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# Designing Retail Facilities to Improve Product Exposure

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# **XIX. DESIGNING RETAIL FACILITIES TO IMPROVE PRODUCT EXPOSURE**

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## **Abstract**

A retail facility should effectively engage consumers during their shopping trips if they want to convert demand into purchases. Unfortunately, the complexity of the retailing environment and lack of scientific tools often results in gut-feel approaches experimented in practice. A key factor to retail design often alluded to, but rarely analyzed, is product exposure to the travelling shopper. We define the extent of the shopper's field of vision in order to determine the actual exposure of products experienced by a traveling shopper. In so doing, we can explore the effect rack orientation has on product exposure. Our main contributions include defining product exposure and an approach to estimate it at any point along the travel path. Our results indicate that certain rack orientations result in product exposures as high as 2.5 times that of the traditional 90° orientation.

## **1 Retail Design Background**

Manufacturing and distribution facilities have received much attention over the years with regards to efficient and near-optimal layout designs. On the contrary, little attention has been given to layout design of retail stores --- the customer-facing component of the supply chain --- despite the fact that operations of more than 3.6 million U.S. retail establishments contribute nearly \$2.5 trillion to the US annual GDP [1].

Retailers have found that it is to their mutual benefit to design shopping environments that effectively engage customers and help convert demand into purchase [2]. The shopping environment, including a store's layout, determines how customers shop, which affects time spent in the store, navigation through the aisles, and allocation of their attention and money across departments and categories [2]. Studies have linked the customer's sense of control to perceptions of good shopping experiences, which improves the probability of higher sales and future shopping trips [3, 4]. To this extent, layout designs should ensure that shoppers feel in control of their activities, affording them greater opportunity to explore the store environment and locate their desired products easily [4], as well as expose the shopper to as many products as possible.

Retail layout problems differ from manufacturing and distribution layout problems in many ways, a few of which include the following: (1) retailers largely focus on maximizing sales

instead of minimizing travel time and/or material handling costs that are typically adopted in manufacturing context; (2) customer travel paths are highly variable and unpredictable as opposed to the well-defined flow of materials in a manufacturing facility; (3) customer demand can be influenced by product placement, promotions, and stimuli; and (4) department adjacencies are often purposely violated to encourage shoppers to travel through most of the store to increase impulse purchase. Unfortunately, the complexity of the retailing environment and lack of scientific tools often result in gut-feel approaches tried out in practice.

A key aspect of retail design (in particular layout), often alluded to but rarely analyzed, is product exposure to the shopper along their travel path. Product exposure is critical because the first condition of a sale is visual reach; “what is not seen does not exist for the shopper” [5]. From a shopper's perspective, a greater amount of product exposure means less time spent searching for items of interest. From a retailer's perspective, converting a shopper's time from searching to purchasing would likely result in increased sales.

We introduce a new paradigm to retail facility layout with the objective of maximizing exposure of products to a shopper as she travels along the main aisles in the store; we refer to a shopper as *her* throughout this paper. Our research was motivated by observing variable rack orientations at stores of two leading retailers in the US and subsequent discussions with the respective store managers. The overall outcome of these discussions was that there is no consensus, and many times insights, into why racks should or should not be placed orthogonally to a shopper's path and how this affects sales. This general lack of understanding in practice and science in academic literature prompted us to develop tools that quantify product exposure with regards to a shopper's field of vision (defined by depth and angle) and the presence (or lack) of obstructions between the product and the shopper. The goal of this research is to develop a framework that not only quantifies product exposure analytically, but also identifies optimal rack orientations that maximize exposure and related measures. We believe this research has the potential to extend IE/OR techniques to an important economic sector that has received limited attention.

We begin by reviewing existing literature in Section 2 and present our motivating research question in Section 3. We discuss how product exposure is estimated in Section 4 and present a space model in Section 5. Preliminary insights are discussed in Section 6, while Section 7 summarizes our contributions.

## **2 Literature Review**

Marketing literature has long established the necessity of product exposure and its relationship with sales. Cairns [6] conjectured that sales are a function of the number of people to whom the product is exposed to in retail stores. The more likely a product is to be seen by a shopper, the more likely it is to be purchased on impulse [7]. Anderson [8] claimed that the significance of product display area in retail stores stemmed from the importance of physical product exposure as a sales stimulus. Drèze et al. [9] maintained that the visibility of a product influenced its probability of purchase. Layout of departments and racks, besides other factors such as lighting, signage, and shelf placement, are primary determinants of the level of product exposure in a retail facility.

While the facility layout problem is well-defined and studied for manufacturing facilities, the focus has primarily been on minimizing cost [10]. Alternative aisle arrangements, such as non-orthogonal aisles, have been proposed in warehousing literature that focus on reducing picker

travel [11]. Realizing that a store's layout impacts customer shopping experience beyond just travel, IE/OR researchers have begun to work on optimizing retail layout in order to maximize store revenue.

The earliest work we know of is that of Peters et al. [12], who applied optimization-based techniques for manufacturing facility design to retail, developing a framework for a quantitative approach to the design of retail facilities. They presented models for expected distance and tour length of various layout designs, assuming that a shortest distance path was always taken for a known shopping list. Building on this work, Botsali and Peters [13] developed a network-based model specific to the serpentine layout that maximized expected impulse purchase revenue. This model used a product visibility factor in its revenue function that was based on the number of times a product was located directly beside the shopper's path.

Li [14] developed a model that maximized total exposure of the retail area by searching all the possible locations of the central racetrack aisle. The final exposure value for a grid in the retail area was defined as the sum of the exposure from the two closest aisle grids. More recently, Yapicioglu and Smith [15] developed a model and solution approach to design the block layout of a single-story department store. Their approach consisted of locating departments within a racetrack layout in order to maximize revenue while maintaining adjacency satisfaction. Revenue generated by a department was defined as a function of its area and its exposure to the aisle network. They broadly defined visibility as the location of a department within a pre-defined traffic zone (i.e. high departmental exposure would coincide with its location within a zone that has a large traffic density).

The above research concerning exposure in a retail setting proposed estimates of visibility/exposure based on distance and adjacency, but none actually considered it from the shopper's perspective. We intend to fill this gap by incorporating how a human eye perceives the world into an analytical framework. We use a multi-disciplinary approach, employing concepts from Marketing, Human Factors, and Operations Research, in order to derive methods and expressions to quantify exposure of products on racks to a traveling shopper. We now state our research question and present preliminary models and findings around product exposure.

