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Warehouse reshuffling: Insights and optimization

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ABSTRACT

Warehouse reshuffling is a reorganization strategy that consists of repositioning items by moving them sequentially. This study investigates how to optimize warehouse reshuffling and quantifies the effect of common assumptions. A mathematical programming formulation for the general warehouse reshuffling problem, the complexity of the problem, several heuristics based on the problem structure, a formal proof delimitating instances where double-handling can be a productive move, and managerial insights on the performance of reshuffling policies in various environments are presented. Experimental results suggest that the proposed heuristics improve upon a benchmark heuristic by relaxing how cycles are handled and incorporating double-handling.

1. Background

An important decision in warehouses and distribution centers (DCs) is determining the most efficient assignment of items to locations. This problem is known in the academic literature as the *storage location assignment problem* (SLAP) (Hausman et al., 1976), and is also known by practitioners as *inventory slotting* or *inventory profiling*. Fortunately, the SLAP has been widely studied and may be easily solved for different storage assignment policies. For example, Gu et al. (2007) and Roodbergen and Vis (2009) provide overviews on warehouse operations, including the most common storage assignment policies and existing solution approaches for the SLAP.

Many of the SLAP policies are based on item demand, and it is inevitable that the item-demand profiles will change over time. Demand profiles may change due to competition, introduction of new products, product maturity, or seasonality (Carlo and Giraldo, 2012). Consequently, the best assignment of items to locations also changes over time. To determine the new best location for the items, the SLAP with the updated item-demand profiles is solved. The process of changing from an initial storage assignment to a new storage assignment is known as *reshuffling* or *reslotting*.

Reshuffling reduces the expected storage/retrieval costs of normal operations, at the expense of the reshuffling costs incurred. Reshuffling can be especially important for large facilities that contain a large number of stock keeping units (SKUs). In such facilities, average improvements of 8–15% in picking and replenishment labor have translated into documented savings of $500,000 per year (Trebilcock, 2011). These savings need to be balanced against the cost of reshuffling activities. The primary reshuffling costs are labor (in manual warehouses) and electricity costs (in automated warehouses). To minimize reshuffling costs in either manual or automated warehouses, the total travel associated with the reshuffling process should be minimized.

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The frequency of reshuffling activities varies. Top performing warehouses typically perform reshuffling at least every quarter (Werling et al., 2008). In practice, reshuffling is commonly completed at the launch of a new product, at the end of each season, or on a monthly, weekly, or even daily basis, depending on the volatility of the demand profile. Consequently, designing reshuffling policies that minimize travel is an important component of effective warehouse operations.

This study focuses on how to optimize warehouse reshuffling and quantifies the effect of common assumptions in the reshuffling literature. The warehouse reshuffling problem is formally defined as determining the item movement sequence and the corresponding open locations to sequentially transform an initial storage configuration to a desired final storage configuration.

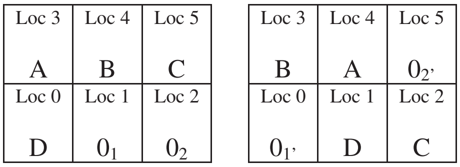
The items that are reshuffled may be stored in pallets, as in most warehouses and in the reserve area of DCs, or in totes as in miniload automated storage/retrieval systems (AS/RSs) and in the forward area of DCs where picking occurs. However, for simplicity, we will describe our system as one where items are palletized and stored in a rack that is served by an AS/RS. Note that our methodology is directly implementable for manual warehouses or order picking in DCs. The main modeling assumptions used in this study are consistent with the traditional assumptions in the warehousing literature. In particular, it is assumed that:

1. each item is carried as a unit-load;
2. only one item may be stored in each location;
3. every item has a unique storage location (i.e., dedicated storage policy); and if more than one copy of an item exists, we treat each unit load as a unique item that has a specific location in the initial and final storage configurations;
4. the initial and final storage configurations are known;
5. reshuffling will be completed by a single material handling equipment;
6. the travel distance between any two storage locations is assumed known;
7. only one rack (i.e., one side of the aisle) served by the S/R machine is considered;
8. every item is directly accessible from the aisle (i.e., a single-deep aisle);
9. the input/output (I/O) point is given and considered as a location in the rack;
10. all moves can be completed in the time available;
11. the objective is to minimize the total distance traveled, measured by distance traveled for both loaded and unloaded travel.

It is important to highlight that although we assume a dedicated storage policy in the third assumption, we also present a mathematical model for the general warehousing reshuffling problem under class-based storage in Appendix A. The objective function in the last assumption can be easily modified from travel distance to travel time by incorporating the travel speed, acceleration/deceleration, and pickup/drop-off (P/D) times. Alternatively, if P/D's are to be incorporated, a fixed distance-penalty may be added for each P/D.

Fig. 1 depicts a sample reshuffling problem in which four items (A–D) require repositioning. Fig. 1(a) and (b) displays the initial and final configurations, respectively. The problem contains two open locations (represented by 0_1 and 0_2 in the initial and $0_{1'}$ and $0_{2'}$ in the final configurations). The I/O point is assumed to be at the bottom leftmost location (i.e., location 0, labeled as Loc 0 in Fig. 1).

Items A and B in Fig. 1 are referred to as *cycle items* because to reposition either of these items, the other item needs to be moved. To break a cycle, an additional move from an item's current location to another location that is not its final location is required. A set of items is classified as *cycle items* if the set's initial locations are equal to the set's final locations. This set may contain multiple cycles, and the set of all cycle items can be decomposed into the union of the disjoint subsets that denote individual cycles (see Appendix B for a polynomial-time algorithm to identify cycles). On the other hand, items C and D are *non-cycle items* because they are not part of any cycles. A possible solution for the problem in Fig. 1 is to move unloaded from the I/O point (location 0) to the initial location of item A. Then reposition item A from its initial location to the open location identified as 0_1 in Loc 1. Next, move unloaded to the initial location of item B, pick up item B and move it to its final location. At that point, item A can be moved from location 1 to its final location, followed by the repositioning of items C and D. For a solution to be feasible, an item cannot be moved to a location unless the location is open and such open locations change as we reshuffle items. Consequently, there are multiple feasible solutions for the sample problem, which increase exponentially with the number of items and open locations considered.



(a) (b)

Fig. 1. The initial (a) and final (b) configurations for a sample reshuffling problem.