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The effect of one-way aisles on retail layout

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A R T I C L E   I N F O

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A B S T R A C T

As part of the initiative to prevent the spread of the novel coronavirus (COVID–19), many retailers implemented one-way aisles in their stores. Moreover, the retailing research literature has shown a significant positive relationship between the distance that shoppers travel within the store and their resulting unplanned purchases. To evaluate the effect that one-way aisles have on the amount of traffic flow in the store, we use the traveling salesperson problem to determine the increase in distance traveled as well as the increase in the area within the store that is covered by the shopper. Overall, our results indicate that shoppers may travel 50 percent further with one-way traffic and cover an additional 67 percent of the store area, a significant increase in the amount of product and in-store stimuli exposed to the customer. We also present other advantages and disadvantages of the continued use of one-way aisles after the pandemic subsides.

1. Introduction

There’s a reason why grocers put the dairy case at the back of the store or why the pharmacy is at the back of drugstores, it’s to get the customer to pass through (and shop) much of the rest of the store (Underhill 2009). “Marketing researchers have long hypothesized that traveling further in a store will lead to more unplanned purchases” (Hui et al. 2013). Hence, the facility layout decision for retailers is different than that for manufacturers in that it may be desirable to increase the distance that shoppers travel through the store—and therefore expose greater exposure to in-store products and other stimuli—in order to maximize revenue (see, for example, Hirpara and Parikh 2021).

Coronavirus disease 2019 (COVID–19) has affected retailers in many ways, not only financially, but also operationally (e.g., Pantano et al. 2020, Roggeveen and Sethuraman 2020). In addition to requiring masks, increased sanitation, and limiting the number of customers in the store, many retailers have converted the aisles in their stores to one-way traffic in order to limit interpersonal contact and disease transmission. “The one-way aisle is the latest traffic-control measure to be implemented by US grocery retailers to encourage physical distancing during the coronavirus pandemic” (Wallace 2020). In fact, Oak Park, Illinois, issued a public-health order concerning social-distancing requirements for stores that sell groceries, which includes “stores must control the flow of shoppers through their stores by use of one-way aisles to reduce the frequency of customers crossing paths” (Oak Park 2020).

One-way aisles have been in use before the current pandemic; over a century ago, Piggly Wiggly utilized a one-way aisle such that the shopper “will be required to review the entire assortment of goods carried in stock, conveniently and attractively displayed” (Tarazano and Daemmrich 2020). More recently, Stew Leonard’s stores, a chain of supermarkets in the northeast United States, employ a single one-way aisle winding through the store to give the shopper an immersive food experience (Acosta and Troy 2020). Nonetheless, the recent COVID–19 outbreak has prompted a number of retailers to institute one-way movement through aisles to slow the spread of the disease; for example, Walmart, The Kroger Company, Hy-Vee, and Giant Food have each implemented one-way aisles in their stores (Redman 2020, Wallace 2020).

As we look to the future, should retailers continue to use one-way aisles after the pandemic subsides? According to Dahlhoff (2020), “retailers’ initial task will be to lure customers back, and that requires making people feel safe in stores.” Horovitz (2020) lists several tactics to keep shoppers safe in the post-pandemic world, one of which is creating one-way aisles. Thus, the focus of this note is to investigate the continued use of one-way aisles. Specifically, we will analyze its effect on the potential unplanned sales increase by evaluating the increased traffic flow through the retail facility, considering both the incremental travel distance as well as the incremental exposure to additional product.

To illustrate this effect, Fig. 1 identifies a path taken through a store with two-way aisles to purchase ten items. Notice that much of the store has remained unvisited by this customer. Implementing one-way aisles that would direct the customer to continue down each aisle—rather than backtrack to the outer racetrack aisle—would considerably increase the

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amount of product and in-store stimuli exposed to the customer which, in turn, would lead to increased unplanned sales.

The remainder of our paper is as follows. In the next section, we review the relevant literature. The model used to measure the effect of moving from two-way to one-way aisles is presented in Section 3. In Section 4, we provide the results of the analysis, which indicate a significant increase in traffic flow. Discussion on the advantages and disadvantages of the continued use of one-way aisles in the post COVID–19 world are presented in Section 5. We then close with our conclusion, limitations of the analysis, and suggestions for future research.

2. Literature review

In this review of the literature, we first consider the marketing side of our analysis, illustrating the effect of increasing the distance that customers travel in the store on subsequent sales. We then look at the operations aspect to take advantage of this effect in evaluating the development of appropriate retail facility layouts. Finally, we briefly examine the emerging research investigating the effects of COVID–19 on retail supply chains, particularly as it relates to our analysis.

