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COVID-19 Pandemic Implications for Order Picking Operations

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Abstract

The deadly global COVID-19 pandemic has disrupted global supply chains and the working environment in most organizations. This paper looks at the safety and physical distancing implications on order picking operations using routing, storage and picking strategies. Research has shown that the use of traversal and in some cases midpoint routing can yield near optimal results and enable physical distancing. The use of ABC storage does result in less travel for order picking workers but can potentially result in more congestion. Picking strategies that utilize picking zones naturally promote physical distancing but may not be feasible given the picking volume and the layout of the distribution center. Overall, this paper shows that order picking managers can still provide safe workspaces for their employees while achieving cost effective results.

Keywords

COVID-19, Distribution, Warehousing, Order Picking

1. Introduction

As of September 8, 2021, authorities in 219 countries and territories have reported 218,823,527 global confirmed cases resulting in 4,548,299 deaths (COVID-19 Dashboard by Johns Hopkins University, 2021). In the United States, there have been 39,480,609 confirmed cases resulting in 642,879 deaths. Although some countries appear to be flattening the curve of new COVID-19 cases, cases seem to be resurging in other countries with the delta variant but even this can change quickly as evident of the various waves that have hit most countries (New COVID-19 Cases Worldwide by Johns Hopkins University, 2021). Although several vaccines have been approved for use as of September 8, 2021, 5.56 billion vaccine doses have been administered worldwide which is 72 doses per 100 people (Holder, 2021). Even after countries get most residents vaccinated or reach "herd immunity", there are concerns for future virus pandemics (Nature Medicine, 2021).

The Centers for Disease Control and Prevention (CDC) (2021) are still recommending that people wear a mask that covers their mouth and nose, stay six feet (or roughly two meters) apart from others, avoid crowds and poorly ventilated spaces, wash your hands or use hand sanitizer regularly, and get a COVID-19 vaccine when it is available to you.

The COVID-19 pandemic has paralyzed the world and unveiled the critical importance of supply chain management (Craighead, Ketchen, & Darby, 2020) and is causing warehouse managers to rethink their labor strategies as they try to balance the safety of their workers with the reduction of warehouse productivity (Ames, 2020). Some of these difficulties and/or challenges faced by order processing organizations include an increase in orders, shipping delays in port and with the temporary blockage of the Suez Canal, shifting government regulations, and continued physical distancing (Dube, 2021). There are also challenges in staffing as firms cannot pivot quickly to robotic picking, extended work shifts, and that there is little time to train new employees if firms can even find new employees in a tight labor market (Dube, 2021). For instance, since March 2020, Amazon has experienced spikes in orders accompanied by customers' complaints of delays (Selyukh, 2020). Reported in June 2020, "Amazon struggled to balance a surge of orders with the health concerns of the one million workers and contractors at its warehouse and delivery operations" (Weise, 2020). Amazon had subsequently launched an AI-enabled program "Distance Assistant" to provide real-time physical distancing at their facilities (Porter, 2020) and announced to hiring 100,000 new employees across the U.S. to meet the surge in demand (Clark, 2020).

CDC (2020) Employer Information for Warehousing gives sound guidance to help isolate people from exposure to COVID-19 and ways to change the way people work. These include:

- All employees should wear clean masks to protect others and that care should be taken when putting on and removing masks.
- Creating work zones to separate workers into teams to reduce the number of coworkers each worker is exposed to.
- Reducing the number of workers onsite by staggering shifts, having more work shifts, or increasing the hours of operation.
- Modify workstations or using physical barriers to separate workers.
- Maintaining physical distancing by using one-way travel is aisles using signs, colored tape or decals on the floor.
- Using touch-free workstations or frequent cleaning of commonly touched surfaces.
- Keeping the warehouse well-ventilated with fresh air.

The long-term implications of this global pandemic might be a move to more e-commerce and less in-person shopping, an increased use of automation due to labor shortages, and more scalable order picking operations to be able to accommodate variable demand patterns (Dube, 2021; Maloney, 2021). There also is a major challenge to small and medium-sized businesses that don't have the resources that larger firms possess (Enesi & Ibrahim, 2021).

