximity measures for batching heuristics, and demonstrated through experiments that none of these measures produced consistently superior results. Elsayed et al. (1993) and Elsayed and Lee (1996) developed batching heuristics that minimize earliness and tardiness for an order picking operation using man aboard S/R machines. Moreover, Hsu et al. (in press) proposed a genetic algorithm based approach to batch orders in a 3D warehouse environment.

Most previous studies on order batching focused on developing heuristics for assigning a small amount of orders (e.g. 5–30 orders) to a few batches (Rosenwein, 1996). Among the related literature, Gibson and Sharp (1992) and Rosenwein (1996) presented heuristics that can obtain results for a relatively realistic warehouse environment. Gibson and Sharp considered a distance measure as the sum of the distances between individual items in the seed order and the closest item in the candidate order. Moreover, Gibson and Sharp demonstrated that their measure outperforms a measure of space filling curves given in Bartholdi and Platzman (1988). Rosenwein (1996) followed the approximated distance defined by Gibson and Sharp (1992), in which the location of each item in a warehouse is indicated by its aisle index, but do not consider the specific location of items within aisles. Rosenwein (1996) devised two proximity measures for grouping orders. One of these two measures was the number of extra aisles that must be visited when an order is added to a batch (namely, minimum addition aisles method; MAAM). The other method averages the aisle numbers and then batches the orders for which this average is nearest (namely, center of gravity method; COGM). The MAAM measure outperformed the COGM measure in the results reported by Rosenwein.

Generally, batching heuristics initially pick a seed order for a batch and subsequently expand the batch using orders with proximity to the seed order as long as the S/R capacity is not exceeded. Defining a measure for the proximity of orders/batches is the primary issue in these heuristics. In many distribution centers, certain products are frequently ordered together. When clustering orders in the warehousing operations, data mining can be employed to