“A fundamental function of retailing is to bring products into the view of shoppers” (Streicher et al. 2021). Sorensen et al. (2017) note that the proportion of a retail store visited by a customer averages approximately 23 percent. Thus, most customers are not exposed to the majority of the product offered by the retailer. Stilley et al. (2010) note that an increase in the number of aisles visited and the time spent in the store tends to increase unplanned purchases. Gilbride et al. (2015) show that “the propensity to make unplanned versus planned purchases increases over the course of the shopping trip.” In a field study of a medium-sized grocery store, Hui et al. (2013) found that a 10 percent increase in path length would result in a 16.1 percent increase in unplanned spending. Yim (2017) found a positive and significant relationship between a shopper’s walking distance and their overall spending (a standardized regression coefficient of +0.30). Data collected at a retail store in Tokyo reveal that the mean as well as the variance of the number of items purchased increase as the customer’s travel distance increases (Ohnori et al. 2019), and this increased variance suggests customers have different needs which may be difficult to meet with a single approach.

Since store layout is known to have a significant impact on consumer behavior (Krasnikolakis 2018), recent research has focused on retail facility-layout design. Yapicioglu and Smith (2012) evaluate a racetrack layout with regard to the degree of adjacency satisfaction among the departments as well as the revenue generated which, in turn, is affected by the area and the location of a department within the store. Association rules—for example, the percentage of customers that purchased item i who also purchased item j—are utilized to develop layouts to reduce customer’s search time by clustering items that are similar to each other (Cil 2012) and to induce customers to increase their in-store walking distance by separating items that are similar to each other (Bermudez et al. 2016). Boros et al. (2016) categorize the customers into a “small finite number of customer types,” then use an optimization model to maximize the sum of the minimal route lengths of customers weighted by the frequencies of the customer types. Ozgürmus and Smith (2020) propose a data-driven approach for the grocery-store block layout problem that incorporates impulse purchases and adjacencies (also utilizing association rules) as well as shelf-space allocation. Hirpara and Parikh (2021) propose a model to optimize the placement of departments in the store to maximize expected impulse revenue by placing the high planned-purchase departments away from the door with the high impulse-purchase departments along the resulting high-traffic aisles.

The coronavirus pandemic has obviously had a major impact on retail supply chains (SC). While resilience to SC disruptions (tsunamis, labor strikes, etc.) has always been a concern, the global and pervasive nature of the COVID–19 crisis has brought this concern to the forefront. Queiroz et al. (2020) conduct a systematic literature review on the impact of epidemic outbreaks on SCs and propose a framework for supply-chain management that spans six perspectives: adaptation, digitalization, preparedness, recovery, ripple effect, and sustainability. Ivanov (2020) proposes the concept of a viable SC spanning agility, resilience, and sustainability, in order to design SCs that can react to disruptions and to guide them on recovery after global, long-term crises. Brandtner et al. (2021) analyze customer satisfaction at the retail point-of-sale and find a general and significant decline due to COVID–19; most relevant to our study, they find that customers “prefer a shopping experience where the store layouts and markings ensure less human to human contacts.” Schleper et al. (2021) study the impact of COVID–19 on one specific retailing company and, among other effects, note that modifications made to the store layout (e.g., the re-direction of customer flows one-way through stores or the protection of certain fresh goods through barriers) in relation to this peculiar crisis may have novel effects. Finally, many retailers have responded to the pandemic by delivering groceries and other retail products or incorporating curbside pick-up options (Fotouhi et al. 2021), and by providing other innovative service-delivery systems, such as “bring-service-near-your-home” mobile service operations (Choi 2020).

3. Model

To analyze the effect of one-way aisles on the distance that shoppers travel in the store, we assume the shoppers will come into the store with a shopping list, and continue through the store based on the shortest distance (i.e., the traveling salesperson problem, TSP). In a study of supermarket traffic flow, Farley and Ring (1966) assume customers travel from one area to another via “the path which involves the least amount of travel” and note that this ‘rational consumer’ or ‘energy-conserving’ assumption seems to yield valid predictions. While it is known that shoppers do not strictly follow the TSP route (Hui et al. 2009), this gives us an unbiased comparison of one-way vs. two-way aisles.