So, what can order picking operations do now in the face of this pandemic? This paper will propose the use of several tried and true strategies for routing, storage assignment, and order picking procedures that can yield near optimal results when still allowing for a safe workplace. These include a move to one-way aisles and traversal or serpentine (also called S-shaped) routing versus using optimal routing algorithms, the use of random storage versus using class-based (CBS) or volume-based storage (VBS), and the use of strict order, batch picking, and picking zones.

This paper is organized as follows: review of the literature, discussion of physically distance routing strategies, discussion of physically distance storage strategies, discussion of physically distance picking strategies, and then some conclusions.

2. Literature Review

There has been a lot of research on order picking and warehouse operations over the past several decades. The focus of most of this research has been on the implementation of routing, storage and picking strategies to minimize order picking costs.

2.1. Routing Strategies

Routing strategies determine the sequence of stock-keeping units (SKUs) on the pick list with the goal of minimizing the travel distance by the picker (Masae, Glock, & Grosse, 2020). Optimal procedures offer the best solution but may result in confusing routes and could easily violate physical distancing (Ratliff & Rosenthal, 1983; Scholz, Henn, Stuhlmann, & Wäscher, 2016). Heuristics often yield near-optimal solutions while being easy to use (Hall, 1993; Petersen, 1997; Ufuk & Öncan, 2021). Traversal or S-shape routing is where pickers must completely traverse the entire aisle, is used in many warehouses because of its simplicity while still yielding near-optimal results with high pick density (Petersen, 1997). This type of routing offers one-way travel which would be a major advantage in physical distancing. Other simple heuristics are return routing and midpoint routing that also are simple to use and offer near-optimal performance as well (Hall, 1993; Petersen, 1997; Fontin & Lin, 2020).

2.2. Storage Strategies

Storage strategies assign SKUs to warehouse storage locations. An easy strategy is random storage where SKUs are assigned to random throughout the warehouse sometimes by using the closest open location. Random storage is easy to administer and ease picker congestion, but typically results in longer picker travel (Petersen & Schmenner, 1999). Volume-based storage (VBS) strategies assign SKUs based on their picking volume to locations near the pick-up/drop-off (P/D) point (Jarvis & McDowell, 1991; Petersen & Schmenner, 1999). This results in minimizing picker travel, but they are information intensive, are difficult to administer than random storage, and picker congestion tends to result (Petersen & Schmenner, 1999). Like VBS, class-based storage (CBS) partitions SKUs into several storage classes (usually ABC) according to pick activity and randomly assigns the SKUs to warehouse locations within their respective class storage area. The storage class with the highest volume SKUs is located nearest to the P/D point. CBS strategies can yield results close to VBS in automated storage and retrieval systems (Rosenblatt & Eynan, 1989) and in manual warehouses while eliminating the administrative hassle (Petersen, Aase, & Heiser, 2004).

2.3. Picking Strategies

Picking strategies determine how SKUs are retrieved from their storage locations by an order picker. Strict-order picking is where pickers complete a single tour of the warehouse to pick all the SKUs for a single order. Strict-order picking is easy to implement, and order integrity is always maintained. Batching is where orders are grouped into batches and has been shown to significantly reduce total picking time (Gibson & Sharp, 1992; Cergibozan & Tasan, 2019). Zone picking divides the warehouse into zones where one worker is assigned to each zone and they only retrieve SKUs from their respective zone. Wave picking combines batching and zoning where each worker is picks SKUs for numerous orders in their zone. The benefit for these types of strategies becomes apparent as the volumes of orders increases, but zone and wave picking require a downstream operation to consolidate orders from the different zones (Petersen, 2000).

A recent paper by Ardjmand, Singh, Shakeri, Tavasoli and Young (2021) developed a multi-objective procedure to mitigate the risk of COVID-19, however this paper primarily focuses on batching procedures. The aim of this paper is to review prior research and to highlight various routing, storage and picking strategies work best in a physical-distancing warehouse where the goals of employee safety and operational efficiency are both met.

3. Physical Distancing Routing Strategies

This section will highlight the use of the S-Shaped (or Traversal) routing strategy and the possible use of the Midpoint routing strategy to allow for physical distancing yet still achieve near optimal results.