### **3 Research Question**

At the heart of our research is the following question: *how does product exposure vary with rack orientation?* When we consider that nearly 80% of total shopping time is spent simply wandering and navigating through the store [5], identifying an optimal rack orientation to maximize product exposure to the traveling shopper has the potential to substantially impact sales.

### **4 Product Exposure**

Our proposed measure to quantify product exposure is based on how a human eye perceives the world; i.e., the shopper's field of view (FOV). While there are two fields of view, namely horizontal and vertical, it is reasonable to assume that the prominent scan-pattern of a shopper while walking through the main aisle is to scan the racks in front horizontally (along the vertical axis), compared to vertically (along the horizontal axis) [16]; i.e., most shoppers turn their heads horizontally rather than vertically when browsing products on the racks (see Figure 1). Note that when standing next to a rack in a cross-aisle, the prominent pattern would likely be vertical. Though this form of product exposure on a rack is important as well, for this preliminary

analysis, we limit ourselves to product exposure when traveling through the main aisles. Considering this assumption, for our preliminary analysis, the measure of product exposure that we propose focuses primarily on the horizontal FOV, in a sense reducing the underlying 3D problem to a 2D one. That is, if a shopper is exposed to any product on a rack face within the horizontal FOV, then we assume that s/he is able to see all products on that rack face.

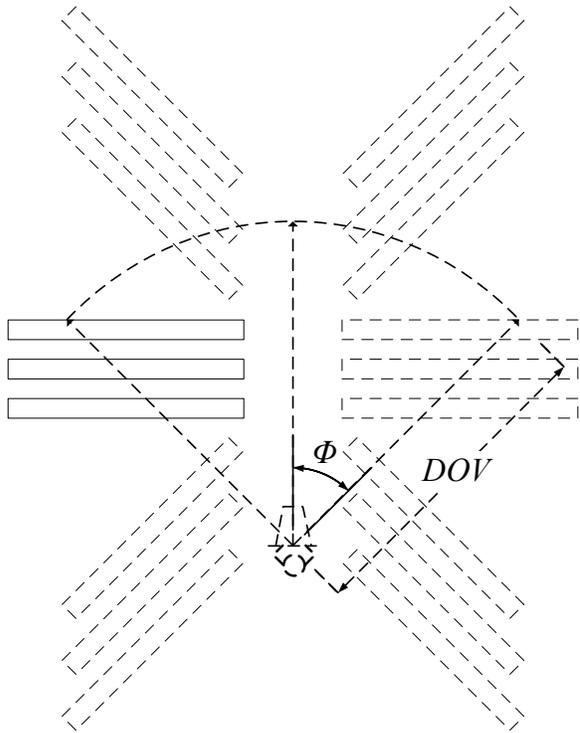


Figure 1: Two-dimensional shopper's field of regard for various rack orientations

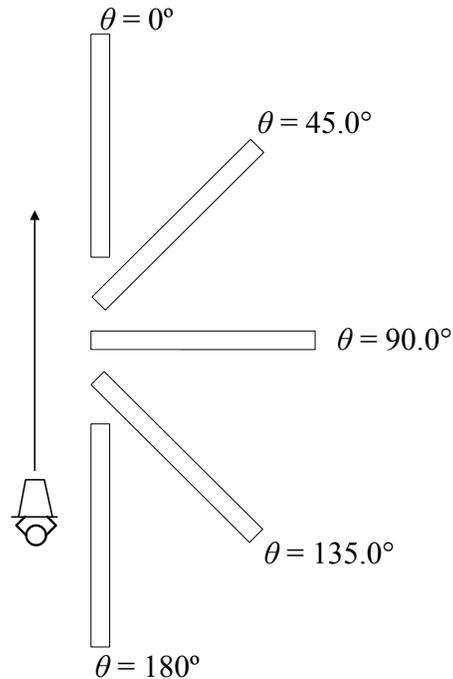


Figure 2: Rack orientation ( $\theta$ ) with respect to the shopper's travel path

The visibility of products in a store depends on both the shopper's FOV (defined by depth and angle) and the presence (or lack) of obstructions between the product and the shopper. While racks are designed to display products to the customer, they can in fact inhibit the exposure of a product to the shopper based on their orientation to the travel path. By defining the extent of the shopper's FOV, we can identify how and when racks obstruct product exposure to the shopper. With this information, it is possible to determine the actual exposure of products experienced by a shopper traveling along a path. Once exposure is quantified, we can then analyze how product exposure varies with rack orientation. Figure 2 provides some examples of different rack orientations where  $\theta$  represents the degree of rack rotation from primary direction of travel measured clockwise. We first discuss the human eye's field of regard and how we use that concept to quantify exposure.

#### 4.1 Human Eye's Field of Regard

Only a small region of our FOV, approximately  $2^\circ$  immediately surrounding the center of our fixation, perceives details necessary for information extraction [16-18]. For this reason, we

approximate our useful FOV to be the fixation point; i.e., our line of sight. In our analysis, we assume that our shopper will scan the racks along the pathway from side-to-side, perpetually. Consequently, the shopper's fixation point can fall upon all products within the field of regard (FOR), which is the total visual field that is potentially available for viewing. More explicitly, FOR is defined as the angular size of the visual scene that is within the range of viewing angles possible for the given system [19]. While this assumption is limiting as a shopper would rarely scan products in such a manner during her shopping trip, this approach does provide an upper bound to the total number of products exposed to such a shopper for a given rack orientation.

We characterize the FOR as a visual sector with 2 parameters, the angular limit of visual scanning from the forward line of sight,  $2\Phi$ , and the depth of focused vision,  $DOV$  (Figure 1). We use concepts from the Human Factors domain to quantify these two parameters as discussed below.