We use a modification of the classic Miller-Tucker-Zemlin (1960) formulation of the traveling salesperson problem in which the items on the shopping list are the ‘customers’ and the shopper is the ‘salesperson’ traveling from one item to the next. Let n be the number of locations that the shopper will visit (i.e., the number of items on the shopping list plus two: the entrance and the exit/checkout), and let d_{ij} be the distance from item i to item j (i,j = 1, ⋯, n) where item 1 is the entrance to the store, and item n is the exit/checkout. Then x_{ij} = 1 if the shopper travels directly from item i to item j, x_{ij} = 0 otherwise. The shopper’s objective is to collect all items on the shopping list as efficiently as possible. Thus, the appropriate formulation is as follows:

Minimize \[ \sum_{i \neq j} d_{ij} x_{ij} - d_{0} \] (1)

subject to: \[ \sum_{j \neq i} x_{ij} = 1, \quad i = 1, \ldots, n \] (2)
$$\sum_{i,j} x_{ij} = 1, \quad j = 1, \ldots, n$$  \hspace{1cm} (3)

$$u_i - u_j + nx_{ij} \leq n - 1, \quad i, j = 2, \ldots, n, i \neq j$$  \hspace{1cm} (4)

$$0 \leq u_i \leq n - 1, \quad i = 2, \ldots, n$$  \hspace{1cm} (5)

$$x_{ii} = 1$$  \hspace{1cm} (6)

$$x_{ij} \in \{0, 1\}, \quad i, j = 1, \ldots, n$$  \hspace{1cm} (7)

$$u_i \in \mathbb{Z}, \quad i = 2, \ldots, n$$  \hspace{1cm} (8)

The objective (1) is to minimize the total distance traveled less the distance from the exit to the entrance (which is included in the TSP tour). Constraint sets (2) and (3) are the standard assignment constraints. Constraint sets (4) and (5) are the subtour elimination constraints. Constraint (6) ensures the tour includes the link from the exit to the entrance which, again, does not exist, but completes the TSP tour and ensures the shopper starts at the entrance and finishes at the exit. IBM ILOG CPLEX Optimization Studio, Version 12.8, was used to identify the optimal tours. Due to the small size of the resulting TSPs, no attempt was made to further tighten the formulation or to otherwise account for the asymmetric distance matrices with one-way aisles (e.g., Sherali and Driscoll 2002).

For the comparison of one-way and two-way traffic, we consider a ten-aisle, grid layout as shown in Fig. 2. This is patterned after “Layout 1” of a 1,200 square meter store located in a shopping mall in Istanbul, as presented by Özgürmuş and Smith (2020), and from “Example 1” of the Own a Dollar Store website (https://www.ownedollarsstore.com/storelayout.php). Note that a larger facility may have multiple grid units (Botsali 2007), so this analysis is also valid for those retailers as well. For both the two-way and one-way facilities, we consider placing the entrance and exit at one corner of the store (Fig. 2a) as well as near the middle of the store (Fig. 2b). Also note that the aisles at the top and bottom of Fig. 2 are two-way aisles even for the one-way configuration; these are “racetrack” aisles to move conveniently from one aisle to another. While this layout will likely result in multiple optimal solutions, the path provided by the TSP was used, no attempt was made to identify alternate tours.

Other than the entry and exit, the item locations (i.e., the aisle and the location within the aisle) were randomly generated uniformly throughout the store. Shopping list sizes of 5, 10, and 20 items were considered (i.e., an average of 5/2, 1, and 2 items per aisle, respectively); five instances were generated for each. For each instance, the traveling salesperson problem was solved for four scenarios: one-way vs. two-way aisles and for the entrance/exit at the corner vs. in the middle of the store. When there were multiple paths of equal distance between two items of the TSP solution, paths were selected to avoid traveling the same route as much as possible.

4. Results

The distance that shoppers travel within the store is affected by all three factors considered in this analysis. A 2 (one-way vs. two-way aisles) × 2 (corner vs. middle location of entry and exit) × 3 (5 vs. 10 vs. 20 items) repeated measures analysis of variance was performed. All three main effects are significant (p-values < 0.01), the items × entry interaction term is significant (p-value = 0.0105), and all other interaction terms are not significant (p-values > 0.25). Looking first at the interaction, the location of the entrance/exit location has a little effect when there are many items (as much of the store is visited with either location), but more of an effect with fewer items. Even with fewer items, the entrance/exit location has a relatively small absolute effect on the distance traveled, while that of the number of items is considerably greater.

