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# Prioritizing replenishments of the piece picking area

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ABSTRACT

Having sufficient inventories in the forward or piece picking area of a warehouse is an essential condition for warehouse operations. As pickers consume the inventory in the piece racks, there is a risk of stockout. This can be reduced by the timely replenishment of products from the bulk reserve area to the forward area. We develop and compare three policies for prioritizing replenishments for the case where order picking and replenishments occur concurrently because of time restrictions. The first policy, based on the ratio of available inventory to wave demand, reduces the number of stockouts considerably. The other two more sophisticated policies reduce the number of stockouts even more but require much more computation time, and are more costly in terms of implementation, maintenance and software updates. We present the results of implementing one of these policies in the warehouse of a large cosmetics firm.



## 1. Introduction

Warehousing plays a major role in physical distribution and has been researched extensively in the past decades, see Gu, Goetschalckx, and McGinnis (2007, 2010a), and de Koster, Le-Duc, and Roodbergen (2007) for reviews. Among all warehouse activities, order picking has received the most attention. It is estimated that more than fifty percent of operational costs are related to the order picking process (Coyle, Bardi, & Langley, 1996), so that optimizing this process is of utmost importance. Optimization can be achieved by developing (combinations of) order batching, order picking routing and rack assignment strategies.

The increasing popularity of e-commerce has made order picking even more important, as warehouses are faced with later order cut-off times and less time available for picking. In addition, serving end-customers instead of retailers involves dealing with much smaller quantities in the order lines. Warehouses are therefore increasingly picking units (pieces) of products instead of larger handling units, such as boxes or pallets. One of the strategies to speed up order picking and to deal with small quantities in the order lines is to operate a forward area from which the most demanded products can be picked quickly, see Gu et al. (2007, 2010a) and de Koster et al. (2007). Piece picking, as opposed to bulk picking, takes place in this area. The stocks in the forward area are limited and they are replenished from a bulk reserve area at the back of the warehouse.

Due to time pressure, many warehouses perform order picking and replenishment operations simultaneously, and in practice it sometimes happens that an order picker has to pick a product before the replenishment crew has had time to replenish it, and thus faces a stockout (which we will call a 0-pick). We observed this problem in a warehouse of a renowned luxury cosmetics firm. Stockouts or 0-picks reduce the productivity of picking operations, because the missing products can only be picked once the restock has taken place. This causes delays in shipping and unproductive travel of the picking crew, since the orders with missing products are completed outside the optimal picking routes.

The problem of 0-picks can be tackled if the short-term demand of each product is known. This information allows us to identify products which could cause a 0-pick if they are not replenished in time. In the warehouse studied in this paper, this demand information is available because the warehouse uses a wave-picking strategy, in which 'waves' of picking orders are released in succession. Namely, at the beginning of each wave, information is available about each order line in the picking wave. However, predicting the exact moment at which the products will run out of stock is difficult, as there can be quite some variation in order picking times and the exact order pick moment depends on the routes taken.

Although there is some literature about the design and operation of forward and reserve areas (Van den Berg, Sharp, Gademann, & Pochet, 1998; Gu et al., 2010a), it mainly focuses on the size of those areas and the quantity of replenishments, but does not consider the sequence in which orders are replenished. Our problem is

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also similar to inventory-routing problems and our results could be used in that area as well. In this paper, we propose three policies that prioritize replenishment orders based on the short-term demand information mentioned above. These policies aim to minimize the number of 0-picks. We first prove optimality results of these policies, we compare them using simulation, and we present the real life results of implementing one of these replenishment policies in a warehouse of a cosmetics firm.

This paper is organized as follows. Section 2 contains a detailed description of the problem. In section 3, a short overview of the literature dealing with this problem is given. Next, three replenishment policies are proposed in Section 4. In section 5, these policies are compared by means of simulation. Section 6 contains the results of implementing one of the three stock replenishment policies. Finally, Section 7 states the general conclusions that can be drawn from this paper.

## 2. Problem description

The warehouse studied in this paper has separate areas for order picking and storage activities. The *forward area*, also called fast-pick area, is used for piece picking, while bulk or mass storage takes place in the *reserve area*. The main advantage of this configuration is that it reduces the order picking time. Because order picking takes place in this limited part of the warehouse, the pickers only need to travel short distances. The main disadvantage is that the stock of one Stock Keeping Unit (SKU) is split into two different zones in the warehouse, thus requiring periodic replenishments from the bulk storage to the fast-pick area.

