Distributor Cost Inefficiencies from Partial Pallet Ordering

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Limiting inventory and fulfillment models to unit costs does not reflect current practice at distributors. Storage and material handling costs are appropriately incurred at the pallet level. Growing emphasis on accumulation and repalletization of customer partial pallet order quantities necessitates consideration of the costs of pallet splitting and case picking. Each cost category may contribute to expensive inefficiencies at a distributor. We describe these inefficiencies and suggest their use in developing customer cost premiums.

INTRODUCTION

According to Supply Chain Digest, warehousing contributed over 30% of surveyed companies' logistics cost in 2015, and over half of warehouse labor expenses stem from picking, packing, and shipping outbound orders. As companies strive to adopt more efficient operations, orders placed with distributors continue to be for smaller and smaller quantities (Richards 2011), and labor costs for order staging and repackaging grows (Wulfraat, 2013; Piasecki, 2000-2012). Competitive responsiveness to customers leads to such activities as customized packaging or palletization, which must be integrated into the already expensive order-picking process (Van Hoek, 2001; De Koster et al., 2007).

Within a warehouse, product is typically stored on pallets, with order pickers using lift trucks to transport pallets from pallet racks and to a staging area (Piasecki, 2000-2012). Using pallets is beneficial to distributors for a number of reasons. Pallets can be moved more quickly than can individual case units, allowing for higher productivity of in-warehouse transport equipment. Use of lift trucks reduces the need for manual handling of inventory and, hence, less risk of worker injury or product damage (Ackerman, 1997; LeBlanc, 2013). Ordering and/or shipping in full pallets makes loading and unloading of trucks cheaper, easier and faster, for both distributor and customer (Kulwiec, 1985).

While the customer still benefits from having individual cases of product picked and stacked onto a pallet, these benefits are lost to the distributor when orders are not in full pallet quantities.

Typically, research on order quantities focuses on the customer: determining optimal order sizes given ordering, holding, and shortage costs. Existing research does not appear to study the impact of customer partial pallet order quantities on the costs at the distributor. Research focusing on the distributor pertains to warehouse design, storage methods, route optimization, order collecting, picking zones, etc. (Ackerman, 1997; Wheeler, 2013; Rouwenhorst et al, 2000) In effect, treatment of solely distributor costs associated with pallet or partial pallet orders is something new.

For distributors, order picking consumes the most labor and may determine the level of service provided to customers. Customers expect distributors to achieve transportation economies that contribute to low cost logistics (Lambert et al., 1998). Furthermore, customers often demand that distributors "split"

pallets and repalletize with multiple SKUs, a practice known as *accumulation* or *consolidation* (De Koster et al., 2007). Hence, considering the costs of this service is natural.

Twenty years ago, pallet orders were the norm. Now, case picks for partial pallet orders are common, yet distributors may offer different charges based on whether full or partial orders are placed. If customers have an incentive to order quantities in full pallets, picking costs are saved (Kulwiec, 1985). Companies may offer customers a discount when the order quantity is in full pallets (Ackerman, 1997). In local interviews, one of our students found this to be true for tile manufacturers working with flooring distributors.

In the following section, we develop a profit model that includes picking and inventory costs associated with customer orders that may or may not be in full pallet quantities. Next, we determine the inefficiency cost to the distributor for any partial pallet order quantities. We then provide some concluding comments.

DISTRIBUTOR PROFIT MODEL

Partial pallet orders yield numerous inefficiencies within warehouse operations: storage, picking, asset utilization, etc. Partial pallets consume storage space better utilized by full pallets, wasting square foot of space either on the floor or on pallet racks (Ackerman 1997). Partial pallets may either wait in the picking area or be returned to the pallet racks. They cannot proceed to receiving for reuse until emptied (Kulwiec 1985, Richards 2011).

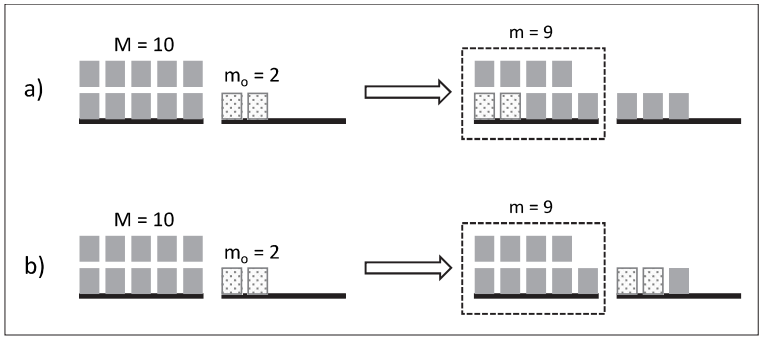
Primary cost components are those for picking and inventory carrying. Picking costs for partial pallet orders include labor fixed cost B of splitting a full pallet, while variable cost b is the unit cost for each case picked. Per unit inventory carrying cost h is supplemented by the per pallet carrying cost H.