3.1. S-Shaped or Traversal Routing Strategy

One of the simplest strategies for routing pickers is the traversal strategy where a picker enters an aisle from one end and leaves from the other. A picker begins from the P/D (pick-up/drop-off) point and proceeds through all aisles containing picks before returning to the P/D point. This strategy leads to a route in which the aisles, that are to be visited, are totally traversed. Aisles where there are no SKUs to be picked are skipped and the aisles are visited in the shape of a serpentine S that is why this is also called the S-shape strategy. After picking the last SKU, the order picker returns to the front end of the aisle and back to the p/d point. This strategy is used frequently, because it is very simple to use and to understand (**Figure 1**).

Research shows that the traversal routing results in about 20% more travel distance than optimal routing when the Within-Aisle storage strategy (see Section 4.2.1) is used (Hall, 1993). However, it should be noted that as the number of SKUs to be picked (aka the pick density) in an order/batch increases the gap between traversal and optimal routing decreases to almost zero (Petersen, 1997). In examining the effect of the number of SKUs to be picked, the literature shows that with random storage that the gap between traversal routing and optimal routing is 20% with a pick list size of only five SKUs but with the pick list size is 40 SKUs the gap is only 2% (Petersen, 1997). When ABC Storage is used, the gap is 13% for a pick list of five SKUs and down to 3% for 40 SKUs (Petersen, Aase, & Heiser, 2004). In terms of physically distancing, S-shaped travel has one-way travel in aisles making it easier for employees to maintain the proper distance between themselves. It is also an easy route to follow, and this consistency leads to fewer picking errors as well.

3.2. Midpoint Routing Strategy

A midpoint strategy essentially divides the warehouse into two sections. A picker can access an aisle only as far as the midpoint. A picker performs either a return route from the front aisle, a return route from the back aisle, or return routes from the front and back aisles. The picker traverses the last aisle to enter the back section and the first aisle to exit the back section (**Figure 2**).

Heuristic strategies can develop near-optimal routes with less confusion and fewer picking errors (Hall, 1993; Fontin & Lin, 2020). The order picking operations visited by the authors have often used heuristics, ostensibly because they are easy to understand and form routes that are fairly consistent in nature. The heuristics used, however, have tended to be overly simple either the transversal strategy exclusively, the return strategy exclusively, or no set strategy at all. Petersen and Schmenner (1999) showed that the Midpoint routing strategy was only 4% above optimal routing when the Perimeter/Split-Vertical storage strategy was employed. These routes tend to follow the perimeter of the warehouse except for small U-turn trips inside picking aisles to retrieve SKUs. A drawback to midpoint routing is that workers must make a U-turn in a picking aisle and so to maintain physical distancing only one worker should be permitted in each half of the picking aisle, which can be accomplished with employee training and signage.

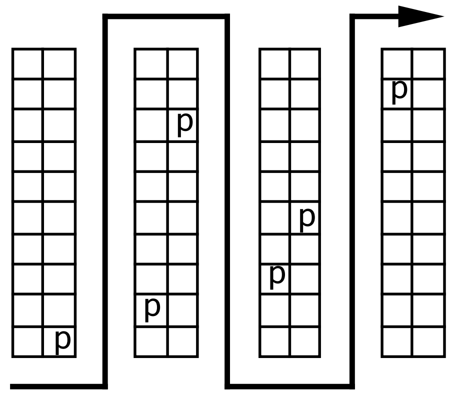

Figure 1. Traversal (S-Shaped) routing strategy.

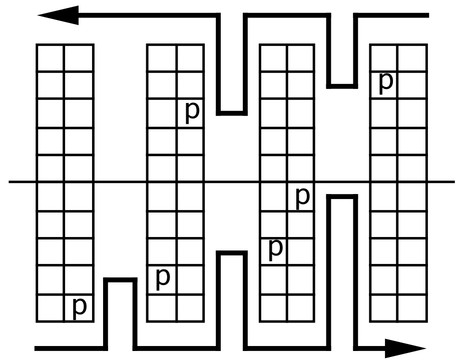

Figure 2. Midpoint routing strategy.

4. Physical Distancing Storage Strategies

This section discusses the use of random storage and the use of several ABC storage strategies that can provide for safe physical distancing and yet still minimize picker travel.

