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SHELF SPACE ALLOCATION MODELS IN RETAIL ENTERPRISE

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Abstract

Shelf space is a limited and very expensive resource as a lot of products are presented in a retail store. Shelf space is used in retail enterprise for multiple purposes e.g. allocation of products, ensuring brand visibility, improving customers satisfaction etc. This paper proposed two new practical shelf space allocation models which may be used in retail enterprise helping the retailer to increase gained profit. Both models enrich basic shelf space allocation problem with complicated merchandising rules such as allocation of product on different vertical levels according their price subcategories (1st model) and allocation of products in different shelf segments based on the products types, brand, weight, and package (2nd model).

Keywords

Retailing, merchandising, shelf space allocation, assortment planning, industrial engineering.

1. Introduction

Shelf space is very scarce resource that a retailer has to manage in a retail enterprise or retail chain. Therefore practical and rational merchandising decisions as well as management of limited shelf space are of key importance [14].

The category planning process in retail enterprise combines several steps:

- *Assortment planning* is the process of choosing the collection of products which will be displayed on shelves in particular retail chains during specified periods of time. The selection of such products sets is based on customers' preferences and needs. Appropriate assortment planning involves the following product attributes: size, style, color, brand, function, and price.
- *Shelf space planning* is the detailed process of determining the amount of shelf space for the product, defining the number of facings of each product, and selecting position of the product on the shelf. It starts from planning on macro level up to the planogram level at the stores. Nowadays process of planogram creating is highly automated.
- *In-store replenishment planning* is the process of creating and releasing store replenishment plans with regard to in-store logistics, amount of replenished products and cycles periods .

Borin, Farris and Freeland [3] admitted that assortment and shelf space allocation steps in the above mentioned processes are routine decision-making ones. For this reason some product assortment planning decisions and shelf space allocation decisions are generally solved simultaneously within the given time period. In another way, Hübner and Schaal [7] claimed that despite the fact that shelf space planning and in-store replenishment process are strongly interrelated, generally shelf space models do not consider replenishment refilling plans. Obviously, when shelf space is limited, the reduction of shelf space determined for other items should be reduced, which results in faster and with more frequency reordering and replenishment decisions.

In retail enterprise the shelf space allocation decisions involve two levels:

- determining the amount of shelf space for a product category;
- determining the amount of shelf space for a product within each product category [10].

A classical shelf space planning tool is a planogram. It is a virtual shelves illustration which represents the place on the shelf where product will be physically exposited and the inventory level that it should hold. While generating a planogram the retailer needs to plan carefully the products location, the number of visible to customers items (facings), the number of items stacked behind and above each facing row, the packing and packaging style, and possible orientations (front, side, back, top) among others [1, 2].

A good planogram is crucial to the success of the whole project. Because of a lot of merchandising rules most retail enterprises make emphasize on automated planograms but whatever very frequently this leads to manual adjustments by category managers.

The objective of this article is to propose practical retail shelf space allocation models which can reduce manual retailer's adjustments. Real retailer models have not been sufficiently addressed in the existing literature; most of the literature investigates only basic cases. The first shelf space allocation model which we propose addresses nested product categories and product price subcategories considering such groups of constraints as: shelf, product, multi-shelves and category constraints. The second shelf space allocation model with virtual segments considers shelf, product, multi-shelves, shelf type (appropriate shelves for products), and virtual segments constraints (suitable shelf parts for products).

One of the key limitations from the literature is that it neglects merchandising rules considering only product facings but real retail models should be investigated with not only facings but also with capping, i.e. placing the product on the top of the other one rotating the top one, and nesting, i.e. placing the product inside the other one as a basket or plate. To the best of our knowledge there is the first idea which adds to general shelf space allocation model caps and nests parameters which we incorporate in both our models.

2. Formulation of the problem and determination of the goal

The common shelf space allocation problem is formulated as follows. There are given number of shelves and number of products, the goal is to determine maximum profit through allocating the products on shelves subject to various constraints [11]. Linear or non-linear profit function represent gained profit received from the product allocated on the shelf, i.e. if the profit differs when the similar product is allocated nearby or if distinct profits could be received while allocating products on identical shelves.

The literature presents a great variety of shelf space allocation models with linear or non-linear profit function. As a result there is no common shelf space allocation model which could be applied in all enterprises. Each model should be adapted to reality; it also must include key practical features which could be implemented at the given enterprise. Some of the most known optimization models are presented below.