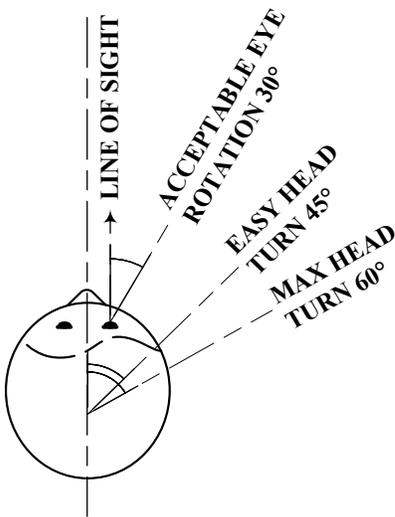


Figure 3: Horizontal extent of head and eye movement

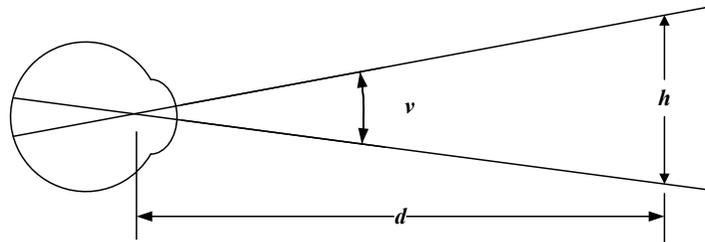


Figure 4: The visual angle

Easy horizontal head movement is considered to be  $45^\circ$  on each side from the forward line of sight [20]. In addition to head movement, the eye can also easily rotate  $15^\circ$  on each side from the forward line of sight (Figure 3). Combined, the shopper's fixation can be located anywhere between  $0^\circ$  and  $60^\circ$  on each side (right and left) from the forward line of sight [20, 21]. It is, therefore, reasonable to assume that the overall FOR ( $2\Phi$ ) may assume any value between  $0^\circ$  and  $120^\circ$  since  $\Phi$  (FOR on one side) may assume any value between  $0^\circ$  and  $60^\circ$  as shown in Figure 3.

To determine the depth of a shopper's focused vision,  $DOV$ , we use the visual angle ( $v$ ) expressed as  $v = 2\arctan\left(\frac{h}{2d}\right)$ . Here,  $h$  is the height of the object and  $d$  is the distance from the optical center of the eye to the object; see Figure 4 [18]. If we assume recognizable packaging encountered in the retail setting to be at least 0.5 inches tall, and that the average shopper has 20/20 vision ( $v = 5$  arcmin), we can estimate the approximate depth of vision ( $DOV$ ) for a shopper to be approximately 25 ft. We next discuss how we use these two parameters in estimating product exposure.

## 4.2 Estimating Product Exposure

Given the diversity of product sizes and packaging, we estimate product exposure at any point on the shopper's travel-path using rack-length (in ft) as a surrogate for actual products. In the case where the shopper perpetually scans the area in front of her to the maximum degree possible ( $2\Phi$ ), we further assume that (i) the shopper will travel down the center of the pathway (main aisle) and (ii) racks on both sides of the pathway will be oriented and arranged symmetrically (i.e., the left side will mirror the right side). Based on these assumptions, the exposure for the entire system will be twice the amount determined for one side. We can therefore estimate the exposure of one side of the travel path, by defining a section of the FOR using  $DOV$  and  $\Phi$  (representing the angle of the sector on one side of the forward line of sight).

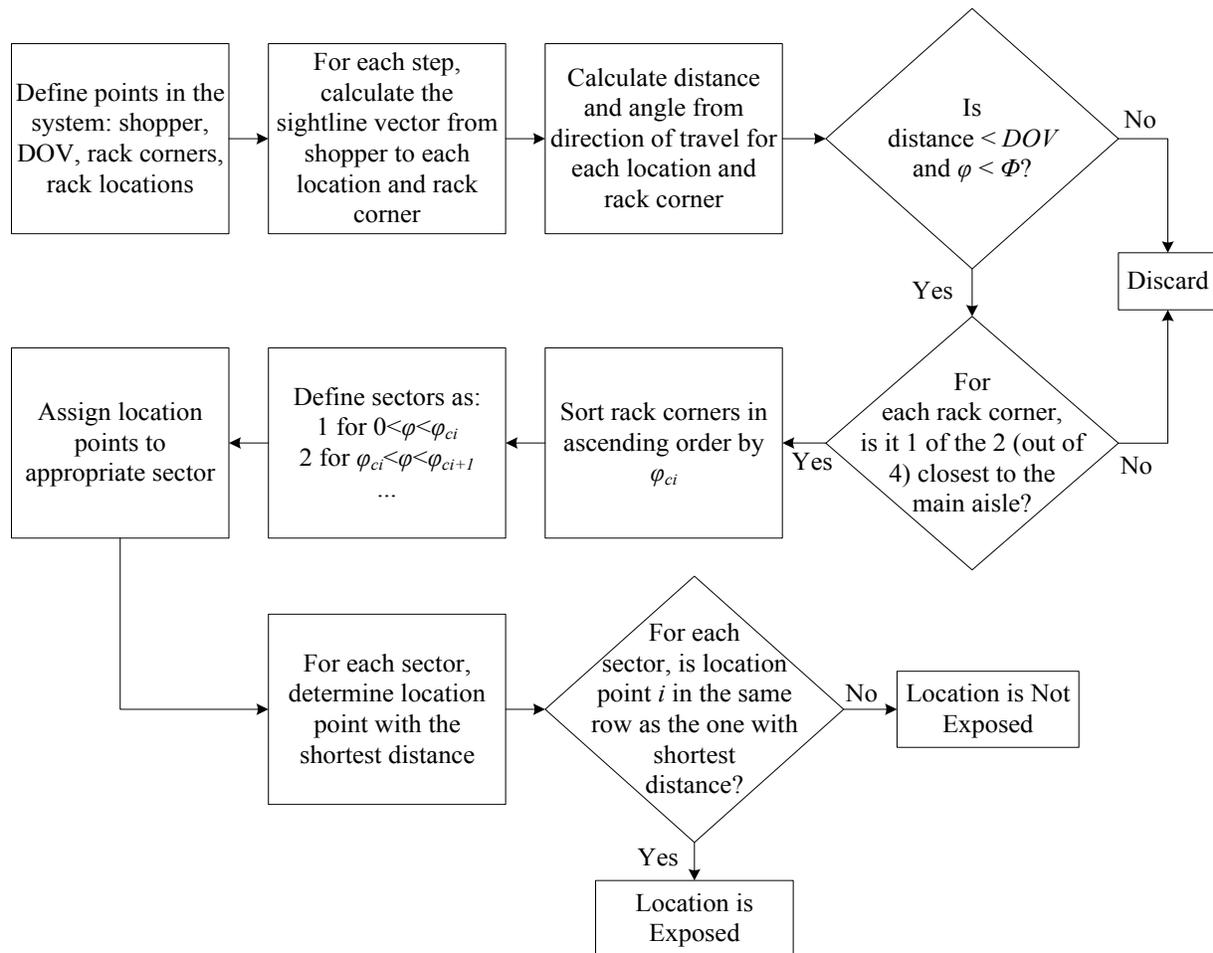


Figure 5: Flow chart depicting the details of the slicing algorithm

We propose a slicing algorithm (Figure 5) that determines the total rack-length that lies within one side of the shopper's FOR and differentiates which parts of the rack are exposed. This algorithm sweeps across the FOR, just like a human eye does, in estimating the total exposed rack-length. We discretize the individual rack faces into multiple locations. Each location

represents a prespecified length of the rack on that face (say, 1 ft), potentially representing a rack opening.