4.1. Random Storage Strategy

The biggest advantage of random storage is that it disperses SKUs throughout the entire warehouse and thereby avoiding any congestion and unsafe physical distancing that results from workers being in the same aisle to pick high-volume SKUs. The major drawback is the increase in picker travel as workers might have to traverse each and every picking aisle. However, this can be offset if the pick density is high so that the traversal routing strategy is optimal or near optimal (Petersen, Aase, & Heiser, 2004).

4.2. ABC Storage Strategy

The other storage strategy is the ABC strategy. If you store your SKUs with the use of this strategy, the SKUs are subdivided into three categories. The grouping of the SKUs into categories is based on the nature as well as the size of the SKUs. Fast moving SKUs (category A) preferably are stored at pick height (the height at which the SKUs can be picked with the least effort) and at the front end of the warehouse. In this way, the distance between depot and pick location will be reduced to a minimum. Slow moving SKUs (category B and C) are stored at the back. To maximize the efficiency of this strategy, it is necessary to change the division of SKUs into categories if changes in demand are large. If some items of category B are ordered more frequently at a certain time, these SKUs might be grouped into category A instead of B. Category A accounts for SKUs which turnover rate are high, and the number of locations is rather small. Category C exists of SKUs which average storage time are much longer than the storage time of the category-A SKUs. These SKUs need relatively more space in the warehouse. Category B is in between category A and C, concerning turnover rate and space needed. With the help of these categories, the warehouse is grouped into three zones in each of which only one category of SKUs is stored).

Prior research has found that using the ABC storage strategy can result in considerable savings in picker travel time (Rosenblatt & Eynan, 1989; Jarvis & McDowell, 1991; Petersen, Aase, & Heiser, 2004; Li, Moghaddam, & Nof, 2016). The layout of the division of the SKUs into categories depends on the location of the depot. Since the depot is the starting point of the route, the A-category will be situated as near as possible to the depot. For instance, if the depot is located at the right side of the warehouse this leads to a layout with the A-zone at the right side.

4.2.1. Within-Aisle (Horizontal) Storage Strategy

Jarvis and McDowell (1991) presented within-aisle (horizontal) storage where the quick-turnover (category A) SKUs are placed in the first aisles closest to the P/D point, the category B SKUs in the next block of picking aisles, and the slow-moving (category C) SKUs are placed in the last aisles of the warehouse. This is shown in **Figure 3** with the category A SKUs in the dark grey shading, the B SKUs in the medium grey shading, and the category C SKUs in the light grey shading. This storage strategy works best with traversal routing but can result in picker congestion which makes physically distancing more difficult (Petersen & Schmenner, 1999; Petersen, Aase, & Heiser, 2004).

4.2.2. Across-Aisle (Vertical) Storage Strategy

In across-aisle (vertical) storage, the category A SKUs are stored across all the picking aisles in the closest storage locations to the front aisle. The category B SKUs are located between the category A SKUs and the category C SKUs which are found closest to the back aisle. This is shown in **Figure 4** with the category A SKUs in the dark grey shading, the B SKUs in the medium grey shading, and the category C SKUs in the light grey shading. Across-aisle storage works best in a warehouse with picking zones of one to several picking aisles so that the highest volume SKUs are always located closest to the front aisle where a conveyor can move the picked SKUs to the shipping area (Petersen & Schmenner, 1999; Petersen, Aase, & Heiser, 2004).

4.2.3. Perimeter (Split-Vertical) Storage Strategy

In perimeter (split-vertical) storage the category A SKUs are located next to the front and back aisles. The low volume C SKUs are placed within the middle of the aisles. This is shown in Figure 5 with the category A SKUs in the dark grey shading, the B SKUs in the medium grey shading, and the category C SKUs in the light grey shading. This strategy would work well with the midpoint routing strategy as the midpoint routes follow the perimeter of the warehouse (Petersen & Schmenner, 1999; Petersen, Aase, & Heiser, 2004). These routes would have less congestion than a traversal route with within-aisle storage and therefore makes physically distancing easier to achieve.