We distinguish inventory and order quantities according to the number of full pallets and the number of cases on a partial pallet. Suppose a full pallet holds M units. Distributor inventory at the beginning of the period is $n_oM + m_o$, where n_o is the number of full pallets and $0 < m_o < M$ is the number of units on any partial pallet that may be on-hand. The customer's order is then $nM + m$, where n is the number of full pallets ordered and m represents an additional partial pallet order quantity.

At the beginning of the period, the distributor observes her inventory level $n_oM + m_o$. She then communicates to the customer per unit price p and possibly cost premium ψ_m for an order with partial pallet order quantity m. The customer's order for $nM + m$ results in fixed cost B, if necessary to split a new pallet, and variable cost b for each case picked. The customer pays $p(nM + m) + \psi_m$, the charge for an order quantity $nM + m$ plus a cost premium ψ_m for $0 < m < M$. The customer order is filled in the same period, bringing distributor inventory to $[(n_oM + m_o) - (nM + m)]$. At the end of the period, the distributor incurs carrying cost h for each case in inventory and H for each pallet in inventory.

In what follows, we address pallet splitting in two ways. *Partial pallet picking* (Figure 1a) reflects current practice in which labor picks from partial pallet order quantity m_o, splitting new pallets later as needed (Ackerman 1997). This practice is further justified in cases of short shelf-life items, for which first-come-first-served treatment of inventory is appropriate (Kulwiec 1985). *Efficient pallet picking* (Figure 1b) considers the efficiency of splitting a new pallet first, when the number of case picked units exceeds remaining pallet capacity.

FIGURE 1
PALLET PICKING METHODS



Given M, n_o, and m_o, the total period profit at the distributor is

$$\Pi_{n,m} = p(nM + m) - \alpha_{n,m} - \beta_m, \tag{1}$$

where β_m is the cost of pallet splitting and case picking, and $\alpha_{n,m}$ is the cost of inventory carrying. The pallet splitting and case picking costs at the distributor differ between *partial pallet picking* (β_m^P) and *efficient pallet picking* (β_m^E). This cost can be represented as follows.

$$\beta_m^P = [B + b(m - m_o)]I_{\{m>m_o\}} + bmI_{\{m<m_o\}} \tag{2}$$
$$\beta_m^E = \left(B + b\left[(m - m_o)I_{\left\{m<m_o+\left(\frac{M}{2}\right)\right\}} + (M - m)I_{\left\{m\geq m_o+\left(\frac{M}{2}\right)\right\}}\right]\right)I_{\{m>m_o\}} + bmI_{\{m<m_o\}},$$

where $I_{\{.\}}$ is the indicator function.

Recall that the cost of carrying inventory is divided into two categories. Opportunity cost, shrinkage, obsolescence, insurance, and taxes are applied at the case level. Storage requirements and material handling costs are appropriately applied at the pallet level. For this reason, we express the cost of inventory carrying as follows.

$$\alpha_{n,m} = h[(n_o - n)M + (m_o - m)] + H\left[(n_o - n) + \left(1 - I_{\{m\geq m_o\}}\right)\right] \tag{3}$$

Inserting (2) and (3) into the expression for distributor's total profit leads us to examine the impacts of pallet holding cost H, pallet splitting cost B, and pallet picking cost b.

COST INEFFICIENCIES

The distributor prefers that her customer order in full pallet quantities, as this would eliminate inefficiency cost of pallet splitting and case picking. Accordingly, we redivide the components of $\Pi_{n,m}$ to readily display the distributor's cost of inefficiency from customer partial pallet orders. That is, $\Pi_{n,m} = \gamma_{n,m} - \psi_m$, where

$$\gamma_{n,m} = p(nM + m) - h[(n_oM + m_o) - (nM + m)] - H(n_o - n) \tag{4}$$

is the standard revenue minus inventory cost and

$$\psi_m = H\left(1 - I_{\{m \geq m_o\}}\right) + \beta_m \quad (5)$$

is the inefficiency cost. Note that $\psi_{m_o} = 0$. Otherwise, the following proposition presents the inefficiency cost for four scenarios.

Proposition 1. When ψ_m^P and ψ_m^E are the inefficiency costs under partial pallet picking and efficient pallet picking, respectively, we have the following.