Figure 6 illustrates the slicing algorithm, where rack corners are used to slice the FOR section into sectors. Those locations whose angle and depth are unobstructed and lie within the FOR section will be exposed; e.g., a rack is only exposed partially, not in terms of height, but in terms of depth.

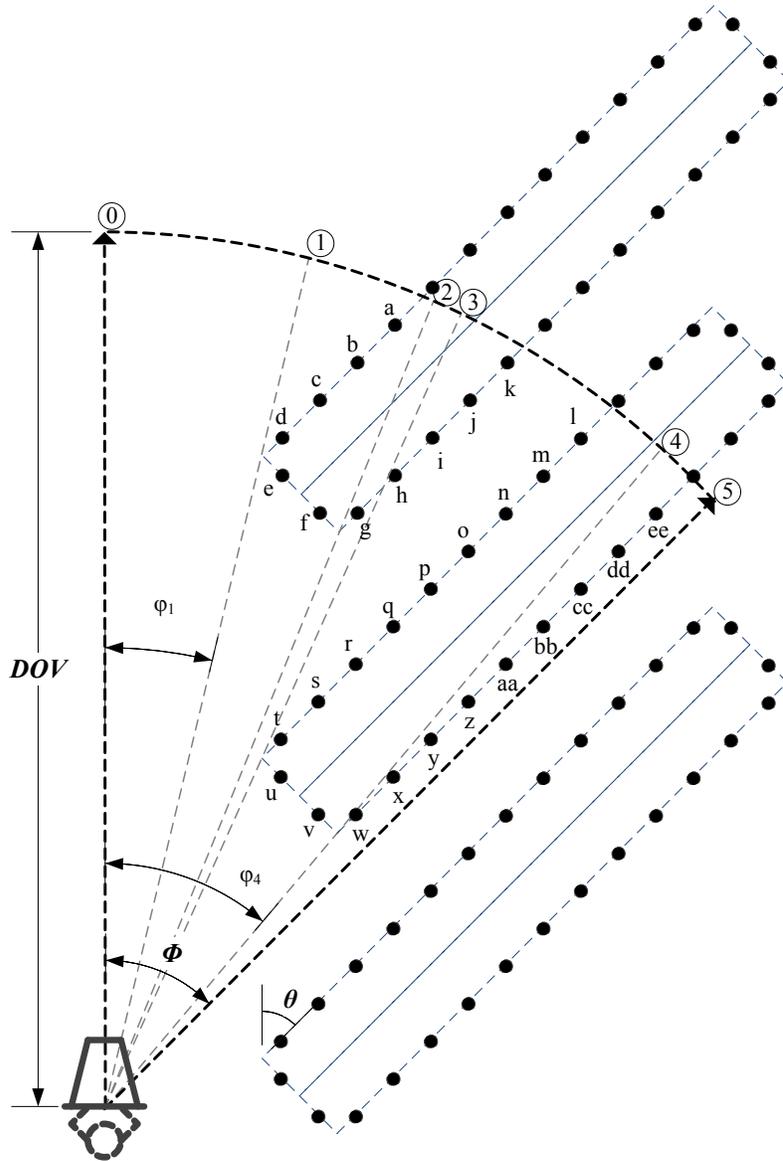


Figure 6: An illustration of the slicing algorithm

To understand how the slicing algorithm operates, consider the scenario presented in Figure 6 where the angle of rack orientation,  $\theta$ , equals  $45^\circ$  and each discrete location on a rack represents the midpoint of a 1 ft rack length. We represent  $DOV$  as Vector 0 and the extent of our FOR section as  $\Phi = 45^\circ$  (one side of the FOR). We discard all locations and rack corners whose angle  $\phi$  from the direction of travel is greater than  $45^\circ$  or whose distance is greater than  $DOV$ . In

Figure 6, locations 'a'-'ee' are located within the FOR section. We then create line segments originating from the shopper that pass through each corner and terminate where they intersect the boundary of the FOR section. The area between these segments makes up sectors, or slices of the FOR section. In Figure 6, the area between Vector 0 and Line Segment 1 make up Sector 1. Similarly the area between Line Segments 1 and 2 make up Sector 2, between Segment 2 and 3 make up Sector 3, between Segments 3 and 4 make up Sector 4, and finally the area between Segments 4 and Vector 5 make up the 5th and the final sector.

Notice that in this example no locations lie within Sector 1. Locations 'a'-'f' lie within Sector 2, location 'g' lies in Sector 3, locations 'h'-'v' lie within Sector 4, and locations 'w'-'ee' lie in Sector 5. We next determine which location in each sector is located closest to the shopper. In Sector 2, location 'f' has the shortest distance and so we conclude it is exposed. Because location 'e' is located in the same row (face of rack) as location 'f', we conclude it is also exposed. All other locations in this sector are obstructed and are determined to be not exposed. Following this same logic we determine that location 'g' is exposed in Sector 3, locations 'u' and 'v' are exposed in Sector 4, and locations 'w'-'ee' are exposed in Sector 5. The exposure,  $E$ , of the scenario presented in Figure 6 is 14 exposed locations each 1 ft long (i.e.,  $E = 14$  ft) out of a total 31 location that fall in the FOR section. Notice that this way of defining exposure only accounts for whether or not a product is exposed (a binary outcome), and does not consider how many times it may have been exposed as the shopper continues to walk past the racks. To capture the frequency of exposure, we use intensity as another measure, as explained later.