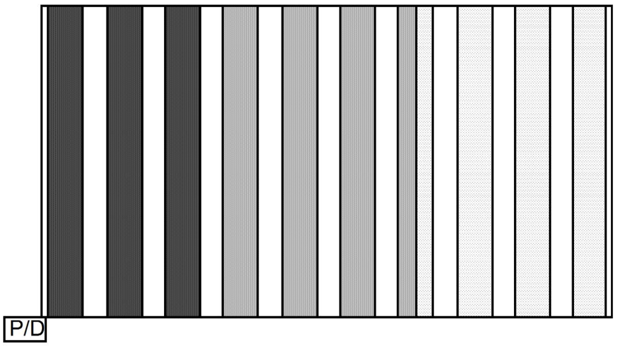

Figure 3. Within-Aisle storage strategy.

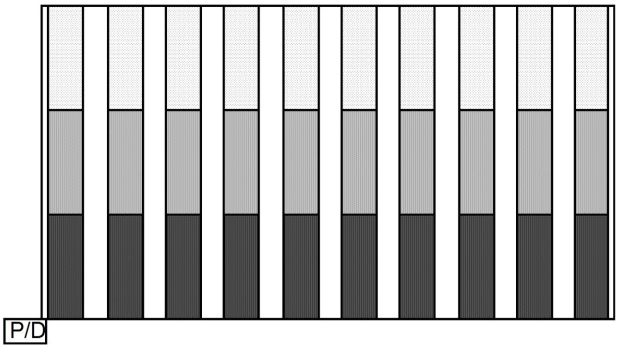

Figure 4. Across-Aisle storage strategy.

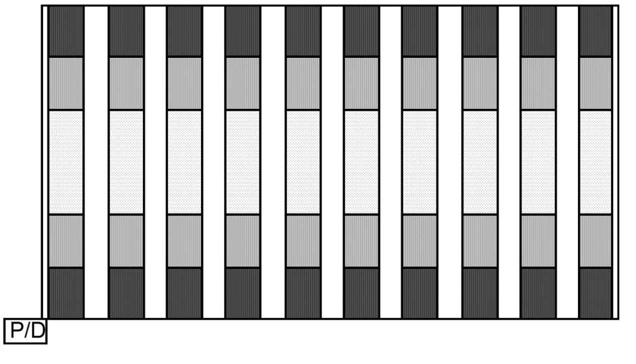

Figure 5. Perimeter storage strategy.

5. Physical Distancing Picking Strategies

There are two basic methods that SKUs can be picked in a warehouse. The first method is where a picker possible travels throughout the warehouse retrieving all the SKUs on their pick list in either strict order picking or batch picking. The second method is where the picker only picks those SKUs in their respective picking zone through either sequential zone, batch zone or wave picking. For picking strategies that uses batches one needs a procedure to construct a batch of SKUs to be picked that doesn't exceed the capacity of the picking vehicle.

5.1. Strict Order Picking

Strict order picking has each picker picking just one order at a time. A picker travels to the first pick location. After the item has been picked, the picker moves to the location of the next item on his pick list. If there are no more items on the pick list, the picker travels to the conveyor and place the items on the conveyor. The picker then proceeds to the P/D point to obtain a new pick list. This process continues until all the orders have been picked. The main advantage of strict order picking is that no sorting or order consolidation is required.

5.2. Batch Picking

Batch picking has each picker picking more than one order on his picking tour. Orders cannot be split between pickers. The procedure for batch picking is similar to strict order picking. A picker proceeds to every pick location on the pick list. After the last item in the batch is picked, the picker travels to the conveyor, places the items on the conveyor and then proceeds to the P/D point to obtain a new pick list. This process continues until all orders have been picked. Since more than one order is picked in a batch, each batch requires sorting prior to packaging. It is assumed that each picker sorts the items into respective orders as he is placing the items on the conveyor (Petersen, 2000). Batch picking usually results in shorter travel distances per item than strict order picking (Petersen, 2000).

5.3. Sequential Zone Picking

In sequential zone picking, a bin containing the pick list for a single order moves from zone to zone on a conveyor. In each zone, the picker picks only those items from his zone that are required for the order. The order is then passed on to the next picker. After the last item of an order is picked, the order is transferred to the packaging area. The advantage of sequential zone picking is that it does not require sorting. The main disadvantage of sequential zone picking is that delays can result if there are imbalances in the workload of the picking zones. If there is an imbalance in the workload between picking zones, a bin may be delayed at a zone causing the worker in the next zone to wait for the bin to arrive at his zone. Delays can also occur from the sequencing of the orders. A worker could be idled if the worker in the previous zone has a string of orders that require more than the expected workload (Petersen, 2000).