The warehouse we observed implements three U-shaped piece picking zones. Managers periodically reassess the decision of what quantities of which SKUs are to be stored in these zones to ensure that the capacity of the rack assigned to each item meets its long-term demand. This is done by solving the well-known forward-reserve allocation problem (FRP), which will be further explained in Section 3.

The warehouse uses a wave-picking picking policy. Each picking wave corresponds to a pre-defined shipping schedule, meaning that all picking orders which have to be shipped together are released at the same moment in a certain order. There is no information about when exactly an individual order line will be handled, except for the fact that it will take place sometime between the beginning and the end of the wave. Each picking wave is made up of several batch picking orders. More specifically, the pickers process up to six picking orders in the same picking route using a sort-while-pick process. While the pickers move around in the U-shaped zones, the inventory in the picking racks decreases and replenishment orders are triggered to restock the forward area.

A replenishment order corresponds to *one* product that is restocked from the reserve to the forward area. Replenishment orders are launched following an $(s, S)$ policy, whereby the stock of a product in the forward area is replenished up to level $S$ as soon as the inventory drops below $s$ items. The $S$ denotes the order-up-to level (the rack capacity) and the $s$ is the reorder point (in this case taken as 30% of the total inventory capacity of the rack). The *Warehouse Management System* (WMS) provides real-time monitoring of the on-hand inventory level in each location, so that an automatic replenishment order is triggered as soon as the stock level of a given product declines below the $s$ level. The rack capacity allocated to each product is based on the long-term demand information for that product.

As soon as the WMS detects a need for restocking a rack, a replenishment order is released and placed at the bottom of the list of pending replenishment orders, following a FIFO (first-in-first-out) queuing discipline. The replenishment orders in the list are then processed by a crew of forklift drivers that groups them in small batches to reduce travel time while respecting the priority marked in the queue. The three new policies proposed in this paper assign a priority to every replenishment order and execute the one(s) with the highest priority in the first replenishment batches. Due to time pressure, there are no idle periods in the warehouse that would allow the forward area to be fully replenished prior to the start of a picking wave. Stockouts could be avoided if order pickers and replenishment workers were to share responsibilities and work together to restock the piece picking area at the beginning of the wave and then to fulfill the order picking tasks. However, in practice, this sharing of responsibilities is not feasible. First, piece picking and forklift driving require very different skills, the workers are not interchangeable in terms of training (and salary) and belong to separate functional units within the warehouse. Second, the number of forklifts dedicated to replenishment is limited. If the picking crew were deployed to perform replenishment tasks, the warehouse would have to invest in an additional fleet of forklifts that would only be in use at the beginning of the wave while remaining idle the rest of the time.

Therefore picking and replenishment operations take place continuously and simultaneously throughout the day. Although the forklift drivers usually carry out the replenishment orders efficiently, a stockout (restricted to the piece picking area) of the most frequently demanded products in the picking wave can occur before the replenishment crew has had time to restock. The main cause of this problem is that for these products, the quantity to be picked per time unit varies considerably, which is because the picking orders involving the same kinds of products are often batched. The rack capacity allocated to each SKU in the forward area is a tactical decision that cannot be modified in each picking wave. Hence the problem of reducing 0-picks needs to be tackled by focusing on operational decisions. Specifically, we try to avoid 0-picks by designing policies which determine which products need to be replenished from the reserve area and the sequence (priority) in which these replenishments should be processed. To our knowledge, existing literature has not yet focused on a replenishment policy aimed at avoiding 0-picks in a forward area where picking and replenishment operations take place *simultaneously*. In this paper, we propose such a policy.

## 3. Literature review

Hardly any literature addresses the problem described in Section 2. Some more details on the problem and the proposal of one simple priority rule can be found in Carrasco-Gallego and Ponce-Cueto (2009), but no analytical analysis of the performance of priority rules is provided here.

Particularly the combination of wave-picking and replenishing during the order-picking process makes our problem very specific. We only found two papers that can be applied (partly) to our situation.

Gagliardi, Ruiz, and Renaud (2008) also consider a warehouse with a forward area, a reserve area, and a pick-to-belt operation. The warehouse faces stockouts during picking and only one technician is responsible for a continuous replenishment. The authors propose four heuristic replenishment policies. Two are based on long-term demand information, while the other two also consider short-term demand information by checking incoming picking orders. They consider only the next product to be replenished, while we consider wave-picking and set priorities for all products to be replenished by several people. Van den Berg et al. (1998) also address replenishment policies. However, they consider replenishment during idle periods and therefore ignore the priorities of