Main parameters:

- S – total number of shelves,
- P – total number of products,
- i – shelf index, $i = 1, ..., S$,
- j – product index, $j = 1, ..., P$,
- w_j – width of the product j,
- p_j – unit profit of the product j,
- π_j – scale parameter of product j (potential demand of product j),
- α – space elasticity parameter of the product j, $0 \leq \alpha_j \leq 1$,
- β_{jk} – cross-space elasticity parameter of the product j to product k, $-1 \leq \beta_{jk} \leq 1$.

Decision variables:

- d_j – demand of the product j,
- $x_{ij} = \left\{ \begin{array}{ll} 1, & \text{if product } j \text{ is put to the shelf } i \\ 0, & \text{otherwise} \end{array} \right\}.$
- $f_j\ (f_{ij})$ – the number of facings of the product j (on the shelf i),
- c_{ij} – the number of caps of the product j on the shelf i,
- n_{ij} – the number of nests of the product j on the shelf i.

Corstjens and Doyle [5] proposed a non-linear multiplicative model and included space- and cross-space elasticities into it (1)

$$d_j = \pi_j f_j^{\alpha_j} \prod_{\substack{k=1;\\ j\neq k}}^{P} f_j^{\beta_{jk}}. \tag{1}$$

Irion et al. [8] defined the demand as (2)

$$d_j = \pi_j (w_j f_j)^{\alpha_j} \prod_{\substack{k=1;\\ j\neq k}}^{P} (w_k f_k)^{\beta_{jk}}. \tag{2}$$

Because of non-linear by nature of space- and cross-space elasticity parameters which are hard to be estimated most of scientists use linear model as Yang and Chen [12]. They formulated the shelf space allocation problem where the objective is (3)

$$\max \sum_{j=1}^{P} \sum_{i=1}^{S} p_j f_{ij}. \tag{3}$$

We propose to formulate the model as (4)

$$\max \sum_{j=1}^{P} \sum_{i=1}^{S} x_{ij} p_j (f_{ij} + c_{ij} + n_{ij}). \tag{4}$$

General set of constraints includes:

- shelf width limitation;
- lower and upper bound of number of facings allowed for each product;
- integer numbers of facings;
- number of shelves on which product could be allocated;
- supply limit of number of items reserved for a product [9, 11].

In most cases shelf space allocation problem covers only one visible facings row in one dimension because facings behind are not visible. The vertical dimension, i.e. placing facing row above, is also ignored because the shelf height can be adjustable [4].

The model should optimize retail profits by determining the optimum number of facings of each product that must be allocated on planogram shelves while accounting for limited shelf space.

3. Proposition of the shelf space models

Information technology plays an important role in assortment and shelf space management in retail enterprise. With the help of shelf space optimization models retailers perform optimal shelf space decisions in retail stores calculating the number of facings for each product included in assortment.

In this study we propose to enlarge the basic shelf space allocation model with additional parameters and constraints that are required in retail enterprises. We formulate two variants of the main shelf space allocation problem. In each problem there is one planogram, which is used for placing a set of products on shelves, and to define the amount of space dedicated for each product category in order to maximize the predicted profit from selling these products. The main goal in each problem is determining the shelves for the product items and the number of facings, caps and nests of each chosen product under the constraints of limited shelf size subject to various additional categories of constraints related to: shelves, products, product orientations, feasible allocations, categories and price subcategories, virtual segments and various relationships between products.

Common constraints proposed to be used in all problems are:

- Shelf length, height, depth, weight.
- Minimum and maximum number of shelves for a product.
- Product supply limits, minimum and maximum number of facings, minimum and maximum number of caps, minimum and maximum number of nests, product front or side orientations.
- Availability of only one orientation (front or side) for multi-shelves product, restriction of the same product orientation on all shelves.
- Placing the product the neighbor shelf only, adjust the same number of facings ensuring its better visibility and displaying of it in rectangular blocks on several shelves.
- Allocation of products in clusters on the same shelf.

The two mentioned problems and the additional constraints used in them are:

1) Shelf space allocation problem (Fig. 1) with nested product categories in which allocation of the product on the shelf depends on the product categories and product price subcategories. Figure 1 shows the rules of allocating products on shelves. Products from the category A and price subcategory 10 can be allocated on the shelves for categories A, B, C and subcategories 10, 20, 30. Opposite products from the category C and subcategory 30 can't be allocated on the shelves for other categories and subcategories. Products B20 can be placed in B20, B30, C10, C20, C30.

	A		B		C	
30	A20	A30	B10	B30	C20	C30
20	A20		B10	B20	C10	C20
10	A10		B10		C10	

Fig. 1. Possible categories and price subcategory allocation with strict border between the vertical categories.

- Minimum category size ensuring the visibility of the product category.
- Category tolerance between different shelves in order to form the straight or flexible border between neighbor categories on different shelves.
- Product price subcategory allocation which means that cheaper products can be placed on shelves dedicated for cheap and expensive ones, otherwise expensive products can't be placed on the shelves dedicated for cheap products.