5.4. Batch Zone Picking

In batch zone picking orders are batched together and each picker is responsible for picking only the items within his zone. When all items in the batch have been picked, the picker places the items on the conveyor. The next batch does not begin until all pickers have unloaded their previous batch on the conveyor. Workers are positioned downstream to consolidate the items into orders. Batch zone picking is different from the other picking policies described so far in that separate workers are needed for picking and sorting. The advantage of batch zone picking is that the travel time for the picker is shorter than batch picking because each picker is assigned to a zone within the warehouse. The main disadvantage of batch zone picking is that it requires order consolidation. Another drawback is that workloads can vary between zones (Petersen, 2000).

5.5. Wave Picking

Wave picking is a special subset of batch zone picking where pickers pick very large batches based not on a number of items or orders, but rather on a length of time. The length of a wave is commonly anywhere from one half hour to two hours. In wave picking each picker picks continually for the entire wave, pausing only to unload his picking cart as it becomes full. Wave picking is analogous to a two-machine process involving picking and sorting. Pickers pick the first wave and the next wave does not begin until the pickers have completed picking the first wave. Then sorters begin to sort the first wave while the pickers begin picking the second wave. This continues until all orders are picked and sorted. The staffing levels for both pickers and sorters are set at levels that allow all work for a given wave to be completed before the next wave begins (Petersen, 2000).

5.6. Batch Construction

The simplest method for forming batches is first come, first served. As the title suggests the first order in placed into the first batch. This means that the sequence of the arrival of the orders determines how the orders are grouped into batches. Thus, the first batch consists of the first order, the second order, the third order etc. until the maximum capacity of the picking vehicle is reached. If the fourth order cannot be added to this batch one (because there is not enough space left on the picking vehicle), a new batch (batch two) is created. The next several orders are added to the fourth order. The order, which does not fit to this batch anymore due to capacity limitation, is the first order of the next new batch. This algorithm is very simple to use but does not lead to the best batching results (Cergibozan & Tasan, 2019). This procedure can also be used to batches for batch zone picking and wave picking. For batch zone picking, the batch size is based on the picking vehicle capacity in any of the picking zones. Whereas for wave picking, it would be based on estimation of how many orders could be picked within each picking wave.

6. Conclusion

The COVID-19 pandemic has been deadly, has upended the lives of almost everyone on earth, and has been challenging for businesses to provide their products and services while protecting their employees and customers. In a survey of subscribers to Modern Material Handling (2021), more than 200 responses confirmed challenges such as labor shortages and supply chain delays of products deliveries are compounded with increase customer demand. This paper focuses on showing how tried and true heuristic procedures pertain to routing, storage and picking can be used with physical distancing and still yield near-optimal solutions.

If picking zones are possible, utilize them. Picking zones make physical-distancing easy to implement. Sequential zone picking would require workers to transfer bins/totes to each other, but order integrity is maintained so that no downstream sorting of orders is required. Batch zone and wave picking are very efficient and satisfy physical distancing but both methods do require downstream order sorting/consolidation.

If zones are not possible, batch orders to increase pick density for traversal routing. Traversal routing has the big advantage of utilizing one-way travel which makes physical-distancing easier to implement. Utilizing within-aisle picking offsets some of the potential increase in picker travel caused by using traversal routing. If fewer order pickers are used, one may consider using midpoint routing and perimeter storage. This does cause workers to make U-turns in every aisle that must be accessed but make it a rule that only one worker may be in each half of an aisle to ensure physical distancing.

The major limitation of this research is that it only examines the use of routing, storage, and picking strategies in adjusting order picking operations to the current state of safety precautions due to the COVID-19 global pandemic. An extension of this paper would be to simulate physical distancing in the warehouse while using various routing, storage, and picking strategies. Further research should examine the use of order picking technologies that might better protect workers from COVID-19 and keep firms competitive.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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