### 4.3 Effect of Orientation on Product Exposure

To discern the effect rack orientation has on exposure, we analyzed a system composed of  $n$  ( $= 5$ ) racks that were  $r_l$  ( $= 25$  ft) in length with  $r_w$  ( $= 4$  ft) end-caps. We assumed the shopper was walking  $d_a$  ( $= 5$  ft) away from the closest point of the rack and that cross-aisle width is  $a_c$  ( $= 5$  ft). To quantify exposure, our shopper's FOR section was defined as having a 25 ft  $DOV$  with  $\Phi = 45^\circ$  for easy head turn.

Figure 7 shows the exposure at each point of the pathway for a given rack orientation. We discretize the shopper's pathway into a series of 0.25 ft steps; recall that we also discretized the rack as a series of locations in the slicing algorithm. The discrete approximations of the continuous (i) shopper pathway and (ii) rack face allow us to estimate exposure using our proposed slicing algorithm. Additionally, recall that we use the amount of rack-length exposed (in linear ft) as a surrogate for product exposure.

As is illustrated on the right side of Figure 7, 0 on the X-axis denotes the point of origin. Essentially, the point of origin is defined as the lowest corner of the first rack. A negative value on the X-axis indicates the distance (in ft) back from the point of origin from where a shopper could still be exposed to the racks at certain orientations.

From Figure 7, we see that each  $\theta$  exhibits a repeating pattern that corresponds to the alternating cross-aisle and end-caps the shopper passes by. Furthermore, product exposure is very sensitive to the location of the shopper in reference to the rack; a slight movement forward or backward can change the exposure at a location drastically by creating or eliminating obstructions. The long rises and falls found in both these orientations imply that some product locations are visible for longer periods of time to the traveling shopper. Additionally, the distance at which exposure returns to 0, once the shopper's FOR has cleared the last rack, shows that  $90^\circ$  produces the shortest pathway (in terms of length) and  $30^\circ$  produces the longest.

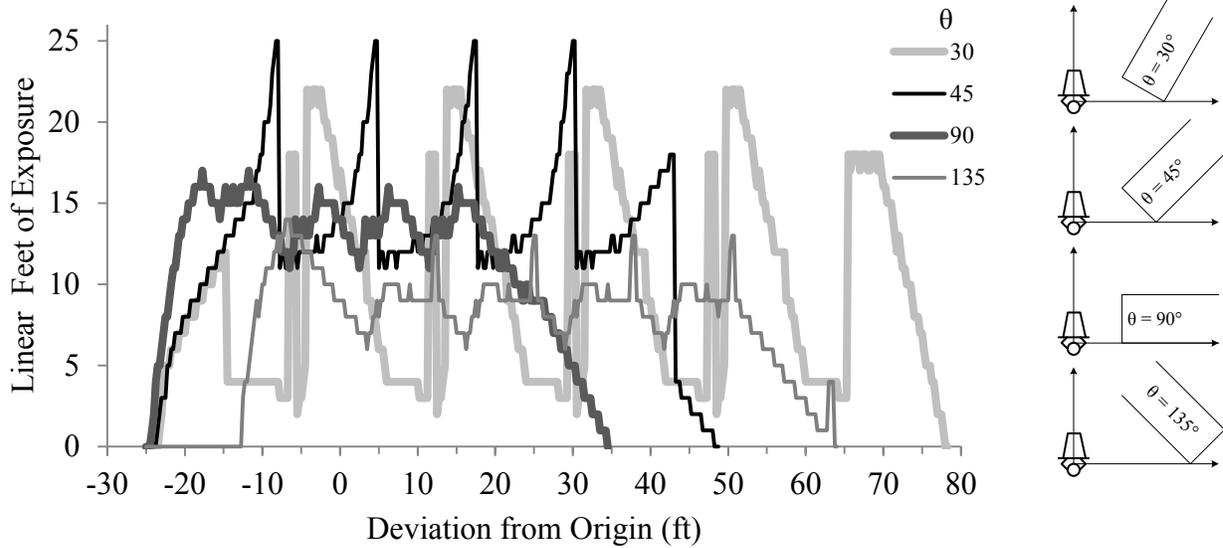


Figure 7: Exposure vs. distance shopper traveled from origin location illustrated

To estimate total exposure along a pathway (and not just a point as depicted in Figure 7), we used the previous algorithm to determine the exposure at each step along the pathway for various orientations. Product exposure was aggregated across all steps for each orientation in order to determine the number of unique product/locations that were seen at least once. Figure 8 is a graphical representation of exposure as  $\theta$  increases from  $0^\circ$  to  $180^\circ$ .

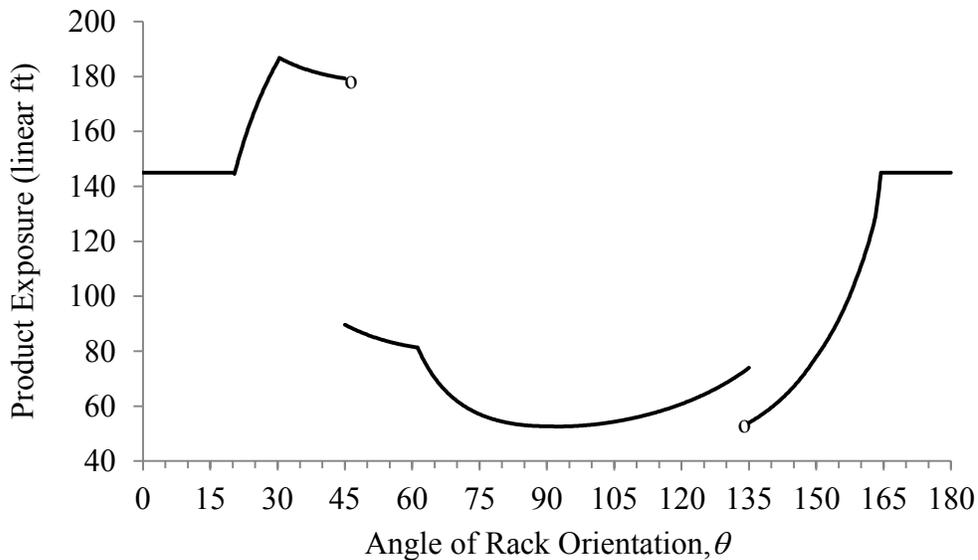


Figure 8: Exposure of pathway for various rack orientations  
( $n = 5$ ,  $r_l = 25$  ft,  $r_w = 4$  ft,  $a_c = 5$  ft,  $d_a = 5$  ft,  $\Phi = 45^\circ$ , and  $DOV = 25$  ft)