Of particular interest for this study, though, is the effect of one-way aisles on the traffic flow. To illustrate this, Table 1 presents the mean percent increase in distance traveled using one-way aisles relative to two-way aisles. Overall, shoppers travel an average of 50 percent farther with one-way aisles, which would likely result in a considerable increase in unplanned sales. It is particularly evident with smaller shopping lists, with increases of 68 percent, 49 percent, and 33 percent for the 5-, 10-, and 20-item instances, respectively. As the number of items increases, more of the facility is visited even with two-way traffic, so the impact of one-way aisles is diminished although still quite substantial. An interesting observation is that when there are an odd number of aisles with items on the shopping list, there will necessarily be at least one empty aisle trip for the one-way aisles, providing additional product exposure.

A striking aspect of many of the paths for the two-way aisle solutions is that a fair amount of backtracking occurs, as illustrated by the path from one of the 10-item instances as presented in Fig. 1 in the Introduction. Note that the shopper goes into an aisle for an item and returns to the racetrack aisle the same way. This is consistent with the analysis of Larson et al. (2005) using RFID tags on shopping carts; they note that shoppers “tend to travel by short excursions into and out of the aisle rather than traversing the entire length of it.” Perhaps the store area coverage would be a more meaningful measure than the distance that shoppers travel due to the exposure to additional product and displays, instead of seeing the same product twice.

| Number of Items | Distance Traveled | Store Area Coverage |
|-----------------|-------------------|---------------------|
|                 | Corner Entry | Middle Entry | Corner Entry | Middle Entry |
| 5               | 64.1        | 71.4            | 76.7        | 80.3        |
| 10              | 48.4        | 50.1            | 78.4        | 76.5        |
| 20              | 33.2        | 32.6            | 47.1        | 46.7        |

Note: These figures represent the mean percent increase for one-way over two-way aisles.
Therefore, the store area coverage—that is, the proportion of the store layout that the shopper visits—is also considered in Table 1, again providing the mean percent increase for a one-way aisle configuration over that of two-way traffic. A\(2 \times 2 \times 3\) repeated measures ANOVA was also conducted on this measure, with the aisle and items main effects significant at the one percent level, the entry main effect significant at the ten percent level, and none of the interaction terms significant (p-values > 0.25). Overall, the shoppers visit 67 percent more of the store area with one-way aisles while only traveling an additional 50 percent. This ranges from 78 percent for the 5- and 10-item instances to 47 percent for the 20-item instances. While the impact of one-way traffic is greatest for relatively small shopping lists (one item per aisle or less), it is still quite substantial for all scenarios considered.

5. Discussion

So, should retailers continue to use one-way aisles as part of the new normal after the pandemic subsides? Our analysis indicates that one-way aisles have a considerable impact on the traffic flow within a retail facility which may result in additional sales. While a great deal of research has been conducted in areas such as shelf planning (product assortment, shelf-space allocation, and product positioning; see Bianchi-Aguirau (2021) for a review), inventory-level-dependent demand models (Balakrishnan et al. 2004, 2008), promotional displays (Pak et al. 2020), and rack orientation (Guthrie and Parikh 2020), these undertakings would have little effect on sales if the shopper does not visit those aisles. Incorporating one-way aisles would ensure that a greater proportion of the facility will be seen by the shopper. And an unexpected consequence identified by this analysis is that this benefit exceeds the extra effort required; with a 10-item shopping list, for example, one-way aisles increase the store’s area covered by the shopper by an average of 77 percent with just a 49 percent average increase in distance traveled.

In addition to the potential for greater unplanned sales, there are other advantages of continuing the use of one-way aisles. Research shows that implementing one-way movement within stores can be effective for reducing the number of close interactions among customers (Shumsky and Debo 2020). People at increased risk, such as older adults, immunocompromised individuals, persons with certain underlying medical conditions and—depending on the efficacy of vaccines, perhaps everybody—may continue to prefer some measure of social distancing. Even disregarding the pandemic, perceived retail crowding may have an effect on shopper’s satisfaction and attitude towards the store (Mehta 2013, Blut and Iyer 2020, Aydilin et al. 2021). And with one-way movement, the aisles could be somewhat narrower, so a retailer could potentially install more of them in a given footprint. Disadvantages include the difficulty in enforcement, including the cost of signage, workers needing to remind shoppers, etc. Shoppers may not follow the one-way signage, either due to simply forgetting or intentionally flouting one-way aisle policies (Silverstein 2020). The concept of spatial convenience may extend from the distance between stores in a shopping center or mall (Reimers and Clulow 2004) to the wider variety of stores/layouts would be relevant. Research incorporating shelf-planning decisions with facility layout design utilizing one-way aisles would be useful. Finally, it should be noted that the focus should be on improving a firm’s profitability—not simply an increase of unplanned sales—as these two goals may be correlated but not necessarily identical.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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