2) Shelf space allocation problem (Fig. 2) with virtual segments in which allocation of the product on the shelf depends on the position of aisle, center, local and convenience virtual segments on the fixture. In this model we differentiate virtual segments according to the product types such as local (regional) and convenience (complementary) ones. Figure 2 shows allocation of the extended and reduced virtual segments on a planogram.

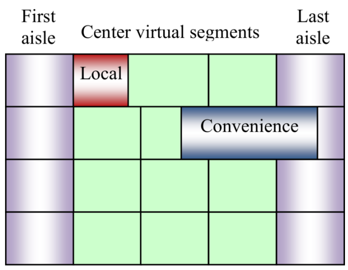

Fig. 2. Extended and reduced virtual segments on a planogram.

- The adjustable size of the center and aisle virtual segments ensuring the possibility of their reducing and enlargement with regard to the amount of products placed there.
- Pallet, low level, eye level shelves. The products in big packs must be placed on a pallet because of their weight. Some products must be placed at eye level (which will increase their selling). The cheapest products with high rotation are generally put at a lower level.
- Aisle and non-aisle virtual segments. First-aid products should be placed near the first or last aisles. In the center of the shelf should be put expensive, new, and brand products. Based on the retailers experience, at the end of the shelf (aisle segments) the client spends less time therefore there should be placed more demanded products. Otherwise near the shelf center client spends most time in order to have a look into the whole assortment. So to stimulate impulse buying the most profitable products and new products are placed there.
- Local, convenience shelves. Convenience products are commonly unplanned purchases as an addition to the main planned product, and they should be located on the shelf near the main product (e.g. if customer buys vegetables for a fresh salad, then dressing and spices should be seen in the nearest vicinity, or on the meat cooler planogram one can find spices

for bouillon and meat dishes). Local products generally are not included in the main assortment and can be different in each store.
- Shelves with dedicated virtual segments and special products as well as shelves for non-special products.

The research is motivated by the real shelf space management problems arising in the retail industry. Figures 3 and 4 represent caps and nests allocation method.

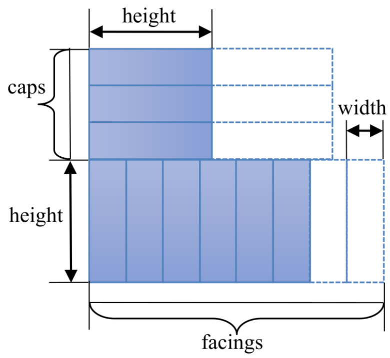

Fig. 3. Caps allocation.

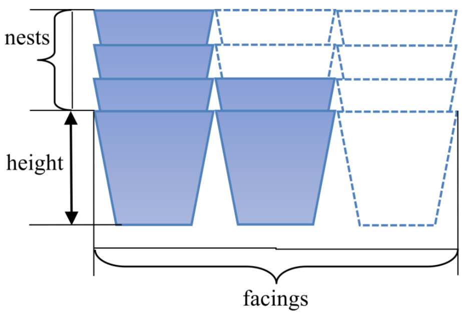

Fig. 4. Nests allocation.

4. Data collection

In Yang's experiment [13] he proved that the problem size is a key factor in the algorithm performance therefore we propose to use instances of different problem sizes. In retail enterprises planograms proceed from a complex structure of merchandising rules that try to reflect customers' buying behavior and the enterprise strategy for the different product categories.

The shelf space planning process includes initial planogram generation from scratch following a set of merchandising rules and later replication of them to a new store. Next, some manual corrections are performed possibly including non standard adjustments [1, 2].

The problem is that different shelf space is available in each store, but the set of products that must be placed on the shelves is the same in each store of the retail chain. Therefore the basis of the experimental data should represent the real data. We propose to generate a number of planograms with different shelf lengths and a number of product sets. It is allowed to set the same shelf lengths within a planogram because in real store the shelf lengths differ within the same planogram very rarely (i.e. sometimes obstruction prevents customer to see a part of the shelf).

5. Conclusion

Shelf space is one of the most critical and influential resources which retailers have to manage. Wise merchandising rules and retailer experience improve vendor relationship and increase customers' satisfaction. Because of this shelf space allocation decisions are of high importance in retail enterprise management and therefore in this article we focus on them in order to maximize the retailer's total profit.

In this article we proposed two new practical models with the objective of maximizing the retailer's profit for shelf space allocation problem with product price subcategories and shelf space allocation problem with dedicated shelf segments.

Further research will include implementation of the proposed mathematical models and performing a set of experiments using data samples generated on the basis of industrial data.

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