(a) $\psi_m^P = \psi_m^E = H + bm$ for $m < m_o$

(b) $\psi_m^P = (B - bm_o) + bm$ for $m_o < m$

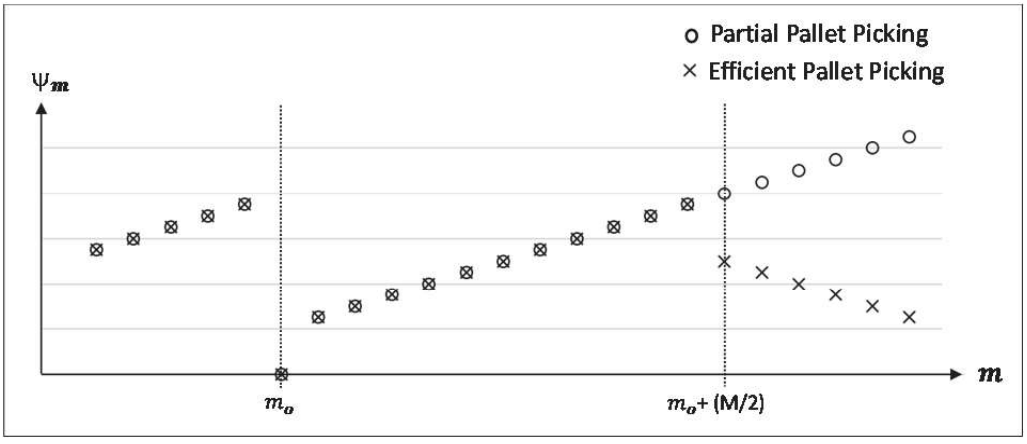
(c) $\psi_m^E = (B - bm_o) + bm$ for $m_o < m < m_o + \left(\frac{M}{2}\right)$

(d) $\psi_m^E = (B + bM) - bm$ for $m_o + \left(\frac{M}{2}\right) \leq m$

For Proposition 1(a), because $m < m_o$ the distributor picks m cases from a pallet, at a unit cost of b, to repalletize elsewhere. However, the partial pallet with m_o still remains in inventory, so it still incurs holding cost H. Note that this inefficiency cost increases with m. For (b), because $m > m_o$ and we are considering partial pallet picking, the distributor will pick $m - m_o$ cases, at a unit cost of b, to add to the partial pallet. The distributor no longer pays holding cost H on the partial pallet with m_o units, but she must pay the cost B of splitting a full pallet to complete the order. Again, note that the inefficiency cost increases with m. For efficient pallet picking, the inefficiency cost for customer partial pallet orders changes between (c) and (d). Below $m_o + \left(\frac{M}{2}\right)$, partial pallet order quantity m gives the same result as for partial pallet picking. For high partial pallet orders, $m \geq m_o + \left(\frac{M}{2}\right)$, the distributor must still incur B for splitting a pallet. However, she now just removes enough $(M - m)$ from the originally full pallet to leave a partial pallet with m units. Again, the number of pallets decreases, so the distributor does not incur H. In this case, note that the inefficiency cost actually decreases with m, because fewer cases must be removed.

One visualization of the behavior of the cost inefficiency can be seen in Figure 2.

FIGURE 2
EXAMPLE: DISTRIBUTOR COST INEFFICIENCIES
(M=24, m_o=6, H=5, B=2, b=0.5)



Proposition 1(b) and (d), as well as Figure 2, demonstrate the following result.

Proposition 2. For $m \geq m_o + (M/2)$, we have $\psi_m^E \leq \psi_m^P$.

From Proposition 2, we confirm that efficient pallet picking is just that. This practice inherently reduces the distributor's inefficiency cost from customer partial pallet order quantities. Hence, efficient pallet picking is the best strategy when attempting to maximize profit. If a distributor is using ψ_m^E to determine an appropriate cost premium to charge a customer purchasing $nM + m$ for $m > m_o + \left(\frac{M}{2}\right)$, the practice may also help the distributor be more competitive for customer orders.

CONCLUSION

Considering pallet-level inventory, pallet splitting, and case picking costs is both appropriate and critical for understanding the inefficiencies faced by a distributor with partial pallet order quantities in a customer order. A model of distributor period profit is incomplete without including the inefficiency costs. The model established distinctly separates this cost from the standard model of revenue minus inventory cost.

The level of inefficiency differs by the partial pallet order quantity but is not continuous. Furthermore, we note that *efficient pallet picking*, reduces inefficiency costs when partial pallet order quantities are sufficiently high.

Expansions on this topic may include new assessments of classical optimal ordering policies, with or without shortage cost penalties.

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