Notice that there is a discontinuity at  $\theta = \Phi = 45^\circ$  and  $\Phi' = 135^\circ$  ( $\Phi' = 180 - \Phi$ ). For rack angle  $\theta = \Phi$ , exposure decreases drastically as the length of the rack facing away from the traveling shopper falls in line with  $\Phi$  and ceases to be seen; i.e., when a certain rack face falls in

line with  $\Phi$ , it instantly changes the exposure of that face from being exposed partially to none at all. For rack angle  $\theta = \Phi'$ , a less drastic decrease occurs when the end-cap closest to the traveling shopper falls in line with  $\Phi'$  and also ceases to be seen.

For a given travel path, fairly acute or obtuse rack angles synchronize well with human FOR and tend to increase the product exposure of a pathway. For the system analyzed, racks placed at  $\theta = 45^\circ$  to the shopper's travel path have an exposure,  $E$ , equal to 90 ft, which represents an increase of approximately 70% over the traditional orthogonal layout of  $\theta = 90^\circ$  ( $E = 53$  ft). The less traditional orientation of  $160^\circ$  produced an even greater increase of 109% ( $E = 111$  ft). The maximum exposure of  $E = 187$  ft for the pathway (253% over  $\theta = 90^\circ$ ) was observed at approximately  $\theta = 30^\circ$ . Interestingly, rack angles closer to  $90^\circ$  had nearly the lowest product exposure values.

To further characterize exposure, we consider that some locations are exposed to traveling shoppers more frequently than others and refer to this characteristic as the *intensity* of exposure. While there are many different ways to quantify the intensity of a location, we define it as the ratio of the number of times a location is exposed to the maximum number of times any location can be exposed for a given FOR. We obtained these numbers by summing the number of steps a location is exposed from the moment it enters the shopper's FOR to the moment it leaves.

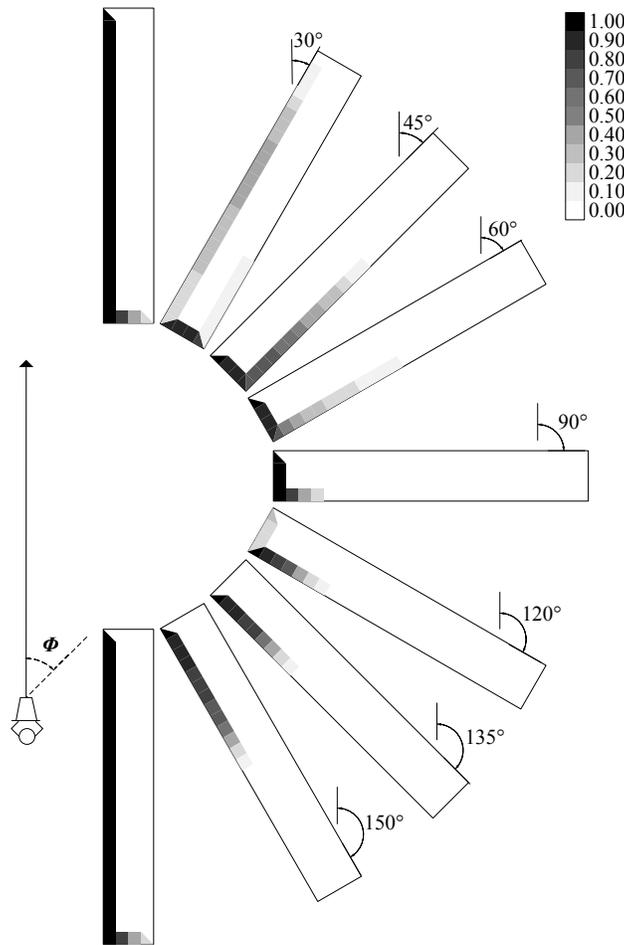


Figure 9: Intensity of exposure for each product location on a rack for the given orientation ( $n = 5$ ,  $r_l = 25$  ft,  $r_w = 4$  ft,  $a_c = 5$  ft,  $d_a = 5$  ft,  $\Phi = 45^\circ$ , and  $DOV = 25$  ft)

For the system analyzed, the maximum number of times a product could be exposed was 20. Locations that are always exposed, like the nearest end-cap of the rack when  $\theta = 90^\circ$  or the nearest length-wise face when  $\theta = 0^\circ$  or  $180^\circ$  would have an intensity of  $20/20 = 1.0$ . Locations that are not always exposed might be obstructed by the current or preceding rack for part of the time that they fall within the shopper's FOR, such as the one 4 ft from the end-cap when  $\theta = 90^\circ$ . Other locations, such as the one located 12 ft from the end-cap when  $\theta = 150^\circ$ , are located farther away from the shopper, thus reducing the number of opportunities they can be exposed. In both of these cases, the intensity of exposure of the location is  $4/20 = 0.2$ . Figure 9 shows the intensity of exposure for each 1 ft location along a rack (in grayscale; 1.0 refers to exposed the entire time, and 0 refers to never exposed) as the rack orientation changes from  $0^\circ$  to  $90^\circ$ , and finally to  $180^\circ$ .

Notice, in Figure 9, that while  $\theta = 30^\circ$  may have the largest number of unique product locations exposed, the intensity of exposure for each location is relatively low. In contrast,  $\theta = 0^\circ$  and  $180^\circ$  has the largest number of high intensity locations. Though  $90^\circ$  does not produce many exposed locations, those that are exposed show moderate to high levels of intensity.

Intuitively, one would expect that changing the orientation of racks would not only affect the exposure and intensity of exposure for a given rack configuration, but also overall space and shape of the sales floor. We next derive the space requirements corresponding to a certain rack orientation.

## 5 Space Model

To determine the required space for a given configuration, we first decompose the total length and total width of the resulting layout into separate components. The length of the space required for a layout is broken into (i) the length contributed by the angle of orientation of the first rack ( $l_1$ ), (ii) the length contributed by the angle of orientation of the additional rack end-caps and cross-aisles ( $l_2$ ), and (iii) the length contributed by the angle of orientation of the last rack's end-cap ( $l_3$ ). The width is similarly broken into (i) the width contributed by the angle of orientation of the rack's end-cap ( $w_1$ ) and (ii) the width contributed by the angle of orientation of the rack ( $w_2$ ).

Figure 10 illustrates these parameters.

The width of a single column rack configuration is

$$W = W_1 + W_2, \quad (1)$$

where the end-cap and face components of the width are defined as  $w_1 = r_w \sin(90 - \theta')$  and  $w_2 = r_l \sin \theta'$ . The length of a single-column rack configuration is

$$L = l_1 + l_2 + l_3, \quad (2)$$

where the component of the first rack is defined as  $l_1 = r_l \cos \theta'$ , the length component of the interior racks is defined as  $l_2 = \frac{(n-1)(r_w + a_c)}{\sin \theta'}$ , and the length component of the last rack is defined as  $l_3 = r_w \sin \theta'$ .

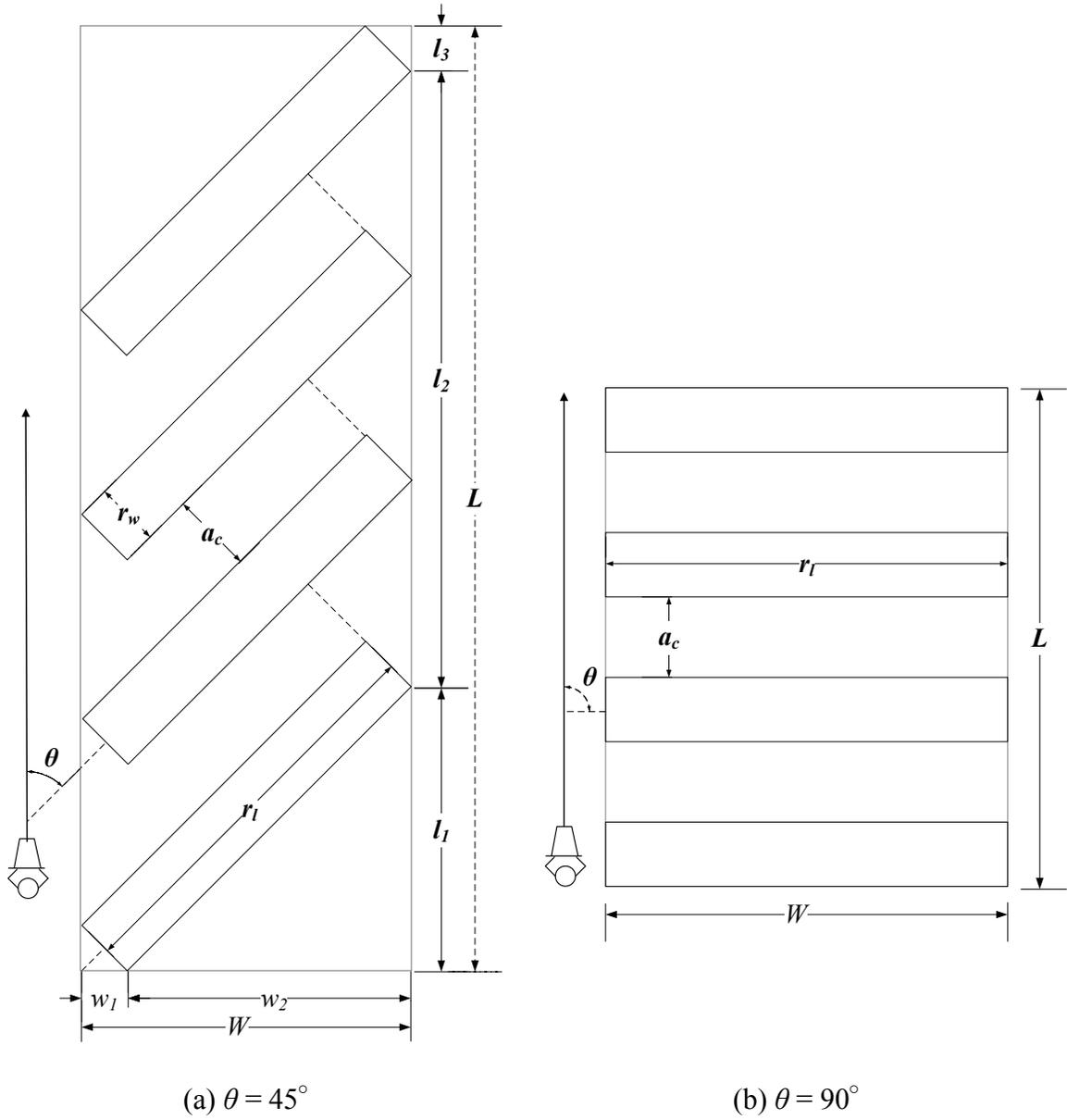


Figure 10: Example rack configurations ( $n = 4, r_w = 4, a_c = 5, r_l = 25$ )

The total required space,  $S$ , for a single-column rack configuration can then be found by substituting (1) and (2) into  $S = W \times L$ , giving

$$S = (r_w \sin(90 - \theta') + r_l \sin \theta') \left( r_l \cos \theta' + \frac{(n-1)(r_w + a_c)}{\sin \theta'} + r_w \sin \theta' \right), \quad (3)$$

where  $\theta'$  is the adjusted degree of orientation expressed as

$$\theta' = \begin{cases} \theta & , \text{ if } 0^\circ < \theta \leq 90^\circ \\ 180 - \theta & , \text{ if } 90^\circ < \theta \leq 180^\circ \end{cases}$$

Notice that when  $\theta = 90^\circ$ , (3) reduces to

$$S_{90} = r_l(r_w + (n-1)(r_w + a_c)). \quad (4)$$

The analytical space model developed can be applied to all rack orientations from  $0^\circ < \theta < 180^\circ$ . For  $\theta = 0^\circ$  or  $180^\circ$ , when the racks become parallel to the direction of travel, we calculate space as

$$S_{0,180} = r_w(r_l + (n-1)(r_l + \hat{a}_c)), \quad (5)$$

where  $\hat{a}_c$  is the cross-aisle distance between two adjoining end-caps. In our analysis, we assume  $\hat{a}_c = a_c$ .

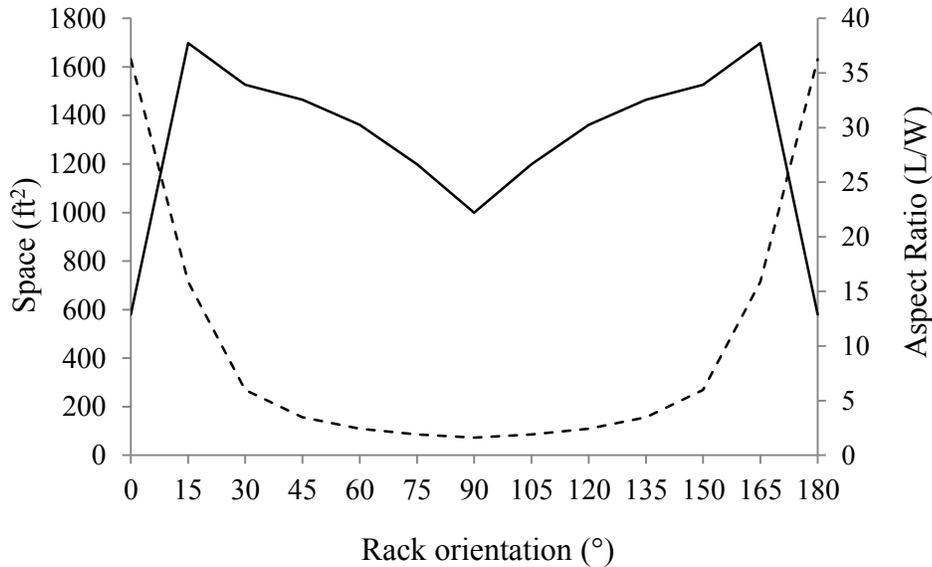


Figure 11: Rack orientation vs. space (solid line) and aspect ratio (dotted line)

Observe in Figure 11 that the rack orientation that uses the least amount of space is  $\theta = 0^\circ$  or  $180^\circ$ , which is seconded by  $\theta = 90^\circ$ . When  $0^\circ < \theta' < 90^\circ$ , the length component attributed to cross-aisle space ( $l_2$ ) between two adjacent racks elongates, resulting in an increase in space as compared to the traditional  $\theta = 90^\circ$  rack orientation. This additional cross-aisle space substantially increases the total space at low  $\theta'$  values ( $0^\circ - 15^\circ$  and  $165^\circ - 180^\circ$ ). While  $0^\circ$  and  $180^\circ$  may have the lowest space requirement, they also have the largest aspect ratio (length/width), and so would result in a long and skinny sales floor (which may not be desirable to the retailer). Not shown in Figure 11 is a spike in space and aspect ratio that occurs (for both cases) at  $5^\circ$  and  $175^\circ$  ( $S = 2,700 \text{ ft}^2$  and  $L/W = 71$ ). This spike is a result of the increase in cross-aisle space that occurs at low  $\theta'$  values. Recall that  $\theta = 30^\circ$  produced the largest exposure value.

We see in Figure 11 that it also requires a considerably large amount of space. While  $\theta = 90^\circ$  requires the second least amount of space and appears to have a favorable aspect ratio, it produced one of the lowest exposure values with moderate intensity. We summarize the insights gained through these preliminary results below.

## 6 Preliminary Insights

Our preliminary analysis leads us to the following insights:

- Product exposure is very sensitive to the location of the shopper in reference to the rack. This is intuitive as a slight movement forward or backward from any location can change the view from clear to obstructed (and vice versa) directly affecting the exposure (see Figure 7).
- For a given travel path through the main aisle, fairly acute or obtuse rack angles seem to synchronize well with human FOV and tend to increase the amount of product exposure throughout the pathway. Rack angles close to  $90^\circ$  (nearly orthogonal to the travel-path) appear to have the lowest product exposure (see Figure 8).
- Racks placed at  $45^\circ$  to the shopper's travel-path can boast upwards of 70% increase in exposure as compared to racks placed at  $90^\circ$ . However, less traditional orientations like  $30^\circ$  and  $160^\circ$  can produce even greater increases (253% and 109%, respectively) not accounting for space and other constraints.
- Orientations with high exposure values do not necessarily correspond to high intensity of exposure (see Figure 9).
- Tradeoffs exist between exposure, intensity, space, and shape for a given rack configuration. Orientations with high exposure and/or intensity likely require larger systems (in terms of space) and/or produce less desirable shapes (in terms of aspect ratio) of the adjoining departments. Orientations that produce favorable shapes and require the least amount of space seem to exhibit low exposure and/or intensity values.

The implications of our research findings can be critical. The use of angled racks in a retail layout could mean that shoppers may better locate products they are searching for likely reducing the search time and possible anguish. Improved exposure will likely result in more product varieties offered to a shopper during their typical travel-path along the main aisle without unnecessarily elongating the travel paths or requiring them to venture into cross-aisles to essentially explore such products. The resulting improved sense of control and overall shopping experience would likely strengthen loyalty for the retailer among the shoppers. For the retailers, the ability to quantify product exposure will help them identify the proportion of rack length (and so the products) that could be seen by a shopper, allowing them to prioritize the products that should be placed at the front of the rack and end-caps. More products shown to a shopper has the potential to increase unplanned and impulse buys, in turn boosting the retailer's revenue.

## 7 Summary

What a shopper buys is, in part, influenced by the physical layout of the store. Shopper travel paths are highly variable and unpredictable; products (brands, types, mixes, etc.) are frequently phased in, out and around the store throughout the year. A store's ability to expose products despite ever-changing product mix and variable shopper paths affects the store's revenue.

Motivated by rack layouts at two leading retailers in the region, and subsequent discussion with the store managers, we introduce a new paradigm to retail design --- design to maximize product exposure. Our main contributions include defining product exposure and adapting the concept of the human eye's field of regard into a slicing algorithm to estimate product exposure at a point and along the travel path. Results indicate that exposure can increase by as much as 2.5 times the exposure of the traditional 90° orientation. Our solution procedure is general enough to estimate exposure for a variety of system configurations.

We believe this research will lay the foundation for future work that will measure the value of exposure in terms of reduced time searching for items from the shopper's perspective and an increase in sales from the retailer's perspective.

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